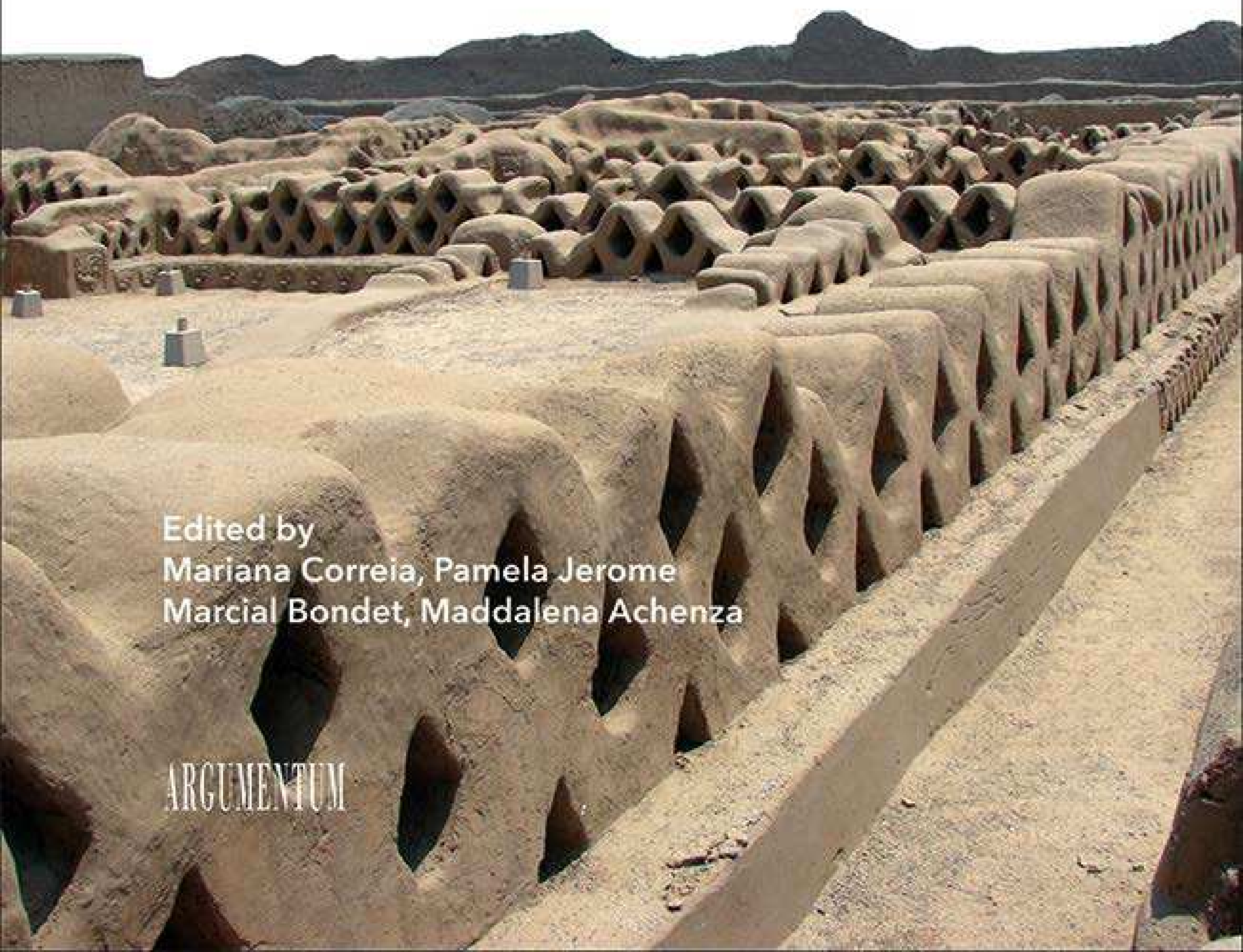
TERRA 2012 | 12th SIACOT
PROCEEDINGS

11th International Conference on the Study and Conservation of Earthen Architectural Heritage

12th SIACOT Iberian-American Seminar on Earthen Architecture and Construction



Edited by
Mariana Correia, Pamela Jerome
Marcial Bondet, Maddalena Achenza

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Lima, Peru, April 22-27, 2012

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The TERRA Conference, which occurs every three to five years approximately, is an international conference, whose themes relate to the study and conservation of earthen-architectural, archaeological and cultural landscape heritage. The reach of the earthen architecture study was also extended to research, intangible knowledge, earthen contemporary architecture, housing, standards, education and awareness, among others.

TERRA conferences occur under the aegis of ICOMOS - International Council on Monuments and Sites, and its expert Committee on earthen architecture: ISCEAH - International Scientific Committee on Earthen Architectural Heritage. TERRA 2012 took place in Lima, Peru, from the 22nd to the 27th of April 2012, followed by post-conference tours to earthen-architectural sites in Peru. Pontificia Universidad Católica del Perú organized the international conference with the partnership of Universidad Nacional de Trujillo and PROTERRA; the aegis of ICOMOS-ISCEAH and UNESCO-WHC; and the support of the Peruvian Ministry of Culture, ICOMOS-Perú, The Getty Foundation, The Getty Conservation Institute, CRAterre and the Chair UNESCO-Earthen Architecture and Sustainable Development.

The Post-Conference Tours were organized to significant Peruvian routes, emblematic of its outstanding natural and cultural heritage. This was the case of the MOCHE ROUTE, that included the archaeological complex of Chan Chan, and the sites of Huaca Cao, Tumbas Reales de Sipán, Túcume y Huacas de Moche; the MACHU PICCHU ROUTE that integrated visits to Cusco, Machu Picchu and the Inca's Sacred Valley; the PUNO AND TITICACA LAKE ROUTE, which comprised a visit to Cusco and the Titicaca Lake; the AREQUIPA AND CUSCO ROUTE; and the PUERTO MALDONADO AND CUSCO ROUTE, which embraced a visit to Cusco and the Natural Reserve of Tambopata.

The conference received 550 participants from more than 50 countries. The main theme of TERRA 2012 was the conservation of earthen-architectural heritage in the face of natural disasters and climate change. The international conference TERRA 2012, the 11th International Conference on the Study and Conservation of Earthen Architectural Heritage was organized in collaboration with the 12th SIACOT, the Iberian-American Seminar on Earthen Architecture and Construction, from PROTERRA - Iberian-American Network, as well as under the banner of the 40th anniversary of UNESCO's World Heritage Convention.

Main Theme

Conservation of Earthen-Architectural Heritage in the face of Natural Disasters and Climate Change

Conference Themes

Theme 1: Latin-American Earthen Architecture at Risk: Earthquakes, Rain and Flood Damage
Theme 2: World Heritage Earthen-Architectural Sites, Natural Disasters and Climate Change
Theme 3: Dcumentation, Conservation and Management of Archaeological Sites
Theme 4: Conservation and Development of Human Settlements and Cultural Landscapes
Theme 5: Local and Regional Knowledge, Intangible Heritage and Social Impact
Theme 6: Research in Materials and Technology for Conservation and Contemporary Architecture
Theme 7: Ancient/Historic and Innovative Solutions for Damage Prevention and Performance Improvement
Theme 8: Charters, Standards and Guidelines for Heritage and Construction
Theme 9: Education, Dissemination and Outreach

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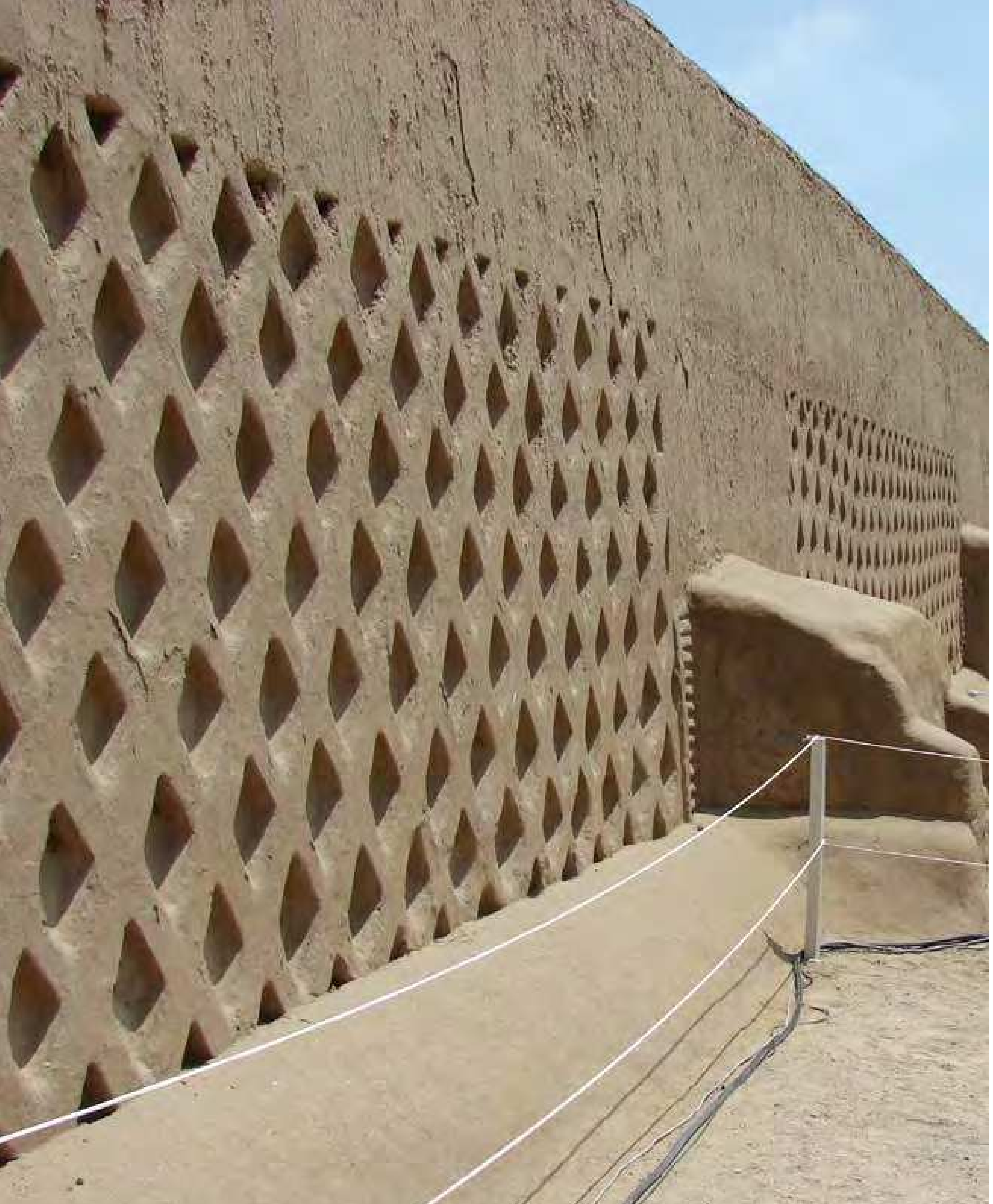

Chan Chan, Peru (credits: Luis Fernando Guerrero)

TERRA 2012 AND ITS MAIN THEME: Conservation of the Earthen-Architectural Heritage in the face of Natural Disasters and Climate Change

Julio Vargas-Neumann, Marcial Blondet and Daniel Torrealva

TERRA 2012 Chair Committee

Climatic change acceleration has been scientifically demonstrated and its evidence has been widely recognized. Even though some components of cyclic changes on the planet are not well known, it is clear that planet warming is associated with this acceleration. This means that the intensity of future natural disasters will increase and will be more difficult to predict, because the geographic characteristics used to indicate propensity to certain natural disasters are also changing.

One of the most significant phenomena in the planet is the El Niño Southern Oscillation (ENSO). It affects four continents and three oceans. ENSO has caused heavy rains, inundations and landslides, which have produced incalculable loss of lives and has had an impact on earthen-built heritage. It has also caused droughts and dramatic weather changes, which have generated famine, epidemics and social conflicts. Even though the correlation between climatic change and the occurrence of earthquakes has not been scientifically established, it is known that climatic change can trigger the rupture of the earth's crust and transform the stored potential energy into kinetic energy, that can cause destruction of cultural buildings, and other less damaging forms of energy.

For these reasons, the organizers of TERRA 2012 chose as a central theme for the Conference "Conservation of the Earthen-Architectural Heritage in the Face of Natural Disasters and Climate Change". All of the contributors to the conference were encouraged to consider this important theme with nine sub-themes within their papers. It is hoped that these proceedings will contribute to the development of this central preventive concept in the work of heritage conservation.

The Pontifical Catholic University of Peru (PUCP) is grateful for having been selected as organizer of TERRA 2012: 11th International Conference on the Study and Conservation of Earthen Architectural Heritage by the ICOMOS International Scientific Committee on Earthen Architectural Heritage (ISCEAH).

Many people contributed to the success of TERRA 2012. The Organizing Committee would like to thank them for their effort and dedication. Thanks are due to the members of the Scientific Committee, the Theme coordinators and the Advisory Committee. Many thanks are due to the editors of the conference proceedings Mariana Correia, Pamela Jerome, Maddalena Achenza and Marcial Blondet, assisted by Melissa Madge, Malena Serrano and Jacob Merten. Thanks are also due to the The Getty Foundation and CRAterre, both of which kindly provided support for the travel of participants from Latin America and Africa, as well as the Peruvian Ministry of Culture, ICOMOS-Perú, Universidad Nacional de Trujillo, PROTERRA, ICOMOS-ISCEAH, UNESCO-WHC, The Getty Conservation Institute and the Chair UNESCO-Earthen Architecture and Sustainable Development. Last but not least, the organizers would like to thank the many members of the PUCP's support personnel that facilitated every aspect of the conference. All the work and dedication were gratefully appreciated.

PREFACE

Francesco Bandarin

World Heritage Centre Director (2000-2012)

The 11th International Conference on the Study and Conservation of Earthen Architectural Heritage, TERRA 2012, organized by the Pontificia Universidad Católica del Perú (PUCP) with the ICOMOS International Scientific Committee on Earthen Architectural Heritage (ISCEAH) and the Ministry of Culture of Peru, in collaboration with the UNESCO World Heritage Centre, CRAterre, ICCROM, and the Getty Conservation Institute was held in Lima, Peru, from 22nd to 27th April 2012. TERRA 2012 brought together a group of over 500 heritage professionals committed to the preservation of earthen architecture, as well as to the safeguarding of the communities that have, since time immemorial, handed down traditional knowledge and skills that are still studied and appreciated as examples of low-cost, adaptive and sustainable technology.

The fundamental relationship between communities and heritage has also been at the core of the celebrations of the 40th Anniversary of the World Heritage Convention in 2012. With 193 States Parties and over 1,000 sites inscribed, the Convention can certainly be considered a global success. Throughout the world, the Convention has driven change in national institutions, promoted the improvement of heritage-conservation policies, and the building of national capacities, fostered the participation and involvement of a wide range of stakeholders, and generated great opportunities for partnerships, and the development of innovative financial mechanisms.

Forty years on, the Convention faces new challenges brought about by the changes that have characterized the economic, social and environmental scene on a global scale. Globalization, with its ever-increasing social and economic interdependencies, provides opportunities for development, while also presenting enormous challenges to local communities, livelihoods and identities. Global challenges, such as climate change, conflicts and wars, endemic poverty, the financial crisis, rapid urbanization and environmental degradation, have rendered people all the more vulnerable to change and to the impacts of natural disasters, and have led to the progressive loss of local cultures. It is increasingly evident that the future challenges of heritage conservation will be linked to sustainability and to the integration of heritage into the life of the communities within a development framework.

The nexus has now been finally recognized, with the adoption in 2015 by the UN General Assembly of the 2030 International Development Agenda, that identifies culture and heritage as important dimensions in many sectors, ranging from education to environment, from health to urban development. The decision of the World Heritage Committee in 2012 to link the 40th anniversary celebrations to the theme of development has played an important role in this process, as it has linked the effective and long-term conservation of sites to a sustainable-development process aimed at benefiting local communities.

Throughout 2012, during the 40th anniversary of the World Heritage Convention, the international heritage community has held a number of events, conferences, and workshops to examine achievements and identify challenges for World Heritage. In December 2012, over 200 international experts assembled at UNESCO's Headquarters in Paris to discuss the state of conservation of World Heritage Earthen Architectural sites, as part of the activities of the UNESCO World Heritage Earthen Architecture Programme (WHEAP, 2007-2017), an initiative aimed to improve the state of conservation and management of earthen-architectural sites worldwide. In addition to carrying out pilot projects at selected World Heritage sites, the program implements activities for capacity building, identifying and disseminating best practices and techniques for the conservation and management of these properties, as well as research and development activities for earthen architecture.

Nine years after its inception, WHEAP has had a number of achievements in support of sustainable conservation and management, notably its various pilot projects and capacity building activities that have benefited a large number of World Heritage sites and communities and built a global network of experts. WHEAP receives the technical support of the main international conservation institutions: besides the traditional partners, ICOMOS, ICCROM and CRAterre-ENSAG, it is supported by regional institutions like the School of African Heritage (EPA, Benin), the Centre for Heritage Development in Africa (CHDA, Kenya), the Centre for Conservation and Restoration of Atlas and Subatlas Architectural Heritage (CERKAS, Morocco), Pontificia Universidad Católica del Perú (PUCP, Peru) and PROTERRA Iberian-American Network, as well as by the University of Udine (Italy).

Thanks to the activities of these institutions, the periodic Terra international conferences, and the growing concern for sustainability and the reduction of energy consumption, earthen architecture has been recognized for its heritage values and for its intrinsic technical and economic advantages in all regions of the world. While threats and prejudices persist, many examples of successful heritage conservation have allowed an ever-greater public to know and appreciate the importance of this material and of the construction techniques associated with it.

The contributions contained in this volume are yet another demonstration of the great heritage value of earthen-architectural sites and buildings, of the relevance of this area of investigation and technical implementation for World Heritage conservation practices, as well as of its importance for the sustainable-development processes of communities worldwide.

Paris, February 2016

40 YEARS OF TERRA CONFERENCES

Pamela Jerome and John Hurd

ICOMOS - ISCEAH Presidency (2011-2014)

This year marks the 40th anniversary of the TERRA series of conferences. The first TERRA conference was held in Yazd, Iran, around the same time as the establishment of the World Heritage Convention, in November 1972. Officially called the First Colloquium on the Conservation of Adobe, the proceedings were small (ICOMOS Iran, 1972). The meeting was held under the auspices of ICOMOS (International Council on Monuments and Sites) and was organized by ICOMOS Iran. The first meeting set the precedent for all subsequent meetings, which have since that time, been under the auspices of ICOMOS.

The early 1970s was a time when conservation professionals began to regularly share their experiences. In this period, about one-third of the planet's population was housed in some form of earthen architecture. Earthen architecture began to be viewed as a heritage worthy of preservation, not just the vernacular housing of the poor. There was an emerging recognition of its remarkable variety, and in some cases, monumentality.

By 1976, a second meeting in Yazd was attended by a larger number of experts (ICOMOS Iran, 1976). It was decided that the "Adobe" event, as it came to be unofficially known, should become periodic. In 1980, the third meeting was considered a symposium (ICOMOS Turkey/ICOM, 1980). Held in Ankara, Turkey, the organizing committee was ICOMOS Turkey, and ICOM (International Council on Museums) was also a supporter. In addition to archaeological adobe structures, earthen mortars, plasters and movable objects were included. UNESCO and UNDP were involved with the fourth meeting held in 1983 in Lima and Cusco, Peru (UNDP/UNESCO/ICCROM, 1985). By 1987, the ICOMOS International Committee for the Study and Conservation of Earthen Architecture (ICSCEA) was established with Dr. Cevat Erder of ICOMOS Turkey as its first president.

The fifth meeting was held in Rome, Italy in 1987, and was additionally supported by ICCROM and CRAterre (ICCROM/CRAterre/EAG, 1988). Living heritage now began to be an important component of the series. The sixth meeting, Adobe 90, organized by the Getty Conservation Institute (GCI) in collaboration with the US National Park Service, took place in Las Cruces, NM under the aegis of ICSCEA (Getty Conservation Institute, 1990). Around this time, regional meetings began to appear. In 1993, the seventh meeting occurred in Silves, Portugal, under the name TERRA 93 (DGEMN, 1993). Since then, the meetings have been called TERRA, reflecting the broader forms of earthen construction. TERRA 2000 was held in Torquay, England (ICOMOS UK, 2000). The meeting returned to Yazd, Iran for TERRA 2003 (ICOMOS Iran, 2003). By 2004, the ICOMOS International Committee, which had become dormant, was re-established as the International Scientific Committee on Earthen Architectural Heritage (ISCEAH) (Hurd and Jerome, 2008, 2010).

The GCI organized the following meeting, TERRA 2008, which was held for the first time in Africa, in Bamako, Mali (Getty Conservation Institute, 2011). By this time, regional meetings had proliferated, along with networks of professionals. For instance, SIACOT (Seminário Ibero-Americano de Arquitectura e Construção com Terra), launched by the Iberian-American PROTERRA Network, organizes one seminar per year in different Latin American countries; there have been two SISMOAdobe seminars; there has been one TerrAsia symposium; as well as two MEDITERRA conferences.

This brings us to the present TERRA 2012, which has returned to Lima, Peru, and is part of the 40th anniversary events celebrating the World Heritage Convention. For the first time, the conference has a focus area, natural and manmade disasters and their impact on earthen architecture. Peru is one of the greatest field experiments in earthen-architectural conservation, particularly when it comes to its archaeological heritage. The Pontificia Unversidad Católica del Perú, specifically, has conducted long-term research in low-tech methodologies for reinforcing adobe buildings against earthquakes. With climate change affecting more than 25% of World Heritage sites, manmade disasters are also taking their toll. Over 100 of the sites on the World Heritage List contain some form of earthen architecture, considered to be amongst the most vulnerable to the impact of climate change (ICOMOS Scientific Council, 2008). Recognizing this, UNESCO developed WHEAP (World Heritage Earthen Architecture Programme), a worldwide research program initiated for a ten-year period in 2007. As part of WHEAP, the World Heritage Centre organized the Colloquium: World Heritage Earthen Architecture in December of 2012 (UNESCO, 2013). About one-quarter of the World Heritage List in Danger is composed of earthen-architecture sites (UNESCO WHC).

Therefore, the need to continue to explore appropriate methodologies for the protection of earthen-architectural heritage is paramount. Furthermore, the field has expanded tremendously, and along with it, the number of experts in earthen-architectural heritage conservation. Over 600 professionals attended Terra 2012. The opportunity to exchange experiences and stay up-to-date on the latest scientific understanding of earthen-materials conservation has always been a goal of the Terra conferences. With the increase in regional conferences, at the annual meeting of ISCEAH that took place during the Lima conference, it was decided to rename the meetings once more, now to be known as the International Congress on the Study and Conservation of Earthen Architecture. The 12th meeting, TERRA 2016, will take place in Lyon, France.

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A GROWING IBERIAN-AMERICAN NETWORK

Mariana Correia

PROTERRA Coordinator (2011-2014)

In 2011, the Coordinator of PROTERRA, the Iberian-American Network on Earthen Architecture and Construction proposed to join the TERRA 2012 conference, with the organization of the 12th SIACOT, the Iberian-American Seminar on Earthen Architecture and Construction. The association of the two international events would support and recognize the growing awareness regarding earthen architecture in Latin America. This event would distinguish internationally the work and knowledge accomplished on the Latin-American region.

The PROTERRA seminar is organized each year in a different country from the Iberian-American region. The main goal is to enhance synergies in earthen architecture through capacity building, local building-culture significance, research development, housing improvement, and risk-mitigation advances. This is possible by recognizing in each country interested entities and stakeholders, professionals and experts in order to value the existing strengths.

For instance, in 2010, the 10th SIACOT in Uruguay revealed the potential that was emerging from contemporary architecture and social cooperatives; in 2011 in Mexico, the 11th SIACOT shown the importance of crossing with other areas of knowledge, and the potential of pedagogical tools that can contribute to awareness; in 2012 in Peru, the relevancy of multidisciplinary teamwork regarding conservation and low-cost non-intrusive techniques for seismic retrofitting; in 2013 in Chile, the rising interest on contemporary seismic retrofitting architecture, and earthen-heritage awareness from different universities, professional orders, and stakeholders, which resulted in the creation of PROTIERRA-Chile network; in 2014 in El Salvador, the relevancy of local NGOs operating in very difficult conditions, and the significance of creating a regional PROTERRA-Central America between Guatemala, El Salvador, Honduras, Nicaragua, and Costa Rica, sharing resources and knowledge especially in heritage conservation and social housing; in 2015 in Ecuador, the importance of valuing earthen architecture through research, preventive conservation, and participative conservation in World Heritage sites. In 2016, the 16th SIACOT will be organized in Paraguay to enhance the significance of native know-how and to strength the knowledge of rural and urban environments. Finally, in 2017 in Bolivia, the focus will be on the quality of housing and living. The different emphasis of earthen-architecture impact emerging from each country contributes to the identity and diversity of Latin America. This provides a non-generalization of criteria and avoids the universality of approaches in a globalized world.

PROTERRA's mission contributes in this way to sustainable development through an integrative approach and by valuing the strengths of each country. The Iberian-American Network addresses technical and scientific cooperation, and operates in Iberia and Latin America, for the development of earthen architecture and construction. Presently, PROTERRA has 120 experts and 22 associate institutions from 19 Iberian-American countries, having Spanish and Portuguese as the working languages. The establishment of statutes formalized the structure, mission, aims, organization and procedures of the Iberian-American Network. Each member seeks funding to research and participate in the events and activities of the Iberian-American Network, which operates without formal financial support.

In the last years, PROTERRA activities have been directed toward capacity building, outreach, valuing communities' knowledge, terminology and institutional cooperation. At present, activities being addressed are: Recommendations for Standards; Awareness for Risk Mitigation; Technical Recommendations for Earthen-Architecture Conservation; Iberian-American Atlas; Comprehensive Publication on Latin-American Earthen Architecture; Analysis of New Earthen Building Systems; and an Inter-Laboratory Program.

Due to its achievements, PROTERRA was invited in 2012 by the UNESCO World Heritage Centre to integrate UNESCO-WHEAP (World Heritage Earthen Architecture Programme). In the Iberian-American context, PROTERRA is achieving maximum results with minimal financial resources. This is possible thanks to the commitment of its members.

Iberian-American Network on Earthen Architecture and Construction I www.redproterra.org

A WORD FROM THE EDITORS

Mariana Correia, Pamela Jerome, Marcial Blondet and Maddalena Achenza

Editors of TERRA 2012 I 12th SIACOT

In the past few years, a lot has been accomplished in what concerns awareness of earthen-architectural heritage, contemporary earthen architecture and community involvement. This is even becoming a **trend** among leading institutions and organizations that look to hold conferences, organize hands-on workshops, be involved in some kind of earthen-architectural project. Professionals and academics want to experiment building with earth, be involved in participative projects, respond to the material challenge and its structural capacity, or to excavate earthen-archaeological remains. This is because in the developed world, earthen architecture evolved from the image of 'housing for the poor' to an image of 'social involvement'. However, in spite of much awareness, hazard-safe construction, conservation and standardization remain the leading challenges to undertake.

To address earthen architecture **standards** is an enormous challenge, which is often tackled by inadequately adapting existing norms from other world regions with very different climatic, geographic, natural risks, cultural, social and economic issues.

Also, there is little notion for the need to revise and update periodically published standards. It is important to publish norms that engage traditional building cultures, comfort, risk mitigation and the improvement of the quality of life. They will respond to the citizens' needs to address globalization and climate change with integrative approaches, community engagement and a sustainable-lifestyle balance.

Regarding **conservation**, difficulties remain related with a tendency for universal approaches, lack of knowledge on earthen-architecture conservation and little know-how on the preservation of earthen-building cultures. Usually, when professionals have to refer to the best conservation practices that they know, they still refer to their own practice as the reference to be followed. Little is known about other professionals' intervention in earthen architecture. Is this related to lack of openness and of self-criticism?

The fact that very few professionals consider having their work assessed can create an enclosed world with redundant approaches. This is doomed to bring failure to earthen-architecture preservation. Even if today, there is more multidisciplinary teamwork, and more awareness, **critical thinking** among academics and professionals is often missing, especially in research and in conservation of earthen architecture.

A rising interest in earthen architecture exists among the general population, professionals and academics. However, in order to avoid that it merely becomes a short-lived trend, experts and academic institutions need **to leave their comfort zone** and dare to advance by **cross-pollination of knowledge and methods** between materials, disciplines and areas of research.

It is this innovative approach that needs to occur and that will keep the diversity of earthen-architectural identities, a part of this world's richness.

This publication shares some of the input from the 112 authors from TERRA 2012 | 12th SIACOT Proceedings. The event had an attendance of 550 participants from more than 50 countries. The Scientific Committee evaluated 250 papers, and selected 49 papers to be included in this publication. As editors, we thank all the reviewers, theme coordinators, and authors, who prepared excellent contributions, with criteria, rigor and hard work.

With critical thinking and **social-collaborative commitment**, our impact in the challenging world of today will make a difference and improve the quality of life of the millions of people that live worldwide, in earthen buildings.

June 2016

PERUVIAN BUILT HERITAGE AND ITS HISTORY REGARDING DISASTERS' IMPACT: A CONSERVATION PROPOSAL

Julio Vargas-Neumann

Abstract

This paper provides an overview on the history of the built heritage developed within the Peruvian territory from the precarious settlements of the stone period, Neolithic settlements, first cultures, civilization, state formation, colony until the republic. A long history always marked by serious natural disasters and climate change.

Following the primary settlements from the Holocene period of around 10,000 years ago, the first social organizations that can be called cultures, appeared in Peru at the beginning of the Neolithic or agricultural revolution. Later, civilizations and states develop on the American continent. The influence of the states (misnamed empires), such as the Huari, Tiwanaku and Inca, covered much of the west coast of South America, i.e. the Andean region, and also part of the Amazon region. Peru hosts today a breathtakingly prehistoric cultural heritage, vast and valuable, but also vulnerable to disasters.

1. INTRODUCTION

After the arrival of Europeans in the Americas, the first Spanish Viceroyalty was created in Lima and had great influence in South America. Colonial buildings were built on the structures of pre-Hispanic public buildings. The influence of the Viceroyalty of Peru in the region was relevant and adds to the valuable cultural heritage corresponding to the colonial times, which are accrued at the time of the Republic.

Natural and technological disasters (manmade) prevailed throughout history, and they have constantly impacted the preservation of this great built heritage, thus producing a singular and alarming rate of destruction. Telluric natural disasters (within the earth), meteorological (weather) and water (water in earth's crust and atmosphere) originate or are associated with biological disasters (plagues, epidemics), or technological (invasions, conquests, subversions, wars, terrorism). The history of ancient Peru is forged by disasters and their impact on the development of the Andean civilization and cultures.

It has been scientifically proven that there is a relationship between disasters, social conflicts and the growth of populations. The interdisciplinary analysis of archaeological sites permits the obtaining of comparative information on the development of populations throughout history, narrated by hieroglyphs and primary scriptures. These are compared to the populations that settled in areas of recurrent disasters, and often had to abandon their public spaces and private dwellings in situations of social conflict from disaster occurrence, or the possible convergence of more than one type of disaster.

This also elucidates why in ancient Peru, only oral and accounting communication systems were developed, such as quipus. These emerged more than writing types, which would have left a clearer, more permanent message of history to posterity. Quipus appeared only during the Huari era (700 AD), and seemed to be associated with counting of populations, groups, and storage contents. Unfortunately, most quipus were destroyed by the conquerors, and much of the surviving collection is outside the country.

The rate of destruction of Peruvian built heritage, mainly caused by earthquakes, rain, mudslides and floods, and the abandonment of public buildings due to drought, is a problem that extends into the present day. Disaster mitigation is the unsolved task, so as to preserve heritage into the distant future. From the ongoing and developing process, the conservation community, interested in preserving cultural values, reacts with defined approaches, such as the Declaration of Lima (ICOMOS, 2012) produced in December 2010, approved by the Committee of the International Adobe Standard NTE E-080, supported by ICOMOS Peru and disseminated by ICOMOS website.

2. FINDINGS AND STUDIES

In the last 20 years, there has gradually developed in Peru an increase in the knowledge of prehistory, originating in academics, professionals of heritage conservation, increasing state support (public universities, local governments, funding for standards by the Ministry of Culture). The Peruvian model has empowered the development of conservation projects for archaeological sites with sustainable public-private management (Vargas and Mujica, 2007). For instance, numerous vestiges from the Holocene era have been dated by radiocarbon -14 (see Table 1). In addition, there has been the discovery of new archaeological sites, important tombs, and conservation of heritage sites has expanded. There is increased research and intellectual scientific events organized by academics. The spread of these events through museums, conferences, media, international competitions and national meetings has also produced a wealth of information resulting in the rewriting of Peruvian prehistory, and hence the American one too.

The primary settlements known in Peru from the Holocene period date back to around 12,000 years ago at the start of the agricultural revolution, and cover all latitudes of the coast and the mountains (in the wilderness of the Amazon, nomadic signs have not yet been detected). The radiocarbon 14 measurements provided an approximate chronology of sites including: Guitarreros in Yungay of the northern highlands, 12,000 BC; Chivateros in Lima on the central coast, 12,000 to 6000 BC; Paiján, La Libertad on the north coast; Toquepala, Tacna in the southern highlands, 2,700 m above sea level; Lauricocha, Huanuco in the north-central highlands, 4,000 m above sea level, 10,000 to 4000 BC; Paccaicasa, Ayacucho in the south-central highlands, 2,740 m above sea level; and Telarmachay, 8000 to 7000 BC (Jacobs, 2000).

There has also been the study of remote Neolithic settlements, during which time some plants and animals became domesticated. Examples of this include Cerro Paloma in Lima, 4500 BC; Chilca, south of Lima, 3700 BC; the study of new discoveries dating back to the temple of Sechin Bajo, in Casma, 3500 BC; and the public building in El Paraiso in Lima, from 3200 BC. These were added to the transcendent discovery of the Caral Culture, 3000 BC, in the basin of the Supe River valley, just 190 km from Lima. New studies of the ceremonial center of Huaca Prieta from 2700 BC in Chicama, La Libertad; of the Ventarrón Sanctuary of 2600 BC; Pomalca, Chiclayo, Kotosh center, Huánuco from 2500 BC; La Galgada of 2300 BC; Huaricoto, also from 2300 BC; and Las Haldas of 1800 BC are also to be considered (Jacobs, 2000). Not only were great temples discovered in recent years, but also significant infrastructure, such as the important channel Cumbemayo (Cajamarca), an irrigation project that connects the Amazon basin and the Pacific, crossing the roughest terrains. The channel is carved into bedrock and was associated with religious ceremonies for the worship of water.

Also documented in these 20 years are the processes of technological disasters, such as the indolent incursion of Colonial and Republican cities right up to the present, against the built heritage. One catastrophic event is the gradual deterioration of the Garagay complex in Lima that dates to 1400 BC.

There are also the noteworthy studies accomplished by L.G. Lumbreras and J. Rick on the prominence of the Chavín Culture from 1500 BC (which the physician and archaeologist Julio C. Tello considered a matrix culture), the notable sanctuary and pilgrimage center and its Chavin influence on the contemporary Cupisnique culture and other subsequent cultures, such as Tiahuanaco (verified by the similarity of stone carvings, as well as by hydraulics, drains, canals) (Jacobs, 2000). Another important development is the advance of Rafael Larco Hoyle's studies in Cupisnique, Caballo Muerto of 1200 BC (Huaca de los Reyes), as well as his theory on the independence and eventual prevalence in antiquity of the north-coast cultures, along with the discovery of important royal tombs, such as those of the Lord of Sipán (250 AD), the Lady of Cao (400 AD) and the Lord of Sicán (800 AD) in Casma, Trujillo and Chiclayo, respectively, again on the north coast (Jacobs, 2000).

The last two decades also saw the redemption of the significance of the Pre-Lima in Huarmey (100-550 AD), the Cerro Culebras (0-600 AD) and Maranga Complex (200 AD) Cultures, in which more than 60 pyramids were found (Salomon and Schwartz, 1999), and among which there is also the PUCP Campus and Leyendas Park, Mateo Salado, and other archaeological sites. The recent discoveries at the archaeological complex Chotuna-Chornancap located 8km from the city of Lambayeque in Chiclayo deserve special mention. These correspond to the Lambayeque Culture (650-1300 AD) and were accomplished by professionals from the Museum Bruni. In April 2012, the news was published of the discovery of the tomb of a princess in this complex, similar to what had occurred in Trujillo La Libertad.

Recent discoveries of a tomb from the Huari culture in the jungle near Cusco (in the Espiritupampa Archaeological Complex on February 27, 2011) show the Huari Empire's expansion towards the Amazon, an empire that would later dominate the Inca Empire (Regional Directorate of Culture of Cusco, 2011). Considering the knowledge of the construction influence of the Tiwanaku culture on the Inca culture (construction of stone masonry with concave-convex dry and carved joints), narrated by Spanish chroniclers, some facts are understood and relevant conclusions are thereby drawn as a result of the action of the new interdisciplinary conservation teams.

3. RELEVANT FACTS

The following are relevant evidences:

- Pre-Peruvian history reveals the existence of many cultures at different locations, typically with sequential periods

Temporal Spans of Uncalibrated Radiocarbon 14 Measurements. Sites are ordered by oldest radiocarbon measurement.			
Monument	Valley	Oldest Measurement	Most Recent
Huaca de los Idolos	Supe	4900 ± 160	3970 ± 145
Huaca de los Idolos	Casma	4655 ± 95	3070 ± 85
Moxeke	Casma	4540 ± 200	3750 ± 65
Tortugas	Huaura	4530 ± 80	4300 ± 90
Bandurria	Chicama	4380 ± 270	2631 ± 300
Huaca Prieta	Supe	4260 ± 150	3950 ± 150
Huaca de los Sacrificios	Casma	3960 ± 80	2360 ± 90
Las Haldas	Casma	3820 ± 50	2100 ± 160
Cerro Sechín	Supe	3815 ± 90	
Chupacigarro (Caral)	Supe	3815 ± 140	
La Florida	Rimac	3810 ± 170	3645 ± 120
El Paraíso	Chillón	3790 ± 100	3020 ± 60
Cerro Obrero	Santa	3690 ± 60	
Huaca de los Reyes	Moche	3680 ± 80	2800 ± 60
Salinas de Chao	Chao	3600 ± 90	
Mina Perdida	Lurín	3520 ± 100	2870 ± 90
Huaca Herederos Chica	Moche	3450 ± 70	3040 ± 80
Sechín Alto	Casma	3400 ± 100	
Garagay	Rimac	3340 ± 70	2730 ± 70
Huaca Lucia	La Leche	3273 ± 163	
Cardal	Lurín	3120 ± 90	2690 ± 90
Purulén	Zaña	3120 ± 80	

Table 1. Radiocarbon 14 measurements from different archaeological sites (credits: James Jacobs, 2000)

of development (Caral, Chavin or Cupisnique) that were sometimes parallel, and possibly integrated by exchange and trade (Chavin de Huántar and Cupisnique). Abandonment of public buildings or ceremonial centers revealed some of these to have lasted less than 1,000 years (Caral, Chavin, Pachacamacwhich), which also meant serious interruptions in development (writing and communication), and in the consolidation of political-religious organizational structures.

• Unlike Mesopotamia and Egypt, the great Andean cities in the western part of South America, such as Maranga, Cajamarquilla, Chan Chan, and Huari, were assemblage centers that only lasted for about 500 years. Territories and buildings were abandoned. The concept of the Andean city itself differs from the Eurasian one, favoring the community rather than the familiar. The sector for public functions and trade, surrounded by monumental public buildings, occupied two-thirds of the city, whereas housing areas were of lesser significance for a small population. The population was involved in agriculture scattered throughout a rugged geography. Precisely the reverse occurred in the Mediterranean, the public space took up only a third of cities. In addition, the concept of the Eurasian state was that of regulator, while that of the Andean state was theocratic and protector from natural disasters, with "divine nature" rulers under the help of the gods, wielding political-religious influence. The population was fragile and fearful of natural disasters.

• In the Andean area, civilization arose before the city and the state. This does not follow the pattern of the Mediterranean or Eurasia regions. This is confirmed in food sustainability, trade from fishing or agriculture, the development of various products and farming technologies, the organization of labor for vast public works of monumental dimensions, and the advancement of engineering. From Caral, the Andean cultures developed gigantic pyramids, products of the social organization of both dominant and dominated classes. At the time of the emerging states, referred to as empires by the Europeans, ceremonial construction on the rocky peaks is more used, typical of the Andean highlands, as well as the high plateaus. Violence, conquest, and large walls are all features of these times.

• The fear of telluric, meteorological and hydrological natural disasters that produce structural collapses, withdrawal of inshore fisheries, the disappearance of crops, long droughts, food shortages, famines, and epidemics was used as a tool of power by the ruling elites. This provided the organized flow of farmers to the cities with low population density, in order to pay taxes and to worship their protective deities. Roads, sidewalks and canals were the most common infrastructure, in addition to the monumental buildings that had political-religious purposes and, in certain cases, the elites' protection against disasters. People communicated through and maintained the roads. The towns or cities merged into a proper Andean style, whether on the coast or on the steep Andean heights.

• The short periods of cultural validity are associated with climate change and natural and technological mega-disasters, not excluding the possibility of two or more converging disasters, simultaneously or continuously. Disasters influenced the characterization of Andean cities. It is an issue still under debate, and it is intrinsically associated with the designation of the Andean city and the existence or emergence of the state. The city of Caral did not have the same housing elements of a commuter city, organized around a political center. Its theocratic, agricultural and fishery-subsistence features placed the city 20 km from the sea, amid a cluster of villages scattered in the basin of Supe.

• It is surprising to validate the political, religious, and commercial integration that occurred over long distances of influence. This is confirmed through similarities in relations and exchanges between isolated villages of different cultures, but also in contemporary developments. It is proven by the existence of pilgrimage centers and in the offerings' generally found. The integration occurs between different latitudes, as well as transversely between areas of the coast, mountains and jungle (for instance in Caral, Chavin and obviously in the Huari States, Tiahuanaco and Tahuantinsuyo), probably influenced by the need to expand the range of products from distant altitudes and climates, as a way to guarantee survival against natural disaster.

• As mentioned before, climate change and disasters are also associated with social conflicts (Hsiang, Meng, and Cane, 2011; Burke, Satyanath, Dykema, and Lobell, 2009; Tol and Wagner, 2009). Disasters confronted the settlers and their rulers or elites, who were said to rule representing guardians or deities like the Sun, Moon, Earth, and Sea (all indestructible elements against climate change and natural disasters). Rulers who failed to control nature and to prevent disasters and their consequences, such as collapses, landslides, floods, droughts, famines and combinations of these, faced the loss of confidence of their hopeless population. This is one of the reasons for the abandonment of buildings built with so much effort.

• The consequences of disasters were usually interpreted as the will or the anger from protectors and deities and, therefore, associated with the weakness of the authorities and rulers, supposedly of divine origin, to represent the gods of

Fig.1 Migration of prehistoric government centers in Peru (credits: Julio Vargas-Neumann)

protection, and thus producing reactions and subversions from the humblest inhabitants, forced to work for the elites. Lightning and thunder were interpreted as the voice of the deities, which were followed by heavy rains, and these, by landslides and floods. Earthquakes that led to collapse of buildings were followed by many aftershocks that were associated with disgust or dissatisfaction of their protective entities.

• Recent scientific studies of the skeletons of many people have found that these were victims of sacrifice, sometimes considerable and in many cases of cultures from Peru's north coast. These sacrifices executed by the rulers sought to calm the anger of their deities and to avoid new disasters that terrorized their people.

• Earthquakes, extreme rainfall and floods usually did not affect the elites much who lived on the tops of tall and stable pyramids (imitating hills), as in the case of the Lambayeque or Sican cultures. The platforms on earthquake-resistant truncated pyramids were also better protected against rain and flooding. However, disasters affected the population that was in charge of fisheries, crops, processing of textiles, tools, infrastructure works, and safety, and that ultimately paid costly tributes to those elites. In the area of the river La Leche and Lambayeque, the huge pyramids of Pampa Grande first (18 pyramids dating from 600-800 AD) and Batan Grande later (17 large pyramids) were abandoned after several natural disasters (drought between 1020 AD and 1050 AD, then floods in 1100 AD) (Salomon and Schwartz, 1999). Following the natural disasters, they were considered cursed, therefore, they were also burned.

Finally, they moved to Túcume, and there too the population burned the tops of the 22 pyramids in order to purify them. These truncated pyramids surrounded a large hill considered the abode of the gods, and at their summits, there was abundant food and the depot of the elites. There is physical evidence of these large fires: calcined clays and the color of burnt brick of 1 or 2 m.in thickness. The end of Túcume is accelerated with the arrival of the European conquerors, and the subsequent death of the last Inca.

- Seismicity decreases in severity from the coast to the mountains, and practically disappears in the jungle, like the destructive effects of El Niño. The consequences of drought are overcome by territorial domination of empires, ranging from the coast to the jungle (Regional Directorate of Culture of Cusco, 2011).
- Consequently, it is also possible to chronologically determine a transfer of the headquarters of governments of prehistoric cultural centers from the coast (Caral, Lima, Cupisnique, Moche) to the mountains (Chavín, Huari, Tiwanaku, Cusco). This occurred without detracting from the relevance of Amazonian cultures (Kotosh from 2500 BC), and their confrontation to preserve their independence through domain over the jungle (Kuelap, 1100 AD and Chanca, 1250-1470 AD) (Regional Directorate of Culture of Cusco, 2011). It can be stated that there is a transcendent migration process of prehistoric government centers, as it can be foreseen in Fig.1.
- There is also an obvious connection between natural and/ or manmade disasters, their consequences and the rate of development of populations (Cuny, 1983), depending on their dramatic consequences of life loss, loss of fisheries and agro-crops, famines, epidemics, property damage, social conflicts, wars and subversions (Rosenzweig and Hillel, 2008).
- A considerable technological disaster overshadowed and destroyed the Inca culture and much of its cultural heritage: the phenomenon of the Spanish conquest, or the transition from prehistory to Peruvian history. This process was accompanied by the disappearance and modification of pre-Inca and Inca public buildings. However, it was also accompanied by epidemics of new diseases that led to the almost complete disappearance of the natives, reaching levels of 4% to 5% of survival in Mexico and Peru (of the 15 million inhabitants in the Tahuantinsuyo, only 400,000 inhabitants survived half a century after 1532). These communities held part of those buildings, which were obviously abandoned as a result (Cook and Borah, 1963).
- The pace of destruction of the Peruvian built heritage, mainly caused by earthquakes, rainstorms, mudslides and floods, recurring phenomena with periods still unknown for catastrophic or mega-disaster events, is a problem that persists up to today. This requires learning how to mitigate in regards to future heritage conservation. Using modern technological criteria contributes for prevention and controlling of damage. Large earthquakes and El Niño mega-phenomena are the cause of major natural disasters in Peru.

4. TELLURIC DISASTERS: EARTHQUAKES

Global historic seismicity has revealed important statistical data. The amount of energy dissipated in the crust of the planet is practically constant over time. Most seismic sources roughly follow such laws, though there are exceptions. From the above, it follows that the occurrence of earthquakes is not directly associated with climate, except for changes in the known trigger-effect that these produce during a seismic occurrence, and due to variations in atmospheric pressure and temperature when the potential deformation energy stored in the crust suddenly transforms itself into other types of energy that transmit mostly heat and less seismic waves.

It is acknowledged that the Ring of the Pacific Ocean or the Ring of Fire dispels about 85% of the seismic energy dissipated in the world; and the remaining relief occurs in the Ring of Eurasia or Mediterranean. Japan, Chile and Peru are countries with great severity of earthquakes. It is, therefore, easy to understand that Peru and these other countries face, due to earthquakes, a larger amount of heritage destruction than the rest of the world (ICOMOS, 2010).

This heritage obliteration escalates when the vulnerability of earthen buildings is considered. These earthen materials are responsible for the stability of both buildings of adobe and rammed-earth masonry, as well as stone masonry with earthen mortars. The latter is weakest, as in Caral, Chavín, Pikillacta, Marcahuamachuco, Cusco and most of Machu Picchu. As a matter of fact, it corresponds to almost the entire national heritage, including that associated with Colonial and the initial Republican eras.

When written communication appeared, it enabled chronicles that described the occurrence of mega-earthquakes like the one in 1650 in Cusco, and in 1687 and 1746 in Lima. Each of these three earthquakes was accompanied by tsunamis that advanced 6 km inland (near the current Avenue Faucett, where the church of Virgen de la Legua was built, in memory of the deceased, which was almost the entire population of Callao).

The global effort to predict earthquakes progresses very slowly, and the only thing aspired is a way to recognize signs associated with an upcoming event, so as to allow for the organization of the emergency phase (alert actions of civil defense, hospitals, army, firemen, transfer of heavy equipment, firemen, lifelines, etc). PUCP is conducting a significant research effort (Co-Seismic Luminescence) through the Institute for Radio Astronomy (INRAS) in coordination with NASA, USGS and other international organizations within the Peru Magneto Project framework (Heraud and Lira, 2011).

Peruvian heritage requires Considerations and Conservation Principles, which based on the spirit of the universal charters adopted by ICOMOS, consider their ecological and seismic conditions, and also vulnerable earthen-mechanical characteristics as a building material (SENCICO, 2010).

5. ATMOSPHERIC AND HYDROLOGIC DISASTERS: EL NIÑO EVENTS

The El Niño phenomenon is a climate variation on a large scale, covering huge areas of the planet, including three oceans (Pacific, Atlantic and Indian) and four continents (America, Asia, Oceania and Europe) resulting from the joint interaction of the oceans and the atmosphere. In the last 64 years there have been none prominent phenomena. In general, it is considered that these phenomena have a returning period from three to seven years. The last ones affecting Peru occurred in 1983 and 1998.

Their main consequences are heavy and long-lasting rains over desert areas, which were historically built with earth, a material that loses its dry strength when in contact with water and, therefore, threatens the stability of these type of buildings. Long droughts also occur, which ruin crops, produce famines, epidemics and deaths. In addition, excessive rains produce flooding in the lowlands, and landslides in mountainous areas.

Many archaeological sites have been seriously affected by these phenomena, as well as the combination of effects from earthquakes, heavy rains, floods and landslides, which are also the causes of the collapse of Peruvian cultures and the abandonment of its historical buildings. Scientists and statesmen have made great efforts to predict El Niño and La Niña events, the latter a phenomenon associated with El Niño, alternating its effects and expressed as the transition from a cold episode to a warm episode. However, the random nature of the multiple variations involved makes them unpredictable (Chen, Cane, Kaplan, Zebiak, and Huang, 2004). There are forecasts that predict the development of an El Niño-neutral event, precisely in the weeks that include the dates of the Terra Conference 2012, which would mean that no extreme abnormalities would occur.

6. CONCLUSION: PROPOSAL FOR CONSERVATION PRINCIPLES FOR HISTORICAL EARTHQUAKE-RESISTANT STRUCTURES BUILT WITH EARTH

The integration of engineers into conservation teams has influenced the awareness of defining national guidelines to properly preserve the most vulnerable cultural heritage. The first document with this purpose, as mentioned earlier, was presented and approved within the committee of the Adobe Standard E-080, SENCICO, currently under review, and which the author is honored to preside over.

Subsequently, from the Steering Committee of ICOMOS Peru and with the participation of interested members, a consensus version has been outlined, named 'Lima Declaration for Disaster Risk management of Cultural Heritage' (ICOMOS, 2010). Recognition and gratitude is deserved for the dozens of professional, national and international, who have expressed their views and contributions to the document.

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Chan Chan, Peru (credits: Luis Fernando Guerrero)

SIMPLE AND EFFECTIVE SEISMIC-RETROFIT TECHNIQUES FOR EARTHEN-MASONRY BUILDINGS

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Theme 1: Latin-American Earthen Architecture at Risk: Earthquakes, Rain and Flood Damage
Keywords: Earthen masonry, stability-based retrofits, earthquake damage

Abstract

This paper describes how field studies of the seismic behavior and performance of adobe buildings following earthquakes in California, Central and South America, and shake-table tests performed in different countries have contributed to the development of appropriate and minimally intrusive stability-based retrofit measures for culturally and historically significant adobe structures, and for low-strength masonry, in general. It concludes that understanding how these buildings perform during and after earthquakes is the key to directing minimal, stability-based intervention efforts, aimed at the specific needs and structural behaviors of unreinforced-adobe buildings without compromising their historical and cultural integrity.

1. INTRODUCTION

Although earthquakes over historic time have destroyed uncountable numbers of earthen buildings and dwellings, killing and injuring hundreds of thousands people, it has only been in the last three decades that engineers and architects have systematically investigated the types of damage that occur to them, and to develop simple cost-effective techniques of reinforcement in order to mitigate the risks that millions of people who currently live in them face. It is generally assumed that adobe structures are quite vulnerable to earthquake shaking (Mehrain and Naeim, 2004; Torrealva, Vargas-Neumann, and Blondet, 2009; Webster, 2009). However, it has been observed that specific types of damage can be expected to occur, and that these can be addressed by simple, yet effective retrofit measures in order to mitigate collapse and to enhance life safety.

Field studies of seismic performance of adobe buildings have now been carried out in several countries, including: Peru, Mexico and other Latin-American countries, the US, and Iran. In addition, shake-table tests of adobe structures have been conducted in Peru, Australia, the US, and Iran, and have duplicated several of the types of damage observed in the field. Shake-table testing has also been used to study the efficacy of different reinforcing measures, generally known as stability-based retrofit techniques (GCI, 1991; 1993; Tolles, Kimbro, Webster, and Ginell, 2000; Torrealva, Vargas-Neumann, and Blondet, 2009). The principle goals of stability-based retrofit systems are to:

1.Ensure structural continuity of the walls by installing bond beam, tie rods, diaphragm, or some other types of continuity elements at the tops of the walls;

2.Prevent out-of-plane overturning of walls with either horizontal or vertical straps, or surface mesh interconnected with the top-of-wall continuity elements;

3.Limit relative displacement across cracks or potential cracks in the walls by through-wall ties interconnected to the horizontal and vertical straps, or the surface mesh, basically containing the earthen material.

Stability-based retrofit techniques promise to provide simple and effective life-safety measures for mitigating the vast number of deaths and injuries related to damage and collapse of earthen buildings and dwellings in seismic zones.

2. DAMAGE TYPOLOGIES

Designing effective stability-based retrofits for adobe dwellings requires knowledge of the types of structures that are typical in a specific region or country, as well as the types of damage that frequently recur to these typical structures during earthquake events and are life-safety hazards. For example, based on field reconnaissance surveys in California (Tolles, Webster, Crosby, & Kimbro, 1996), the types of damage observed that influence the seismic performance of a typical unreinforced adobe building in the United States are shown in Fig.1.

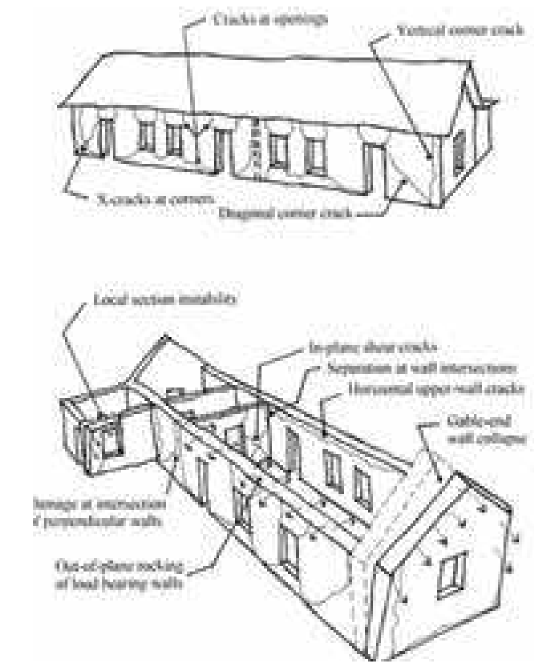

Fig.1 Typical damage observed in unreinforced adobes in the US. Illustration from Survey of Damage to Historic Adobe Buildings after the January 1994 Northridge Earthquake (credits: 1996, The J. Paul Getty Trust. All rights reserved)

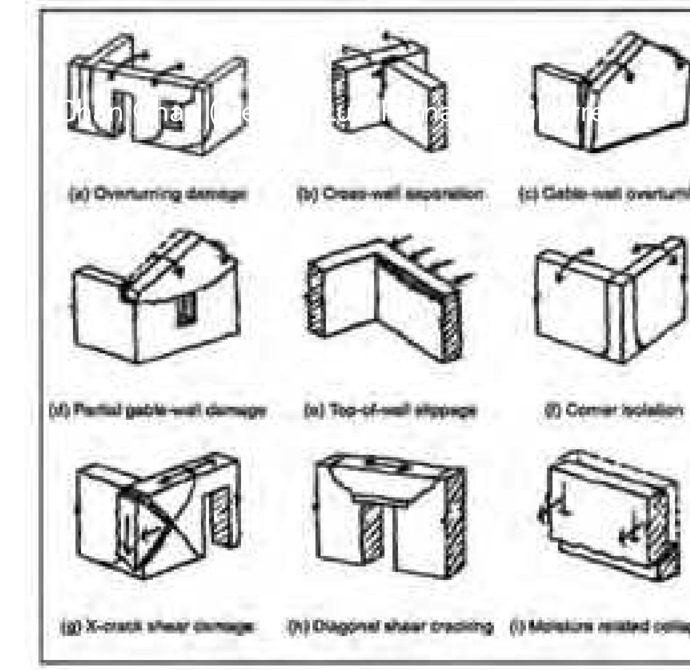

Fig.2 Typical out-of-plane and in-plane wall damage (credits: Fred Webster, 2012)

2.1 Out-of-plane flexural damage

Out-of-plane damage is initiated as vertical cracks that form at the intersection of perpendicular walls. These cracks extend downward or diagonally to the base and run horizontally along the base between transverse walls. A wall can rock out-of-plane, rotating about a horizontal crack that forms at the base [Fig.2 (a) and (b)]. As a consequence, longitudinal walls pull away from the transverse walls. In many cases there is no physical connection at the intersection of longitudinal and transverse walls, having been constructed by simply abutting one wall against another.

Gable walls are taller than longitudinal walls, and usually not well supported laterally. Unless anchored to the roof diaphragm, they can slip out from underneath roof framing.

Slippage [Fig.2 (e)] of the top plate and/or displacement of the top courses of adobe blocks are another result of the out-of-plane movement of longitudinal walls. Very limited friction is generated by the dead weight of the roof bearing on the wall, and due to the friable nature of the top of the walls, slippage may occur.

Finally, vertical cracks on two perpendicular wall faces at a building corner [Fig.2 (f)] due to rocking of one or both walls results in a freestanding column at this location that is quite vulnerable to overturning and collapse.

2.2 In-plane shear cracking

X-shaped diagonal-crack damage [Fig.2 (g)] and simple diagonal cracks result from shear forces in the plane of the wall. These cracks are generally not a serious threat to life safety unless the relative displacement across them is large. These cracks represent a lessening of in-plane lateral stiffness, but unless a segment of wall on one side of the crack is in danger of losing its purchase on the adjacent segment, such as at or near a corner, the gravity-load path remains intact. Diagonal cracks also occur at the corners of doorways and windows and result from peak ground acceleration (PGA) levels as low as 0.1g to 0.2g [Fig.2 (h)].

2.3 Moisture-related wall collapse

Although not the result of earthquake ground shaking, moisture in adobe walls does affect the seismic performance. This includes excessive spalling of plaster and adobe, as the wall rocks out-of-plane; instability caused by basal erosion that removes material at the base of the wall; and reduced wall strength from repeated wet-dry cycles or rising damp. If the base of the wall is wet during ground shaking, a through-wall slip plane may develop along which the upper portion of the wall can slip and collapse [Fig.2 (i)].

3. STABILITY-BASED RETROFITS

Stability-based measures in general do not stiffen the structure. In fact, they typically do not come into play until the structure has developed cracks and has moved enough to engage the seismic-upgrade elements. These measures, however, provide reduction in the response of the building by increased damping in the structure due to sliding friction across the cracks and lowering the response frequency once cracks have formed.

The principle goals of a stability-based retrofit system are to:
1) Provide structural continuity;
2) Prevent out-of-plane overturning of walls; and
3) Contain the wall material.

Table 1 lists some of the more basic types of stability-based measures that have been used recently in some historic and older adobes in California, to meet these goals.

Stability-Based System Goal	Possible Retrofit Elements
Structural continuity of walls:	• Bond beam[1,2] • Tie rods[2] • Continuity hardware[3,4]
Out-of-plane overturning stability:	• Vertical straps or cables[4,5] • Surface mesh[4,5] • Top-of-wall pins[1,5] • Vertical center core reinforcing[1,5]
Containment of wall material:	• Horizontal straps or cables[4] • Vertical straps or cables[4,5] • Surface mesh[4,5] • Vertical center cores[1,5]

1. Fastened to roof structure
2. Anchored to walls
3. Straps, cables
4. Thru-wall ties
5. Connected to structural continuity

Table 1. Stability-based measures recently utilized in some California adobe buildings

3.1 Structural continuity

Probably the most significant improvement in the seismic behavior of any unreinforced-adobe building is the inclusion of structural continuity of the wall system. In the design of an effective retrofit system, providing continuity throughout the structure is the most important aspect. Adobe masonry has substantial capacity to carry compressive forces, but little or no capacity to transfer tension forces from one structural element to another.

During an earthquake, the tendency of walls that are perpendicular to the direction of shaking is to separate or tear from those walls that are parallel to the motion. This occurs at the corners of the building starting at the top, where the tearing or tension stresses are the greatest. This mode of failure has been seen time and time again in both shake-table testing and in damage surveys following earthquakes (Scawthorn and Becker, 1986; Tolles et al., 1996; Dowling, Samali, and Li, 2005).

Providing structural-continuity elements, such as horizontal straps, tie rods, or a bond beam that is anchored to the wall [see Fig.3: (a), (b) and (c)], very effectively resists these wall-separation forces and keeps them from overturning, and thereby stabilizes

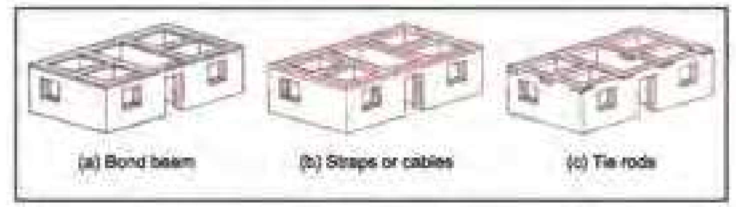

Fig.3 Structural-continuity elements (credits: Fred Webster, 2012)

the structure. It should be noted that for any of these elements to work properly, they must be fastened to the roof structure, and because of the friable nature of the masonry at the top of the wall, anchored down into the wall with rods or pins that engage more of the wall than just the top few courses. Note also that for the strapping or cable-continuity hardware to work, the straps on the inner and outer surface of the wall must be interconnected with through-wall ties.

3.2 Overturning stability

When discussing overturning stability of earthen-masonry walls, it is important to recognize the influence of the thickness of the walls and their inherent stability, or lack thereof. The dynamic out-of-plane motion of thin walls is significantly different from that observed in moderate and thick walls. At tests on the shake table at Stanford University (Tolles et al., 2000), thin walls (height-to-thickness ratio of 11) easily rocked about their base, the principal lateral support being provided by the bond beam. This behavior was not observed in walls of moderate thickness (height-to-thickness ratios of 7.5 and 5) with the same bond beam; the thickness of the wall did not permit easy rocking about the base, which significantly affected the dynamic motion of the walls. The out-of-plane motion at the tops of the walls was not amplified as it was in thinner walls.

Providing resistance to out-of-plane overturning cannot be separated from the structural continuity of the walls that are addressed in Section 3.1. However, to enhance the stability and survivability of the structure, a system of vertical straps or a surface mesh can be applied to the adobe walls [see Fig4: (a) and (b)].

Vertical straps of nylon or some other flexible durable material, when combined with through-wall ties and structural continuity, even though not providing any stiffening of the wall, are simple to install and work to enhance the stability of thin adobe walls. Center-core rods [Fig.4 (c)], on the other hand, are difficult and relatively expensive to install. Where they are most useful is in the application to historic adobe structures where the wall surfaces may be rendered with artwork that needs to be preserved. Center-core rods, when set in an epoxy grout, stiffen the wall significantly, as well as provide limitation on the relative displacement across cracks that form during the shaking. Surface mesh of chicken wire, welded-wire fabric, or some synthetic material such

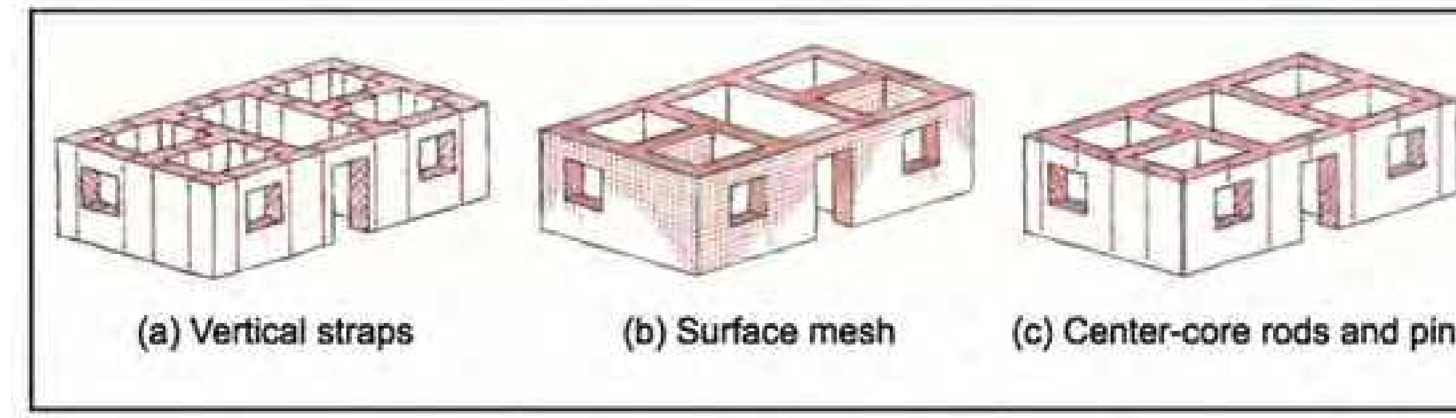

Fig.4 Overturning stabilization (credits: Fred Webster, 2012)

as polypropylene (geo-grid), when through-wall tied and attached to the structural continuity elements, act in similar fashion as the vertical straps against overturning.

3.3 Containment

Containment of the wall material is probably the second most important feature of seismic retrofit of earthen masonry. If the wall material can be contained so that it does not fall from the plane of the wall during a seismic event, it will continue its function of holding up the roof. Even in a severely cracked condition that may occur, adobe is still capable of transferring compressive forces as long as it is contained [see Fig.4 (b) and Fig.5].

Testing of an adobe structure on the shake table at University of California at Berkeley in the 1980s retrofitted with a wire mesh showed the efficacy of such a simple containment system (Scawthorn and Becker, 1986). The idea was then expanded by researchers at the Catholic University of Peru and tested in many different configurations, focusing recently on geo-grid meshes of polypropylene (Blondet, Vargas, Velasquez, & Tarque, 2006). These efforts have also been developed into engineering-design guidelines for new adobe structures (Torrealva, 2009).

During the 1990s, the Getty Conservation Institute sponsored shake-table testing of adobe structures at Stanford University in California (Tolles et al., 2000) and at the Institute of Earthquake Engineering and Engineering Seismology in Macedonia (Gavrilovic, Sendova, Taskov, Krstevska, Tolles, and Ginell, 1996). One of the focuses of these tests was containment with minimal intervention such as vertical and horizontal straps and center-core rods, whereas the mesh solution is more invasive, but does a better job of containment. As a practical matter, therefore, the straps and center-core rod elements are more appropriate for use with historically significant and/or culturally sensitive structures, whereas, the mesh solution to retrofitting and new construction of adobe masonry may be the simplest and most effective overall.

4. CONCLUSIONS

The information obtained during field study of the seismic behavior and performance of historic and older adobes following earthquake events is invaluable to the development of appropriate and minimally intrusive stability-based retrofit measures. Categorization of the types of damage allows an evaluation of the causes and hazards of such damages and has been the basis for development and implementation of effective retrofit measures for earthen masonry in California and elsewhere. Indeed, this information, in conjunction with the shake-table test results, has been the basis for design of appropriate seismic-retrofit measures that ensure life safety, while protecting historic fabric and cultural value.

The challenge of improving the structural performance and mitigating life-safety hazards of adobe buildings, both old and new, for future earthquakes is great. The key is to understand how these buildings perform, and to direct stability-based minimal interventions toward specific needs of known structural behavior. We can, in fact, improve the performance of earthen-masonry buildings without significantly compromising the existing architectural heritage embodied in these resources, and do so both simply and effectively.

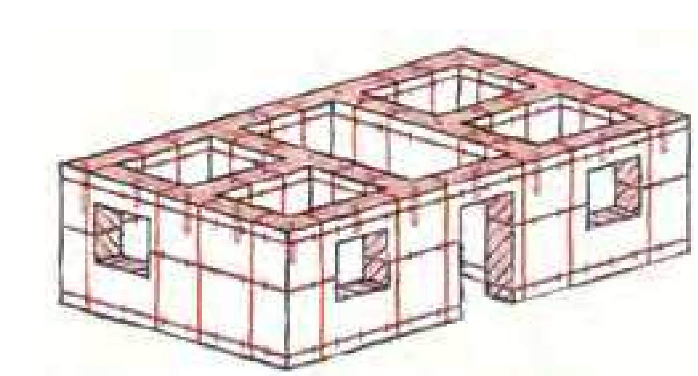

Fig.5 Containment with horizontal and vertical straps and top-of-wall pins (credits: Fred Webster, 2012)

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EARTHEN-BUILDING CULTURES AND SEISMIC HAZARD: CHILEAN TRADITIONAL ARCHITECTURE

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Theme 1: Latin-American Architecture at Risk: Earthquakes, Rain and Flood Damage
Keywords: Building culture, earthen-architecture, seismic hazard

Abstract

This article will disclose the partial results of a doctoral thesis developed between 2009-2012 within the Department of Technology of the Faculty of Architecture of the University of Florence. The final results, were presented during TERRA 2012 conference.

The core aim of the thesis is the seismic-risk assessment of different building cultures in Chilean territory that use earth as the predominant building material, in order to propose retrofitting techniques to reduce the threat. The research is inserted within the context of recent major earthquakes that have affected Chile, which have been particularly destructive to earthen buildings, raising the need to develop preventive actions to preserve this relevant heritage.

1. PRESENTATION OF THE RESEARCH

1.1 Introduction

Two thirds of the Chilean territory have abundant earthen architectural buildings, both in rural and urban areas, from the north (lat. 18, 11'S) until the beginning of the Bio-Bio Region (lat. 36 8'S), down to the south, i.e. between latitudes, where arid-dry and Mediterranean temperate climates prevail.

This long building tradition dates back to pre-Columbian times, when earth was used as molded earth in highland regions of northern Chile (1), and with the *quincha* technique by indigenous people of the central region. The use of adobe, introduced with the Inca conquest of the Northern Territory in the late 15th century, was greatly expanded during the period of the Spanish colonization (16th-19th centuries), when the technique became virtually the only building system used for founding cities. Mixed systems, meanwhile, were developed from the 19th century onwards, incorporating wood, aimed at gaining height, slimness, formal expression and better seismic-resistant behavior, relegating adobe to in-filling of walls.

The long tradition of using earthen construction materials experienced a decline in post 1940s, following the earthquakes of Talca in 1928 and Chillan in 1939 in the southern central region of Chile. Historic adobe buildings were blamed for the numerous deaths. As a result of both disasters, the first General Regulation for Urban Planning and Construction (1929) and seismic-resistant regulations (1940) were created, respectively. Both regulations abolished the use of earth as building material, leading to the massive use of industrial constituents, and to the consolidation of modern architecture.

Since then, earthen construction has diminished but not disappeared altogether. Nowadays in Chile, there is still an important presence of earthen monuments (churches, factories), and a large number of houses, mostly inhabited, that constitute settlements of architectural and environmental significance.

According to the analysis made by Karmelić (2009) based in the Inventory of Cultural Heritage Property (2001) prepared by the Ministry for Public Works, it is estimated that 40% of the Chilean architectural heritage is built of earth, mainly adobe (Karmelić, 2009, p. 212). This number is significant when taking into consideration the high seismic activity that characterizes the Chilean territory, which has propelled the development of seismic-resistant techniques throughout history.

1.2 State of the art

Despite being a rather anonymous architectural heritage, little researched and the focus of ever greater criticism after each earthquake, in present-day and subsequent the earthquake of February 2010, there has been an interesting process of appraisal of the traditional architecture built of earth, recognizing that this is an important part of the Chilean identity (Ministry of Public Works (2010). This process has contributed the following factors:

- The recent concern of the Chilean State for the protection of cultural heritage, reflected in the development of the first program for enhancement and conservation of architectural heritage, the Enhancement of Heritage Program (2007).
- The recent appreciation of earthen architectural heritage by the communities, which inhabit a house or a neighborhood, built of earth.
- The damage caused by earthquakes in the years 2005 and 2007, the criticism of the reconstruction processes responsible for the disappearance of entire settlements built of earth, and inadequate interventions in monuments that have revealed ignorance in the use of the material, and the immediate need to train technical and professional experts.

1.3 Objectives

The overall objective of the research is the identification of the different earthen building cultures in Chile, and the determination of a methodological framework for seismic-risk assessment in each of them, in order to prevent that threat. The specific objectives are to:

Establish a method able to systemically understand the origin and the development of each culture, elucidating and codifying local knowledge;

- Identify the different architectural and technological typologies belonging to each of the building cultures;
- Identify the conservation status of each of the building cultures, and to determine their vulnerabilities and threats;
- Identify the intrinsic critical points of each architectural and technological typology;
- Recommend priority-intervention models for each building type, in order to prevent seismic hazard;
- Propose verification tools for the safety of each building culture after priority interventions.

2. CONCEPTS

2.1 Local building cultures

The various examples of earthen architecture in Chile are part of numerous local building cultures. Building culture refers to a particular architectural technology developed in a specific place that is not only a constructive technique and a repertoire of materials, but a set of functional, constructive and structural solutions that intertwined respond to the problem of living in a human group, where every decision is a synthesis of unwritten rules, which in turn reflects the cultural (the social structure, beliefs, traditions, language) and environmental contexts (geography, climate, available resources, risks), in which a building is erected. For this reason, within a building culture resides countless knowledge about the place, the environment and the rational use of local resources to develop the built environment (Tonietti, 2010, p. 24).

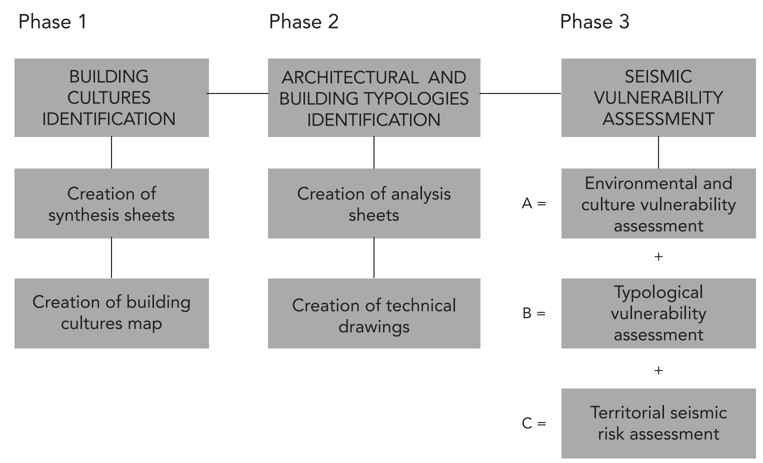

Fig.1 Scheme of the research-analysis phases, leading from the identification of building cultures, up to the evaluation of its seismic vulnerability (credits: Natalia Jorquera, 2012)

The definition of building culture must be holistically understood within the universe of new definitions developed in recent decades for cultural heritage, such as vernacular architecture, cultural landscape, intangible heritage; these are all concepts that emerge as complementary tools for the valuation of earthen architecture. A certain building culture can itself be an example of vernacular architecture, and it can also be a cultural landscape, while the survival of a building culture depends largely on how alive that intangible heritage is, which gave birth to it.

2.2 Seismic risk and local seismic cultures

In contexts of high seismic activity, local communities developed management strategies for such risk early, adapting all its available resources to create accurate seismic-resistant rules, constituting not only a particular building culture, but also a local seismic culture. The earthquake becomes part of the experience of the community, and part of the collective identity of the group, uniting their efforts to achieve stability in the built environment (Dipasquale and Jorquera, 2010, p. 112). The seismic risk remains in the memory of the local community, which together creates a series of simple unwritten rules, clearly read in the building's construction features.

Chile is one of the highest seismic prone areas in the world due to the 4,300 kilometers of coastline that is constantly pressed by the Nazca plate that descends under the South American plate, giving rise to three seismic areas parallel to the coast, of decreasing intensity from ocean to mountain ridge (Chilean Standard Nch433). The country has the unenviable record of registering the earthquakes of the highest magnitude recorded in history. In the 20th century alone, more than 30 earthquakes exceeded a magnitude of 7. For example, the earthquakes of 1906 in Valparaiso with a magnitude of 7.9; 1928 in Talca with a magnitude of 8.3; 1939 in Chillán with a magnitude of 8.3; 1960 in Valdivia with a magnitude of 9.5 (considered the largest earthquake in history); and the recent earthquakes of 2005 in Huara with a magnitude of 7.9; 2007 in Tocopilla with a magnitude of 7.7; and of 2010 in Cauquenes with a magnitude of 8.8.

3. METHODOLOGY: SYSTEMIC KNOWLEDGE AS A KEY FOR THE SAFEGUARDING OF CULTURAL HERITAGE

3.1 Systemic analysis and knowledge management for the identification and classification of building cultures

The identification of different cultures was performed through a systemic analysis that took into account all environmental and cultural factors that gave rise to the built environment. It integrated direct analysis (visits to 40 villages built of earth between latitudes 18° and 36°; accomplishment of architectural and technological photographic surveys; and interviews with residents, builders and local authorities) and indirect analysis (review of records from the Inventory of Cultural Heritage Property of the Ministry for Public Works; review of records of Historical Monuments and typical areas built of earth from the National Monuments Council; and review of literature sources).

Additionally, since the ultimate problem affecting the conservation of earthen architecture is the loss of local knowledge (ignorance or inconsistent local knowledge regarding the construction, maintenance, preservation, and repair), tools of knowledge management were used for the recovery of such information, identifying tacit and local knowledge, then documenting it in order to transform it into transferable data (Stiglitz, 1999, pp. 12).

3.2 Evaluation of seismic vulnerability of each architectural-technological typology

The evaluation of the seismic vulnerability of each architectural typology belonging to a certain building culture was approached from a holistic perspective, and considered environmental, cultural and technical aspects. Seismic vulnerability was evaluated by gathering of three factors: a) the environmental and cultural vulnerability of the building culture to which it belongs; b) the critical points intrinsic to the architectural typology (from problems associated with the choice of material, the construction process, the construction and maintenance of the building); c) the seismic risk of a certain territory where the building culture is located, which, with reference to the Chilean standard Nch433 of 1996, will result from the sum of the seismic zoning plus the classification of the building according to its use, plus the effect of the foundation soil, topography and characteristics of the earthquake.

Fig.2 Map of earthen building cultures in Chilean territory (credits: Natalia Jorquera, 2012)

4. DEVELOPMENT OF THE RESEARCH: EARTHEN-ARCHITECTURAL LANDSCAPES AND LOCAL BUILDING CULTURES

4.1 Origin of the building cultures

The continental Chilean territory (2) has a great diversity of climates (according to latitude and altitude), vegetation, topography and landscapes (starting from the Atacama Desert to the north, and finishing in the eternal ice of Tierra del Fuego at the southern end). The country is divided into 15 regions, and five major climate sub-areas: the **Norte Grande** (lat. 17 56 '- 25 ° S) of desert climate and high steppe; the **Norte Chico** (lat. 25°17'- 29°11 S) of semi-arid steppe climate in the valleys, and cold temperate in the high mountains; the **Central Valley** (lat. 29 - 36 S) of favorable Mediterranean climate; the **Lakes Area** (lat. 37 - 44 S.) of cold climate and abundant rainfall throughout the year, the **Patagonia** (lat. 44 - 56 S.) of cold weather and almost polar region in the far south.

This climate and geographical diversity together with the cultural diversity of Chile (the presence of pre-Columbian ethnic groups and the high number of European immigrants from the mid-19th century onwards) has led to a wide range of architectural forms and technological solutions, through the use of earth and stone in the far north, to mixed techniques in the central valley, up to the massive use of wood in the south. Earthen architecture is abundant in the first three sub-climate regions, appearing with a fairly homogeneous exterior architectural language, especially in residential architecture, but with important typological and technological deviations that respond to climate diversity, natural resources available, and the characteristics of earth as a construction material.

4.2. Building cultures and earthen types

Six building cultures were identified, each with a distinct territorial extension from which a name was assigned. Established for each were: the architectural and technological typologies that form it, the period of historical development, the conservation status (some are "lively" cultures, others instead are in the process of decay and almost vanishing), and the threats (environmental and socio-cultural) within which the seismic risk is the common denominator. Thus, a fundamental aspect within the classification was the identification of earthquake-retrofitting strategies of the building culture.
Ordered from north to south, these are:

Andean-Culture Typologies: Andean church, Andean housing and the "pre-cordillera" housing:

These are located in the Andean region of Norte Grande (highlands and inland valleys of the Andes region, and the regions of Arica and Parinacota, Tarapaca and Antofagasta). The birth of this culture dates back to pre-Columbian times and further development occurred during the Spanish Colony so that architecture is the result of the fusion of Andean and Spanish world visions. The earthquake-resistant strategy is based on the addition of elements attached to the main volumes (buttresses, reinforced-plinth course, terracing) and/or thickening of the main walls. It is a gravitational static principle rather than a dynamic one.

Conservation is critical and the culture is at risk of disappearing, mainly because of the social changes that occurred during the first decades of the 20th century, when a great part of the population left the Andean villages to work in mining industries in the area. Currently, the main threat is the shortage of water, used by numerous mining industries in the area that has contributed to a further desertification of the valley, inhibiting cultivation, and thus survival. The earthquakes of 2005 and 2007 have worsened the situation, destroying the few well-preserved settlements.

Culture of "the Saltpeter" Typologies: Workers' housing, housing for mine owners and civil buildings:

Located in the various mining towns in the Atacama Desert, this culture based their productivity in the extraction of sodium nitrate, the so-called "saltpeter". These mining encampments were established in the late 19th century and most of them closed in the mid-20th century. Its special value is that they represent a single case of industrial architecture built with earthen materials, using mixed systems of iron and earth. At a cultural level, it represents a particular case of a community made up of two opposing groups: the mine owners (British and American), and the mining workers belonging to the lower classes of Chile. The earthquake-resistant strategy was based on the inclusion of tie-rods (metal devices horizontally located every few rows) that complemented the work of the adobe masonry, helping to counteract horizontal thrust.

Currently, only the Maria Elena Saltpeter Mine remains in operation, so this culture is almost extinct due to natural changes in production systems that have led to the closure of most encampments. The earthquake of 2007 affected particularly the city of Maria Elena, which was at risk of completely vanishing, but thanks to its prompt declaration as a Typical Zone, it has been protected and most of its emblematic buildings have been restored.

Culture "Norte Chico" Typologies: Semi-urban housing and rural chapels:

Located in the oases of the interior valleys of the regions of Atacama and Coquimbo, the population of the region originates from the Molle pre-Columbian culture, but it was consolidated as an inhabited area only in the late 17th century after the rise of agricultural production. This culture has less-defined features than the others, but its remoteness from urban centers has allowed it to remain partially alive, keeping typical customs of rural life and, therefore, also the use of traditional techniques even in contemporary architecture. The earthquake-resistant strategy is the incorporation of timber-tying elements (llaves, trusses) within the adobe masonry, which, because of their small size, are unable to efficiently connect the different parts of the building.

Urban Culture "Santiago Poniente (2000)" Typologies: three to four-story style palace:

Located in the western area of the historic center of the capital, Santiago, this culture emerged in the mid-19th century, when, after independence from Spain, the capital welcomed immigrants from different parts of Europe, who built multi-story palaces using mixed techniques of wood and earth, this being the only major type (with some variations). From this culture remain the architectural expressions, but not the community that gave life to it, as it migrated to the upper sectors of the capital. The main threat to this culture has been the depopulation of the center of Santiago by the mid-1950s, the consequent urban decay, and finally, the great real-estate speculation affecting the area since the mid-1980s, when newer buildings of greater height built within the blocks has modified the structural behavior of the housing assemblage. The earthquakes of 1985 and the recent one of 2010 destroyed palaces that were already in a state of great structural vulnerability. The response strategy to earthquakes in the past was based on the one hand, on the use of mixed techniques where wood conferred elasticity to the building, and on the other hand, in the concept of each palace as a part of a structural assembly shaping the entire block, matching the height and size of the mezzanine diaphragms and the global height of the buildings.

Culture of Valparaiso Port Typologies: Multi-family residential complexes of several floors:

Located in the historic area of the city of Valparaiso and established in the mid-19th century in close relation to the cultural exchange, it was the main Pacific harbor. The only recurring types are multi-family residential complexes of several stories, built of the mixed technique of balloon-frame with a wooden skeleton and in-filled with earthen blocks called adobillo (adobe of smaller dimensions embedded in the uprights). The decay of the culture coincides with the opening of the Panama Canal in 1914, which relegated the seaport of Valparaiso to the background, causing social change and a major economic crisis that is only being overcome in recent years thanks to the tourism developed from the designation of the city as a World Heritage site in 2003. The mixed system developed has enabled these structures to efficiently respond to the numerous earthquakes that have affected the city, recording no major damage with the last earthquake in 2010.

Culture of the Central Valley Typologies: Factories, continuous semi-urban housing construction, colonial churches and chapels:

Located in the interior valleys (between the Andes and Costa mountain ranges) of the metropolitan areas of Valparaíso, O'Higgins and Maule, this is the culture of greater territorial extension. Its origin dates back to the first decades of Spanish colonization and the landlord agriculture-production model. Despite the social changes in the production system over the course of the 20th century, this culture remains quite alive keeping the rich traditions and the entire intangible heritage related to the rural world, even though, similar to the other cultures, local knowledge related to earthen construction has been gradually lost. The earthquake-resistant strategy is the appropriate geometric design (symmetry, in respect to proportions) and the incorporation of timber elements, such as llaves and other connecting elements (like tie-rods) in the adobe masonry. Unfortunately, due to the lack of maintenance or modification of the original structures throughout the centuries, a large part of this rich architectural heritage suffered serious damage after the last earthquake in 2010.

The various levels of analysis of each of the cultures and their associated typologies were summarized in fact sheets for greater understanding. These were:

- Factsheet 1: Photographic and plan survey of each of the architectural types that make up the different building cultures;
- Factsheet 2: Summary table of the six building cultures, with their types and the summary of the construction techniques used;
- Factsheet 3: Synthesis of each building culture, with the analysis of the physical context, the cultural context, and the predominant technology;
- Factsheet 4: Analysis of every architectural typology from an architectural and technological (constructive-structural) point of view, towards an earthquake-resistant solution and criticism.

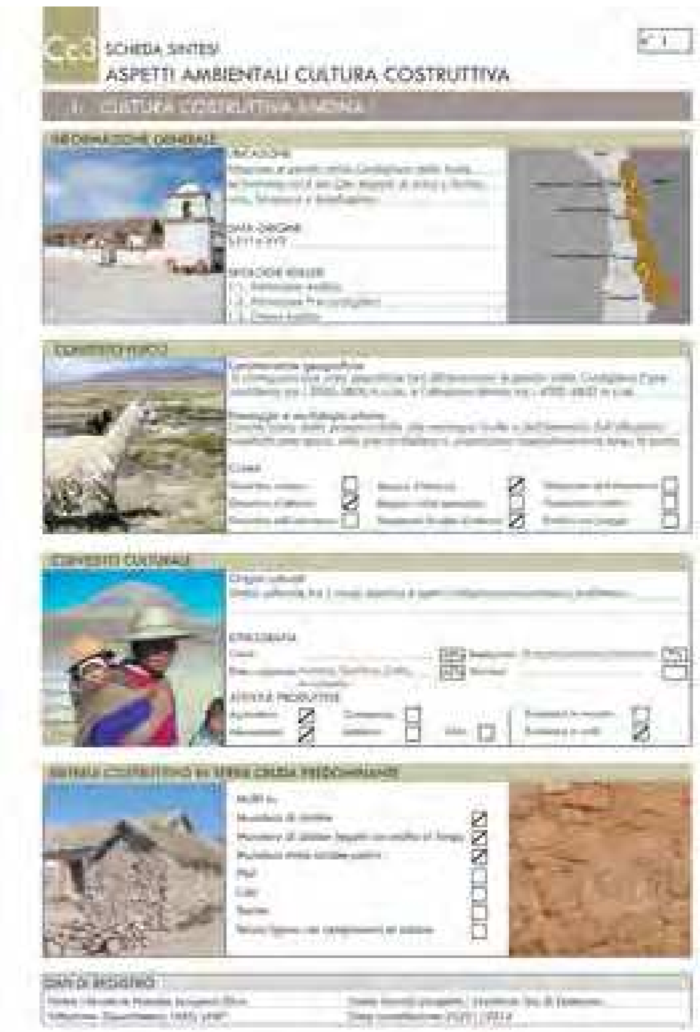

Fig.3 Example of summary fact sheet of the Andean building cultures (credits: Natalia Jorquera, 2012)

A) Assessment of environmental and cultural vulnerability of the building culture:

The building culture is in a great state of environmental and cultural vulnerability. Scarce resources, especially water, have led to a profound change in the production system based on agriculture, generating not only migration to urban centers and the abandonment of settlements, but also adverse changes in the characteristics of local construction materials. The infertile land has lost its clayey features, and the crops of paja brava (straw), useful for roofing and manufacture of adobes, have almost disappeared. To this add the loss of constructive knowledge related to building with earth. A process of disengagement with the house itself is then confirmed, which results in lack of maintenance, and replacement of the original typology with other architectural and technological forms. The introduction of modern materials (such as steel-sheet metal on the roofs) has worsened the already weakened structural behavior of the housing.

Fig.4 Example of the constructive-structural analysis factsheet of the Andean-type housing (credits: Natalia Jorquera, 2012)

B) Evaluation of the intrinsic vulnerability based on the building typology:

The great vulnerability of all types belonging to the Andean culture is the "non-monolithic" behavior of the whole, due to the poor quality of the material used for adobe and associated mortar; errors during the execution of the work (as in the irregularity of the building, and the excessive thickness of the mortar); and construction errors, such as lack of interlocking between the party walls, and the absence of ties (between walls, and between walls and roof), which gives rise to an "accumulation of elements" rather than a structural unit. To this, add the excessive weight of the layer of mud and straw, used as insulated roofing, which generates an overload of around 300 kg/m³, where the structure is weakest. The load is incorrectly transmitted to the walls, due to the misconfiguration of the trusses, which are composed of wood of little structural strength, small dimensions, and excessive horizontal spans that fails to create a triangular shape. Nevertheless, it is still a structure that generates thrust on the walls, which already have problems resisting their own weight. Despite these characteristics, the housing is not highly impacted by the seismic thrust, due to its small size, simplistic and symmetrical geometry.

C) Evaluation of seismic hazard of the territory to which the culture belongs (4):

According to Nch433, the Andean Culture belongs to Seismic Zone 1, which means that earthquakes are seen there with less intensity than in rest of the Chilean territory, and with an acceleration of 0.2 g. The foundation soil is generally rocky, so amplification of the seismic wave is not confirmed. According to its category of occupation, housing belongs to Classification II in degree of importance (importance increases from I to IV).

It could be established in summary that, in relation to the territory, the seismic risk of the Andean Culture, and especially of housing, is lower than in other cultures belonging to Seismic Zones 2 and 3. However, due to the special vulnerability status of its building culture and the intrinsic weaknesses of its architectural and technological typology, the risk turns out to be high, i.e., a shallow intensity and duration earthquake will devastate simple housing (which are already in poor condition, presenting conceptual design errors, even where static conditions are concerned).

Thus, the most recurrent damage observed after the earthquakes of 2005 and 2007, corroborates this thesis: fractures of corners and crumbling walls are related to the intrinsic defects of this typology, rather than to mechanisms triggered by seismic action.

5. CONCLUSIONS

The results achieved to date are:

a) The development of a database with building cultures and their architectural and technological typologies, emphasizing their vulnerabilities and critical aspects. In a hypothetical second phase of this research, it would be interesting to complement the database with a record of damage caused by seismic action for each building culture.

b) Determining a methodological framework for the evaluation of seismic vulnerability.

c) The recommended "priority interventions" for each building culture (a work in progress).

The interventions to be proposed are directly related to the intrinsic vulnerability of each type. For example, it is proposed that any consolidation/restoration project of a structure belonging to the Andean Culture should start to solve the problem of the lack of "monolithic" behavior, either through the employment of ties and/or outer reinforcements (reinforced-plinth course) that confine the elements, taking advantage of the Andean Culture's positive aspects, which is its geometry and the considerable thickness of its walls.

The integration of these three recommendations can become a powerful nationwide tool for seismic-hazard mitigation. Regional actions devoted to intervention (consolidation/restoration) on earthen-architectural heritage could focus on the preventive resolution of the critical issues of each typology, improving buildings' behavior under local seismic action.

Notes

(1) The current regions of northern Chile, Arica and Parinacota, Tarapaca and Antofagasta, once belonged to Peru and Bolivia respectively, during the Spanish colonial period and until 1883, when Chile won the Pacific War, and claimed these territories.
(2) The Chilean territory is formed by the insular Chilean territory and also the Antarctic Chilean territory.
(3) In the development of the thesis, the two most extreme cultures (Andean and central valley) were evaluated as an example, since due to the large geographical distance between them, they represent two contrasting examples from the environmental, cultural and earthquake-resistant response point of view, but also because these two cultures were affected by the recent earthquakes of this century.
(4) This point is still under analysis.

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LA JOYA EARTHEN PYRAMID AFTER HURRICANE KARL, SEPTEMBER 2010, ON THE GULF COAST OF MEXICO

Annick Daneels, Luis Fernando Guerrero

Theme 1: Latin-American Earthen Architecture at Risk: Earthquakes, Rain and Flood Damage
Keywords: Archaeology, Veracruz, Mexico

Abstract

In this paper we analyze the damage a Category 3 hurricane inflicted on a 200-700 AD pyramid located on the coastal plain 6 km inland from the Gulf of Mexico in a humid tropical environment. The evaluation is part of an ongoing preservation program. On the one hand, we report the good performance of a protection strategy consisting of a geotextile covered with an earthen sacrificial layer with very low proportions of vinyl polymers and a silane-siloxane water repellent. On the other hand, we analyze the deterioration and collapse of a section of building fill, caused by the hurricane itself, but also by the heavy rains and afterwards the severe drying period that followed the event. We also evaluate factors of mineral composition of building sediments, rain impact, wind direction, and intrusive vegetation. Based on the evaluation we consider alternatives for the preservation of archaeological earthen architecture in cases of hurricane impact.

1. INTRODUCTION

On September 17, 2010, a Category 3 hurricane, Karl, hit the archaeological site of La Joya, located a mere 6 km inland on the tropical coastal plains of Central Veracruz, Mexico. This paper reviews the damage inflicted on the façade of the earthen pyramid, which has been undergoing a process of preservation since 2009 following its discovery in May 2008. The conservation program is experimental, as there are no antecedents for preserving exposed all-earthen architecture in humid tropical conditions in Mexico. In general, the architectural remnant survived well, except for the collapse of part of the building fill, probably caused by the growth of vegetation. To substantiate this diagnosis, this paper will present a synthesis of (a) the regional climatic and geological conditions, (b) the pyramid´s construction sequence, (c) the preservation process, including a geotextile cover and a sacrificial layer of clay with hydrofugants, partly consolidated with vinyl polymers, (d) the site-monitoring program, (e) the impact of the hurricane, and (f) the assessment of damages. The conclusion is that in contexts of high rainfall, allowing weeds to grow and develop roots through geotextiles is counterproductive, and leads to increased differential humidity that may provoke collapse of unconsolidated fills. Recommendations for preservation include the consolidation of the sacrificial layer and the strict control of root and water penetration beyond the geotextile cover.

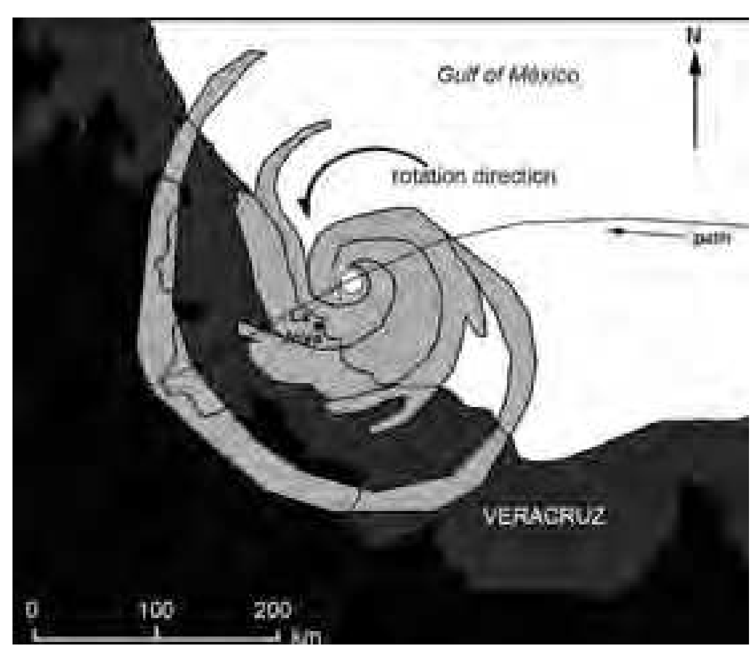

Fig.1 Location of La Joya on the Gulf coast, with respect to Karl's landfall point; inset: location of map area on outline of Mexico (credits: redrawn from Stewart, 2011)

Fig.2 Map of La Joya, with central compound surrounded by a system of ponds. Inset: location of site within the State of Veracruz (credits: Annick Daneels)

2. REGIONAL CLIMATIC AND GEOMORPHOLOGICAL CONDITIONS

La Joya is located 19°04'00''N 96°09'00''W (in UTM Zone 14 799799E 2110514N), at 7 m above sea-level at the confluence of the Jamapa and Cotaxtla Rivers, 6 km from the actual coastline as the crow flies. Part of the coastal lowlands, it stands on top of a paleo-dune, completely surrounded by fluvial sediments eroded from the neovolcanic mountain range dominated by the Pico de Orizaba, Mexico's highest peak. This situation makes for a geological profile dominated by sands and smectite, a highly expansive clay. This very deep sediment layer serves as a cushion absorbing most tectonic movements: the strong earthquakes in Orizaba (1973) and Mexico City (1985) had only minor impact on the lowlands. The climate at the site is tropical savannah Aw, on the limit between Aw1 and Aw2, characterized by predominant summer rainfalls between 1,500 and 2,000 mm annually, and gale-force winds in the winter. Wetter conditions prevail towards Southern Veracruz, where 2,000 to 4,000 mm of rain are common (García, 1970). Hurricanes in this area are rare. Before Karl, only two hit the South-Central Veracruz region in the twentieth century, in 1950 and in 1933, both of Category 2 (Gómez Ramirez, 2006). Thus Karl's Category 3 impact is highly significant to evaluate the efficacy of the preservation strategies applied to the pyramid.

Hurricane Karl is the strongest hurricane on record in the Southern Gulf of Mexico, with maximum winds of 110 knots (204 km/h); at landfall, at the point 19.3°N 96.2°W, the wind speed was still 100 knots (185 km/h) (Stewart, 2011). This is 30 km to the north of La Joya, leaving the site exactly on the edge of the eye of the hurricane, where winds are the strongest. Total rain in the nearby city of Veracruz was reported as 9.21 inches or 234 mm (Stewart, 2011), or 253.75 mm between September 17 and 18, 2010 at the Ylan Ylang weather station located 19.15 W 96.11 N, 10 km to the north of the archaeological site (Servicio Meteorológico Nacional, 2010). The heavy rainfall on the mountainside caused an exceptional flood on the coast, but this did not affect the archaeological site because it was protected by the pre-Columbian drainage system, consisting of connected water reservoirs that conduct excess water back towards the river by a northeastern drainage canal.

3. LA JOYA AND THE GULF COAST TRADITION OF EARTHEN ARCHITECTURE

The heavy summer rainfall and abrasive winter gales characteristic of the Central and Southern Veracruz coastal plains would seem adverse for earthen architecture. Yet this region is home to a millenary tradition, originating with the Olmecs, of monumental architectural complexes built of earth, including ball courts, pyramids, and palaces with porticoed rooms and balustraded staircases, sunken patios and large enclosed plazas, all conforming to the classical Mesoamerican architectural canons. This tradition has only recently been defined, with the oldest examples

Fig.3 Above: pyramid's substructure west façade when excavated in May 2008. Below: reconstruction (credits: photo and excavation data by Annick Daneels, from project authorized by the Archaeology Council of Mexico's National Institute of Anthropology and History, 2008; hypothetical reconstruction by Giovanna Liberotti, 2010)

only probed through test-pits and not exposed or systematically analyzed as to their constructive techniques; these cases, in San Lorenzo and La Venta, were reburied for their preservation (Cyphers et al., 2006; González-Lauck, 1997; Gillespie, 2008).

La Joya is exceptional in this respect, as due to extensive damage by brick makers only 5% of three of the mounds remain (Fig. 2, extant portions shown in black), exposing large profiles of superimposed buildings and allowing the definition of the building sequence and the analysis of construction techniques. The oldest building is the North Platform, apparently starting as a palatial complex enclosed by a perimeter wall, radiocarbon-dated to 400-100 BCE (Daneels, 2008a, 2011). An enclosed plaza complex framed by the Pyramid and the North and East Platforms, including a first version of the water-pond enclosure, arises by 200 CE, in the early part of what is called the Classic period in Mesoamerica. The complex had several renovations, the last one about 800/900 CE, with the site apparently abandoned by 1000 CE. The intervention at the site was done originally as a rescue operation, with no restoration contemplated. But the discovery in May 2008 of the pyramid's substructure led to the decision to attempt the preservation of the extant remains of its west façade.

It was possible to reconstruct the complete contour of the building as a square, twelve-tiered structure, with four staircases of differing width. Its construction technique is different from the fill-block system of the Late Classic period (Daneels, 2008b), and consists of a nucleus of layers of compacted loamy sand, covered and contained by a thick exterior capping of clayey loam, in which the shape of the building is modeled (tiers, staircases and balustrades). The surface was then covered with a series of at least three 2- to 2.5-cm thick layers of clay facings of well-graded loamy clay with finely chopped grass, probably mixed with an organic agglutinant that had consolidating and hydrofugating properties (but remains so far unidentified), and then strongly compacted. As only an 18-m wide segment of the west façade remains, the northern, eastern and southern contours of the vestige expose the sandy fill.

4. THE PRESERVATION PROCESS AND ITS MONITORING PROGRAM

As indicated above, no case antecedents were available in Mexico for preservation of pre-Columbian earthen architecture

Fig.4 La Joya Pyramid in spring 2010: a. arrow indicates collapse of north retaining wall due to weeds, b. geotextile applied directly to north profile, c. west façade protected by tarpaulins, whereas for the southern sector (on the right) with the new sacrificial layer with vinyl polymer (credits: Annick Daneels, from project authorized by the Archaeology Council of Mexico's National Institute of Anthropology and History)

in humid tropical environments. Guided by ICOMOS' general principles of conservation (2003), a fully documented archaeological-excavation report determined the extent and the building techniques of the structure, and samples were obtained of fills, capping layers, and facings to ascertain the mineralogical composition, plasticity, porosity, absorption, compressive strength, and nature of the organic agglutinant, using thin-section petrography, sedimentation analysis, X-Ray Fluorescence and Diffraction, FTIR, and ESM (Daneels and Guerrero Baca, 2011). As an urgent protection measure, conforming to the principles of reversibility and material compatibility, in the spring of 2009, the vestige was covered with a polyester geotextile (non-woven PET 275 gr/m^2, gray), then faced with a sacrificial layer of clayey loam, and treated with a silane-siloxane hydrofugant aspersion at 1/40 concentration (Wacker SILRES BS 1001A), after constructing retaining walls of raw bricks bedded with mud where needed, and filled in with sand. Profile cuts where whitewashed with lime, to bring out the extent of the original façade.

With bi-monthly control visits and photography, it was possible to systematically document that the summer rains of 2009 deteriorated the sacrificial layer, while the geotextile effectively protected the original structure, as the surface below remained firm. The retaining wall on the north profile collapsed because the weeds that started growing on the ledges percolated

Fig.5 La Joya Pyramid in spring 2009: first preservation experiment: a) retaining walls at the foot of west façade and on the north profile, placing of geotextile and protective layer; b) west façade after preservation; c) north profile after preservation and d) weeds growing through geotextile and sacrificial layer (credits: Annick Daneels, from project authorized by the Archaeology Council of Mexico's National Institute of Anthropology and History)

rainwater into the sand fill and weakened the wall. In spring 2010, the debris was cleared and geotextile applied directly to the fill profile. A new experimental layer of increased resistance was developed and tested in the Restoration Laboratory of the Institute of Anthropological Research, and applied only on the southern sector of the façade. It consists of a first thin layer of sand/loam mix in equal proportion, then a second 1.5 cm thick layer of the same sand/loam mix with 1,5% finely chopped Pangola grass (1), 0.8% of vinyl polymer (Wacker VINNAPAS 5044N), and 0.3% of hydrofugant (Wacker SILRES BS Powder D). The cracks that appear in the layer are afterwards sealed with a sand/loam mix with a 5% addition of the same polymer, to insure compatibility and give elasticity to the cover.

5. IMPACT OF HURRICANE KARL AND DAMAGE ASSESSMENT

The 180-km/h winds from Karl hit the pyramid from the south, a direction opposed to the local dominant winter winds. This lessened the impact on the structure, as the wind rode over the wedge-shaped vestige that increases in height and width from south to north. Nevertheless, the tarpaulins where torn off, exposing the surface to the 250 mm of rain. Affecting only a very small part of the façade's edge, part of the original fill of the north profile collapsed, stretching the geotextile to a breaking point. Unknown to us, below the tarpaulins, weeds had started to grow again along the northern edge of the façade.

When removing the geotextile, it was possible to observe the presence of more than 1-m deep weed roots in the fracture zones, penetrating the original compacted-earth fill of the building and the modern sandy fill placed in 2009 as part of the raw brick retaining-wall system. The weeds did not grow on the façade itself, but on its northern edge, formerly exposed, where before preservation attempts, an invasion of a sturdy weed existed, identified as Cyperus rotundus L. of the Cyperaceae family. This weed has long rhizomes forming chains of bulbous tubers that developed below the geotextile, and cannot therefore be removed manually without damaging the textile, nor killed with standard glyphosate weed killers. It was first used FAENA forte (Monsanto) in 2009, then Finale Pro 15 (Bayer) in small experimental patches in 2010, at the recommendation of biologist Pablo Torres Soria, consulting specialist of the National Institute of Anthropology and History in Mexico in matters of site preservation. These applications were suspended in view of their inefficacy and the high toxicity of the products. This weed even broke through the polymer-consolidated sacrificial layer, showing that being cut off from sunlight does not affect its vitality. The presence of the roots suggests a repetition of the 2009 scenario: the weed catches the rain and allows it to penetrate along its roots beyond the geotextile, 1- to 2-m deep into

Fig.6 La Joya Pyramid in September 2010, after hurricane Karl: a. west façade with torn tarpaulins, southern sector (on the right) with polymer layer in good condition, b. collapse of north profile fill, arrows indicating weeds and roots, c. detail of weed roots in old crevices, originally filled with sand (credits: Annick Daneels, from project authorized by the Archaeology Council of Mexico's National Institute of Anthropology and History)

the sandy fill of the building itself. The ensuing differential humidity weakens the fill stratum that does not have the clay content and compaction of the capping layer of the façade. The steep incline of the north profile led to an almost vertical slide, in line with the weed-root penetration.

6. CONCLUSION

The experience obtained at La Joya, in normal (2009) and exceptional (2010) meteorological conditions suggests that our preservation strategy is basically effective. The geotextile, while hiding the original vestige from view, does protect it from the heavy summer rains and scouring winter winds, and is a reversible strategy for as long as it takes to develop a treatment that would allow exposure of the original surface. As all the surfaces of the building have an adequate incline, the geotextile captures the rainwater, and gravity drains it to the foot of the building, where it is absorbed by the sandy subsoil. The sacrificial layer consolidated with very low proportions of vinyl polymer and powdered hydrofugant has successfully passed an extremely hard test with the hurricane; it conforms to the requisites of being of equal or lesser resistance than the original surface, of allowing the building to "breathe" and expand and contract with seasonal cycles.

What has become evident is the necessity of avoiding sandy fills when building the retaining walls, as they allow drainage to occur too rapidly and provoke differential humidity that weakens the compaction of the fill. Also, it is very important to continuously monitor weed growth, especially those that have deep root systems that penetrate beneath the geotextile, curtailing its protective action. A strategy to control weed growth needs to be developed, as the usual weed killers have proven ineffective.

In 2011, the pyramid was completely covered with the experimental vinyl-polymer layer on top of the geotextile, after building a stronger retaining wall around the north profile, filled in with layers of loam stabilized with lime, based on the experiments made at the Materials Laboratory of the UAM-Xochimilco (Guerrero and Roux, 2010: 93-94). These are provisional preservation measures while the laboratory analyses proceed both on pre-Columbian samples of facings, in an effort to determine the original organic agglutinant, and on other experimental sacrificial layers using vernacular techniques extant in tropical-rainforest environments in Central America, as well as other, modern components. Bi-monthly monitoring will continue at least until the end of the year, for the duration of the actual project.

As a parallel action, the members of the project work both on community awareness, to promote knowledge about the coastal tradition of earthen architecture and its importance as cultural heritage, and on a feasibility dossier to involve local and state authorities in the creation of a museum that would integrate the maintenance of the pyramid's façade, so far the only exposed monumental example of this splendid architectural tradition on the coastal Gulf plains of Mexico.

Notes

(1) Pangola grass is an African grass species, introduced as pasture in tropical America. It has shallow roots as it reproduces horizontally through a stolon. It was chosen as a mechanical binder in the sacrificial layer because its size is akin to that of the grasses identified in the pre-Columbian samples, and because even if it would grow, the roots would not penetrate the geotextile, as happened with the damaging weed species.

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DISASTER-RISK MANAGEMENT OF CARAL WORLD HERITAGE SITE, PERU

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Theme 1: Latin-American Earthen Architecture at Risk: Earthquakes, Rain and Flood Damage
Keywords: Caral, disaster, risk, management

Abstract

Vulnerability of World Heritage Properties is increasing, leading to serious and irreversible damage due to natural and human induced disasters. There are many World Heritage properties located in seismic areas, such as the Peruvian region, where the 5000-year-old archaeological site of the Sacred City of Caral is located.

The seismic risk of the site is specifically high due to vulnerability of earthen heritage to earthquakes. Receiving the support of the US Ambassadors Fund for Cultural Preservation, a multidisciplinary team, including conservators, architects and structural engineers, was established during recent conservation works to conduct studies on soil mechanics and geodynamics by using state-of-the-art tools.

A team of structural engineers working through coordination between various field and office activities performed an assessment of the structural vulnerability of a typical ancient pyramid. The interdisciplinary team selected this pyramid on the basis of its size and conservation conditions. The results of this study showed that the organized and reinforced core of the pyramid is very stable compared to the scaled platforms of the pyramids, which are not really part of the structure. Considering this challenge, important changes were recommended in the retrofitting methodology.

Recurrent earthquakes have led to the collapse of many façades in the past, exposing the core vegetal-fiber reinforcement to ultraviolet rays, thereby reducing the fibers' tensile capacity that was controlling the stability, and also leading to the collapse of the core structure during earthquakes. In order to protect this important heritage site from future disasters, the paper will describe-preventive conservation strategies, prioritized through an action plan. This paper will also describe basic principles, methodology and activities for a comprehensive risk-management plan for Caral World Heritage Site that takes into account mitigation, emergency response and recovery and integrates it into the overall management of the Archaeological Site of Caral.

1. INTRODUCTION

Disaster is no longer viewed as an isolated catastrophic event that merely results from momentary natural hazards, such as earthquakes, floods, cyclones etc. The current understanding seeks to recognize the complex relationships between disasters and development. The Hyogo framework for action (2005-2015) resolves more effective integration of disaster risk considerations into sustainable development policies, planning and programming at all levels.

In order to achieve these objectives, the fundamental importance of transmission of traditional technologies, skills, and local knowledge systems, and the conservation of cultural heritage has been recognized, thereby emphasizing the proactive role of cultural heritage during prevention, response and recovery phases of disaster management (Jigyasu, 2006a). This paper will investigate the scope and nature of traditional knowledge in disaster mitigation, its present vulnerabilities and the importance of disaster-risk assessment and management of cultural heritage in the context of the Caral World Heritage Site.

2. TRADITIONAL SEISMIC-RESISTANT BUILDING KNOWLEDGE OF CARAL

Caral is an archaeological complex built 5,000 years ago by the oldest civilization in America. Located in the Supe Valley, 180 km north of Lima and 20 km from the ocean, it is a clear example of the construction/reconstruction cycles due to seismic activity in the area. The remains of Caral's massive public buildings reveal different stages of reconstruction undertaken by rebuilding over the previously damaged structures (Shady, Cáceda, Crispín, Machacuay, Novoa, & Quispe, 2009).

Having existed for almost 1,000 years, this civilization flourished in Peru's most seismic area, withstanding no less than

20 strong earthquakes, according to this area's statistics of seismic recurrence (Shady et al., 2009). The people from this civilization were aware of the damage caused by recurring earthquakes, which destroyed their walls, made out of stone and earth mortar, and caused the collapse of their pyramids' platforms. Consequently, they attempted to implement seismic-resistant methods to their construction techniques. In order to build platforms at different heights, they realized that the core material should not cause any pressure on the external vertical borders or façades, also built with stonework joined with earth mortar. The main goal was to have a very stable core to resist earthquakes, while permitting some damage in the reparable façades.

The builders discovered that angular stones were more rugged, so the core material had a larger angle of repose that produced less horizontal loads on the borders and façades. Moreover, the angular stones without earth fill led to a larger percentage of empty spaces, thereby creating walls with lower specific gravity that produced even less horizontal loads. However, it was necessary to eliminate horizontal loads, and then the core had to be stable and resistant to horizontal seismic movement.

The builders then discovered that by "bagging" the stones with adequate tensile-resistant material (vegetal fibers), they could control stone displacement and also prevent the bags from pushing each other, thereby creating a layered and stable core that did not produce any stress on the façade walls. These bags, shicras, were made with vegetable fibers from the highlands, and contributed to the creation of a seismic-resistant technique that increased the buildings' strength for a very long period, longer than their own average service life, although time, open air and ultraviolet radiation eventually decomposed the bags' organic material. These were precursors of the modern day gabions and thus were earthquake-engineering pioneers.

The builders also used *quincha* (wattle-and-daub), a composite technology using wood, cane, vegetal fibers and earth, coated with a plaster made of mud and straw.

3. METHODOLOGY FOR DISASTER-RISK ASSESSMENT OF CULTURAL HERITAGE

Risk assessment is an informed judgment based on a methodology to determine the nature and extent of risk to cultural heritage by analyzing the hazards and evaluating existing conditions of vulnerability that together could potentially harm people, property, services, livelihoods, the environment and cultural heritage. The World Heritage Resource Manual, Managing Disaster Risks (UNESCO, ICCROM, ICOMOS, IUCN, 2010), outlines key steps for disaster-risk assessment of World Cultural Heritage Sites. This is briefly explained below:

The first step is the Identification of Disaster Risks. Secondary Information needs to be collected on the history of the site, disasters that have impacted it, and past interventions. The existing management systems need to be evaluated using a checklist that includes required equipment, controls, funds, staff, communication and coordination. Activities that can

Fig.1 Staggered Pyramid "La Galería", in Caral, from 3,000 BC. The complex is built in stone masonry, earth mortar and wattle-and-daub (credits: Julio Vargas, 2011)

Fig.2 Remnants of shicras used for bagging stones for stable pyramids cores (credits: Julio Vargas, 2011)

potentially have a negative impact on the values of the site need to be observed and halted.

The second step is analyzing disaster risks to the cultural heritage site. Various hazards and vulnerabilities need to be linked to identify disaster risks and their impact on the cultural heritage site. There are various elements of the site at potential risk: lives and livelihoods, components of heritage, as well as the environmental setting. However, the risk to values cannot be ignored in the case of a heritage site. This would require analyzing heritage values of the site and various attributes in which they are embedded. Importantly, risks to the multiple values embedded in the heritage site need to be addressed. Of course, the challenge is indeed how to analyze safety vis-à-vis values.

However, risks are not mere lists of possible causes and potential effects. Rather they are a "Sequence of Events" unfolding in a particular time period. Alternative risk scenarios need to be constructed considering the sequence of events, the associated time frame and informed assumptions based on risk identification and site conditions.

The next important step is evaluation of scenarios to ascertain various levels of risk. This is primarily based on three indicators. What is the probability of the scenario occurring? What would the consequence be to the site? What would the degree of loss of value, authenticity, integrity and sustainability of the site be as a consequence of the disaster?

The last important step in the risk-assessment process is prioritization of risk-mitigation options. Risk Mitigation involves taking proactive measures to prevent damage to the heritage site and its components or minimize the potential impacts on them. Risk can be mitigated either by eliminating the source, establishing barriers or acting on the agent responsible for the risk or the impacted component. Risk-mitigation options can be prioritized considering effectiveness from each and all hazards, cost-benefit ratio and the effect on one component at the cost of reducing risk to another component. A Risk-Mitigation Plan can be prepared based on the priority list of individual risk-mitigation options.

Fig.3 Remnants of shicras used for bagging stones for stable pyramids cores (credits: Julio Vargas, 2011)
Fig.4 *Quincha* (wattle-and-daub) is an earthquake-resistant composite technology (credits: Julio Vargas, 2011)

4. THE CARAL DISASTER SCENARIO AND ASSESSING RISKS LEVELS

Three alternative disaster scenarios could be prepared for the World Heritage Site of Caral, taking into account the core area and its surroundings, including Supe Valley. However, there are several considerations that need to be addressed.

Regarding sources of hazards, earthquakes are the major hazard. Caral is located in the highest seismic zone of Peru, that is the Pacific Ocean coast near the subduction zone where the Nazca tectonic plate goes under the American tectonic plate (convergent boundaries). There are many studies and information about seismicity in this zone and probabilistic methods for estimating the seismic hazard (Vargas, 1979).

El Niño Southern Oscillation (ENSO) is a natural phenomenon that has occurred for centuries and appeared periodically around Christmas time and lasted for a few months. Ocean and atmospheric conditions in the Pacific tend to fluctuate between El Niño (warming) and a drop in temperature in the tropical Pacific known as La Niña. The fluctuations are rather irregular, but tend to appear every three to six years. In general terms, El Niño means intense rains in summer and dryness in the Andean region.

The random occurrence of these two recurrent disasters produced the collapse of many ancient cultures in Latin America including Caral, which probably was the oldest.

Until recently, the connection between disasters and development was not recognized. In present times, countries on the road to development suddenly lose momentum after experiencing a big disaster (Bates, 1963; Cunny, 1983; Committee on International Disasters Assistance, 1978). Therefore, it is easy to imagine that in ancient times, Peruvian cultures had cycles of existence, shorter than 700 years because of disasters.

The vulnerability of Caral, a stone and earth city, is also because the construction materials were weak. As mentioned in the introduction, builders at Caral could address seismic disasters on the basis of learning from past experience, but probably were not prepared for a severe drought or heavy rains that damaged agricultural produce, both of which are associated with the El Niño phenomenon. Moreover, due to changes in temperature of seawater, some species of fish may have disappeared. A random chain of events of different disasters could have possibly cut forever the cycle of Caral's culture.

The modern world is now learning about the El Niño phenomenon, which was of course unknown 5,000 years ago. The north Peruvian coast suffered heavy damage to infrastructure, agriculture and housing because of long rainfall periods, during El Niño phenomenon, from 1983 and 1998.

Earthquakes are the major hazards to which the Caral site remains highly vulnerable. They continue to occur, periodically. Also, it is known that earthquakes produce cumulative damage in the earthen structures. So, it is necessary to include protective measures in Caral's Management Plan. Old reinforcement measures must be renewed, following a performance-design criterion.

Best, medium and worse scenarios in the case of earthquakes are different only in terms of time, which means that the three scenarios are associated with three different return periods, for a very large earthquake that it is known that it will happen. It is a random situation. It can be reasonably expected that a major earthquake will happen again, but this thinking may imply controlling very large displacements in existing fabric. Although it can be expected, a major credible earthquake for the Caral area, this sole criterion is not reasonable enough for practical planning.

Earthquake-engineering practice uses standards and codes for structural design of buildings. These codes are not directly applicable to architectural heritage, because ancient buildings were designed before this knowledge was developed.

In other words, we must develop a reasonable design performance criterion using minimal, compatible and reversible reinforcement for each structural element, as well as the entire structure. If a major earthquake strikes, we must expect major damage in Caral and significant loss in value. Therefore, while deciding on appropriate interventions, values and their qualifiers, namely authenticity and integrity should be evaluated for the site as a whole and its components (Jigyasu, 2006b).

However, damaged internal bagging with shicras must be renewed in the core of all Caral's pyramids (Vargas, Iwaki, and Rubiños, 2011) because the level of earthquake risk for Caral is so high. The scenarios are ranked based on probability, and consequences on property, values and qualifiers. The façades have a higher probability of damage than the pyramids' cores, as was clearly intended by the original builders. However façade walls are not well connected with the stable core for reasons explained before in this paper. Reinforcement to connect these two elements is surely too intrusive and unacceptable.

Fig.5 Unstable stairs requiring the renewal of shicras (credits: Julio Vargas, 2011)

5. CONCLUSIONS

The case of Caral brings into focus some essential principles for disaster-risk management of cultural heritage. First and foremost, it is important to have a holistic and integrated approach to disaster-risk management that takes into account multiple hazards, which in the case of Caral include earthquakes, droughts, as well as El Niño impacts, such as high rainfall and increased temperatures. It is also important to know the history of disasters at a site, original construction systems and past conservation interventions to understand both the vulnerability, along with the capacity of historic structures to withstand hazards, such as earthquakes. In fact, an important lesson from Caral's structures is that traditional building knowledge should be understood and respected while introducing hazard-resistant measures. Also, it is important to think of measures that take into account protection of heritage values while introducing measures that can improve resistance of structures to various hazards.

The Disaster Risk-Management Plan for a Cultural Heritage Site must link up with the Disaster-Management System for the region, area or country, and with the Management Plan for the Cultural Heritage Site. The implementation strategy for the Disaster Risk-Management Plan would need to be prepared, defining the programs, projects and activities, including the responsible agencies, their roles and responsibilities and a given time period (UNESCO et al., 2010).

Last but not least, disaster-risk management is a multi-disciplinary field that would require juxtaposition of disciplines related to disaster management (such as civil engineering, architecture and planning) and conservation of cultural heritage (protection and management, restoration, rehabilitation and other interventions).

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ATLAS OF LOCAL SEISMIC CULTURES IN CHILE: IDENTIFICATION OF NATIVE EARTHEN-ARCHITECTURAL HERITAGE AND ITS VULNERABILITY TO GREATER RISKS

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Theme 1: Latin-American Earthen Architecture at Risk: Earthquakes, Rain and Flood Damage
Keywords: Documentation, vulnerability, earthquakes, vernacular architecture

Abstract

This paper presents the background for the development of the Atlas of Local Seismic Cultures (LSC Atlas) project in Chile. The aim is to find the tools to intervene and to protect vulnerable earthen-built heritage in Chile, as well as a methodology of analysis to recognize the legacy of traditional construction against earthquakes. Based on the premise of the existence of a seismic resistant construction logic, intrinsic to earthen architecture in seismic prone areas, the influence of the frequency of seismic activity in a place is evaluated, a precedent that establishes the degree of preparedness, response and community resilience against disasters.

The concept of LSC recognizes the existence of communities affected by different types and frequency of earthquakes. These have historically developed an appropriate and relevant constructive intelligence in a specific location, creating a vernacular seismic resistant construction system.

As a platform, the Atlas will permit the management of a database to geo-reference, collect and evaluate the establishment of LSC, by identifying the different technologies used in earthquake resistant earthen architecture, locating them in the territory, and analyzing their socio-cultural, economic and environmental settings. Based on this vernacular knowledge to devise emergency plans and intervention in earthen buildings, appropriate and relevant solutions to each locality will be put forward, leading to the generation of sustainable actions in time.

In Chile, a developing country, it is common to suggest modern and highly sophisticated solutions, denying popular knowledge and their traditional aptitude towards seismic resistant building systems. Through the Chilean LSC Atlas the re-evaluation of the particular knowledge of each community, their intangible heritage and their "know-how" is performed. This form of intangible heritage provides a wealth of knowledge for traditional seismic resistant construction.

1. INTRODUCTION

> *"...know-how needs to be developed within tradition, but with wisdom, if we can improve errors, it will be for the benefit of the technique... Tradition is not necessarily synonymous with outdated methods and stagnation, and even more so, tradition is not mandatorily old, since it can be new and very well designed. Each time a worker finds a new difficulty and finds a way to overcome it, he takes the first step towards establishing a tradition. When another worker decides to adopt the same solution, tradition progresses, and when a third party acts equally and makes his own contribution, tradition is practically established "*
>
> *(Fathy, 1979, p. 59).*

1.1 Rationale of the atlas project

The Chilean LSC Atlas project was born from the collaboration and motivation of two Chilean architects, as well as their professional and academic experience based on the study of earthen architecture and construction. Furthermore, this initiative comes from work in habitats of high vulnerability, both social and geographical.

Given the authors' previous professional experience, together with reflections that emerged after the earthquake of February 27, 2010, that affected much of the earthen built heritage in Chile, it was proposed to find the necessary tools to preserve the vulnerable earthen built heritage in the country. At the same time, to take actions to reduce risks in seismic prone areas, where such constructive cultures were identified.

Thus, the Chilean LSC Atlas project is part of the ongoing research of both architects and post-master students majoring in Earthen Architecture at CRAterre, ENSA in Grenoble, France, and Architecture and Greater Risks at ENSA, Paris-Belleville, France. The purpose of this paper is to present the Chilean LSC Atlas project, identifying the theoretical framework and the methodological basis for its implementation.

1.2 Earthen-building culture in Chile and seismic hazard

In Chile, whole villages systematically suffer loss of their assets due to severe earthquakes. This gives rise to questions, such as: Why do entire villages and buildings built of earth succumb to earthquakes? Why are these constructions not able to resist earthquakes? These lead to the next questions: Should earthen buildings that withstood an earthquake be preserved? Are these earthen constructions safe against earthquakes?

However, these questions, typical of the aftermath of disasters, prevent the recognition of the core of the problem, and cause the omission of reflections and questions such as: Why and what kind of earthen buildings are still standing after an earthquake? What were the causes of high vulnerability to earthquakes of earthen urban and architectural structures? What are the causes of deterioration that trigger further damage or destruction by earthquakes to a building of *quincha*, adobe or adobe-like materials (*adobillo*), some of which have existed for more than two centuries, and in the past have survived other strong earthquakes?

Regarding these questions and the reflection initiated after the recent earthquakes in Chile, including the Cobquecura earthquake in February 2010 (8.8°), the Punitaqui earthquake of 2007 (6.8°), and the earthquake at the inland towns of Arica and Iquique in 2005 (7.9°), a research methodology was developed to demonstrate the high vulnerability that a large number of this earthen-architectural heritage faces. The Chilean LSC Atlas project is based on the hypothesis that the high vulnerability of earthen architecture in Chile results from the disappearance of the 'know-how' of the logic of seismic resistant construction, and the loss of risk consciousness. Both are fundamental elements in the maintenance and preservation of a vernacular constructive culture, which otherwise has been able to survive over time by adapting and evolving itself from lessons learned after each seismic event.

This leads to the questions: What are the causes of the disappearance of the 'know-how' for making vernacular buildings earthquake resistant? To what extent does it affect the earthen buildings depreciation, based on questions resulting from a post-traumatic dynamic in the aftermath of a disaster? How do preconceived ideas condemn non-standard building systems and/or vernacular construction, thereby questioning their structural performance and, therefore, their seismic resistant capability?

Following recent earthquakes, local authorities and construction professionals tended to support the destruction of traditional earthen buildings throughout Chile. This led to the loss of those who knew the earthen materials, building systems and seismic resistant logic. Consequently, this knowledge has been discredited, and these practices have been replaced with new materials or regulations that has condemned traditional earthen construction techniques. Also, by neglecting these materials or earthen construction techniques, the relevance of local seismic cultures was rejected.

Following recent earthquakes is installed tendency on the part of local authorities and construction professionals, which has led to the destruction of traditional buildings in earth throughout Chile. This has disappeared, therefore, those who know the ground materials, building systems and seismic logic. Consequently, these have been discredited knowledge, as these practices are introduced to new materials or regulations that condemn traditional construction techniques on the ground. Also, by not considering or these materials or construction techniques on land, the relevance of local seismic cultures refuses.

Another factor of loss and de-legitimization of seismic resistant vernacular earthen systems in Chile is the regulatory vacuum experienced for many years in the country in relation to structural interventions and new construction in earthen architecture. This has resulted in a deep distrust of the use of earthen materials, as well as ignorance about the physical properties and chemical qualities of earthen materials, and the good performance of these building systems.

Regarding the latter, this research proposes to build tools to mitigate the effects of the ignorance impacting earthen construction in Chile, which has resulted in the gradual destruction of earthen-architectural heritage due to inappropriate interventions with inadequate materials. This has also caused a devaluation of popular earthen construction knowledge. The current construction practices favor imported models, the result of an exaggerated industrialization and investment in technical solutions that often cannot be replicated, either because they are too expensive, or because they are too sophisticated for local inhabitants. All of this is compounded by the low technical mastery and poor quality of execution, as well as the mixing of technologies and/or incompatible traditional solutions (Garnier, Moles, Caimi, Gandreau, and Hofmann, 2011), which are introduced and promoted every time there is a catastrophe, superimposed onto the constructive cultures developed over generations.

2. BACKGROUND ANALYSIS

2.1 Why focus on seismic-resistant vernacular earthen architecture in chile?

While earthquakes have a common origin, that of the release of the internal energy of the earth (González, 2005, p. 9), there are many factors that cause dissimilar effects of earthquakes from one context to another, even within the same region. These include physical factors, such as types of failures or the depth at which they occur, but also the social and economic factors of the affected population, those who have a close relationship with the quality of buildings and especially with the place of settlement.

Chile has a large quantity of monumental and civil heritage built of earth, either adobe masonry, mixed techniques of earth/wood, or stone masonry set in earthen mortar, just to name a few. Earthen building systems present in Chile, as well as the different urban arrangements and architectural typologies, respond adequately to the various climatic and geographic landscapes that are present in the country, from the highlands to the central valley, as well as to social, economic and cultural factors (Hau, 2007, p. 52). Another aspect that characterizes this type of construction is directly related to the seismic context of the country.

The action, frequency and intermittency of earthquakes in the regions where there is earthen construction and architectural heritage influenced directly their structural characteristics and their evolution towards a seismic resistant logic. The recurrence of seismic events in a specific location, directly and actively influences the degree of vulnerability of the community. By identifying the frequency of seismic activity in a locality, the preparedness, response and resilience of this community towards a catastrophe can be claimed. Thus, the Chilean LSC Atlas project aims to demonstrate that the characteristics and typological variety of construction in Chile responds to an adaptation over time and to specific seismic contexts of each region.

2.2 The recognition of constructive aptitude and a local seismic culture (LSC)

"Earthquakes teach how to improve based on experience"

(Astroza, 2005, p.18).

Over time, man has intrinsically known how to overcome and survive natural hazards by evolving his built environment. This has been called by various authors the "development of a constructive culture of risk" (CUEBC, 1989), referring to the constant process of a specific community to rebuild, by perfecting what has not worked, aiming at increasing its performance in the future to danger (e.g. seismic events) and thereby decreasing the vulnerability of buildings over time.

Regarding the studies conducted by professionals associated with the Ravello CUEBC (European University Centre per i Beni Culturali di Ravello, Italy), it can be said that the earthen construction culture in Chile is inherently a "constructive culture of risk", resulting mainly from the evolution of the various "local seismic cultures" (LSC), which live together and are affected by their exposure to different types and frequency of earthquakes. These cultures, therefore, have developed throughout history constructive intelligence capable of building appropriate and relevant structures to a specific location.

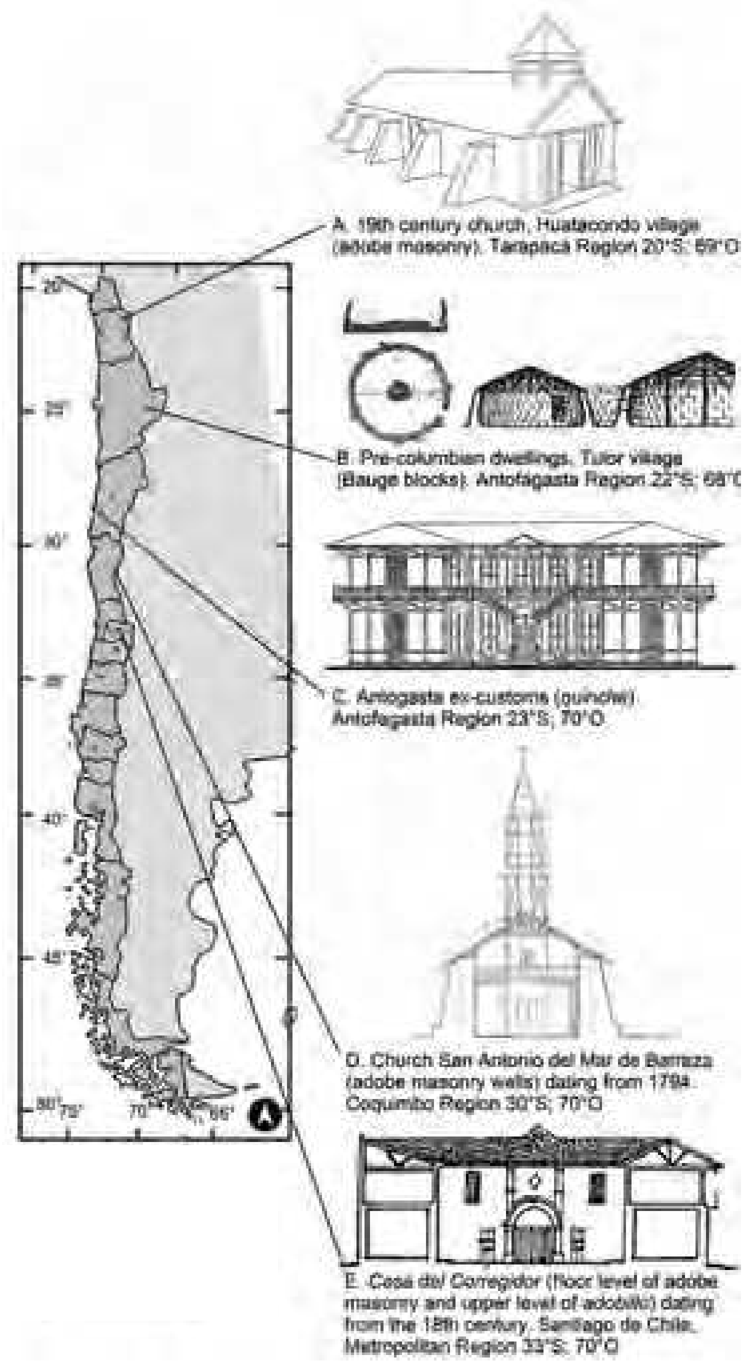

Fig.1 Local seismic culture in Chile (credits: *A.* María Inés Suilan Hau Espinosa, Thomas Sebastien Richard Jarpa; *B.* Gygogne & CYTED (1995) p.53; *C.* Arquitectura Universidad del Norte, Chile (1983); *D.* Archivo CMN Intervención Iglesia de Barraza, Mónica Bahamondez; *E.* Antonio Sahady, (1996) p.31)

The seismic resistant construction knowledge present today, especially in communities that have been constantly affected by earthquakes, has been developed and is defined as the local seismic culture (CUEBC, 1989). The concept of a local seismic culture refers to the constructive aptitude of a specific community, in a specific seismic context, and its ability to evolve over time, through the adoption of techniques aimed at providing increasingly safer buildings. By contrast, losing the continuity of this constructive knowledge, vernacular architecture no longer evolves towards a seismic learning, developed and enhanced from countless disasters. This allows

the only viable solution to be the introduction of new modern technologies.

Without evaluating the quality and relevance of proposed "foreign" solutions, these are not products of the development of vernacular architecture out of the existence of local seismic cultures. Without history, their functionality and effective adaptation, as opposed to those of the traditional technologies, will depend on their reaction (good or bad) when facing a future catastrophe.

To all of this is also added the fact that when seeking to optimize a local construction system, introducing foreign models for structural stabilization will lead to the disappearance of the local building culture. It is common for entities, external to such cultures, to promote the introduction of new technologies. However, in most cases, these entities are involved only after a disaster, without providing any follow-up or concern about the impact of such techniques in the long term. Thus, the vulnerability of communities rather than being decreased, is increased, since ceasing to have a seismic culture or tradition, the communities will not possess the tools needed to prevent damage and protect their property, by preparing beforehand for the next earthquake. In addition, facing a new catastrophe, foreign techniques, materials and actors perform without any empirical certainty that the introduced solution will be relevant to that specific location (Garnier et al., 2011).

3. REGISTERING/TRACING LSC IN CHILE

"…Constructive cultures and the solutions they have produced over time, although not possible to demonstrate with a calculator, are found through their own history, perhaps an even more rigorous way of experience"

(Ferrigni et al., 2005, p. 30)

3.1 Recommended methodology: rediscovery of LSC

Chile is a country where, according to Ferrigni et al. (2005, p.30) "... earthquakes are of an endemic type, where the inhabitants of the regions are fully aware of - to a greater or lesser extent - this fact ... In this way earthquakes belong to the natural order of things, and man is used to living with them..." The first step, then, is to rediscover various LSCs existing in Chile, identify the state of different earthen seismic resistant architecture, and through their identification and location in space, to understand how they have evolved in seismic relation to the specific context in which they were developed.

The analysis of various LSCs is presented as indivisible from the study of heritage, both monumental and civil, as well as the urban and landscape study; this is building culture expressed at different scales. Often, in the fields of research and enhancement of built heritage, value judgments between the monumental and civil are drawn. However, for the study of one LSC it is impossible to separate them, as it is the knowledge in common that enriches each other and that can provide reactions to different problems. In addition, studies already exist that make it possible to know Chile's historical seismography, including possible data from paleo-seismology. This information is important for the establishment of the status of a local seismic culture, as it permits the understanding of how often an earthquake has affected an area and, therefore, what the population's degree of 'awareness' against this risk is.

Along these lines, it is possible to identify areas where an earthquake will potentially cause much more damage, although buildings are apparently in good condition. This was the case for the last earthquake of 2010 in the southern-central Chile, where buildings seemed to be properly preserved, but the absence of major earthquakes for about two centuries caused a loss of knowledge of risk, generating no relevant changes to both the construction and urban levels.

3.2 Why an atlas?

As mentioned earlier, the main aim of the Chilean LSC Atlas project is to identify and to locate different "constructive cultures" that make up the traditional earthen architecture of Chile, from pre-Columbian architecture up to the present. Therefore, the Atlas seeks to cross-reference information as to the geographic condition, architectural typologies, technological evolution, and recurrence of earthquakes (historical seismicity), among other information, that will provide the basis for the existence or absence of a local seismic culture.

3.3 Geo-referencing and development of a database

Developing the study of earthen building cultures through an atlas format will enable the relating of different types of information in time and space. By verifying the existence of different LSCs in Chile, as well as the background on the location and historical identification of earthquakes and their intensity, the frequency and area of influence will be collected. This will identify certain communities and/or specific geographical areas where earthquakes have occurred within a span of three generations, and thus would be more likely to be vulnerable to another possible earthquake.

Among other information, the cultural changes and influences of new players in these LSCs will be identified, which generates, for better or worse, modifications to the building systems, architectural styles, and urban and regional systems. It is also proposed to integrate the study of the availability of different local resources and materials, either traditional or modern, and the degree of people's ownership over these, making them real construction tools. For example, there are building cultures that traditionally use wood as the main construction material. However, at present, for several reasons, this building material has disappeared and is scarce or difficult to access. Therefore, it may be unwise to promote the reuse of these materials for these communities, especially if the reintroduction of these building elements has a high social and economic cost.

4. CONCLUSIONS

"…Disasters are not only caused by the destructive action of natural phenomena forces, but also include changes in the behavior patterns of our communities"

(Ferrigni et al., 2005, p. 25).

The Chilean LSC Atlas project seeks the ultimate goal of reducing vulnerability of earthen architecture to seismic risks, also providing other results, such as:

- Documenting the use, development and presence of vernacular seismic resistant building systems of earthen architecture in Chile.
- Identifying different LSCs.
- Defining the terminology of "know-how" in relation to seismic resistant vernacular techniques, as well as understanding the loss of legitimacy of these.
- Valuing the logic of architectural knowledge (construction and urban) and local materials, its evolutionary spirit, and how that tradition is established.
- Developing a critical view of the use of foreign techniques and the introduction of industrialized materials and building systems into vernacular architecture.
- Establishing a reflection on reinforcement methods and/or structural stabilization (seismic retrofitting) for the interventions proposed for existing earthen buildings, promoting less invasive techniques that maintain the building's authenticity (and especially its original construction logic).
- Introducing the concept of "social cost" for interventions, both in terms of heritage and civil construction (social housing, public infrastructure, among others).
- Encouraging a sense of long-term reconstruction and post-emergency projects, in contexts with a strong LSC presence.
- Enhancing local emergency plans, based on the autonomy of the people and the characteristics of the towns, being that communities are the main actors responsible for their dwellings.

By overlapping the background identified in the Chilean LSC Atlas and its results, sufficient tools to identify the degree of relevance and appropriateness of proposals to rebuild or reinforce earthen buildings can be obtained. Similarly, the necessary background for the evaluation and implementation of emergency or preventative plans against new earthquakes in a specific location will be established.

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A RESEARCH AGENDA FOR CLIMATE AND CLIMATE-CHANGE IMPACTS ON EARTHEN STRUCTURES

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Theme 2: World Heritage Earthen-Architectural Sites, Natural Disasters and Climate Change
Keywords: Climate prediction, damage functions, documentation, test wall

Abstract

Climate change is likely to affect earthen-architectural heritage because the materials are sensitive to many aspects of weathering. Both gradual changes and an increase in the frequency of extreme events seem likely to be important in the future. Both represent threats to earthen materials, which can be especially sensitive to alterations in humidity and water. At the moment there is little research on the mechanisms of damage that might change over the next century. While there are many general questions that relate to future damage to our heritage, research has to be more specific.

The authors examine the potential for a five-year test-wall project to explore climate-change issues. Walls would be designed to facilitate ease of repeat documentation using conventional and 3D methods. These qualitative and quantitative observations would be compared with measurements gathered through an on-site weather station and wall sensors (recording temperature and humidity). This in turn would be compared to the high-resolution climate models. The analysis would, we argue, start to give an indication of observed change, quantified change and the relationship with climate over five years, which in turn could be related to the longer-term climate models.

1. INTRODUCTION

Relatively little research has been undertaken on the impact of climate change on heritage. This is to be compared with the extensive study of climate change on the global environment, human wellbeing, and agriculture. Such topics are widely researched and, furthermore, appear within IPCC reports. The modest number of publications on climate change and heritage are frequently desk studies, interviews or opinion pieces, rather than carefully framed research projects that utilize the vast amount of work that has been done on future climate. Exceptions to this have been projects funded by the European Commission (e.g. Noah's Ark, and Climate for Culture) or that of a small number of publications from individual scientists (such as Lankester and Brimblecombe, 2011; 2012).

The issue of climate change was raised at the Terra 2008 conference in Bamako, Mali (Brimblecombe, Bonazza, Brooks, Grossi, Harris, and Sabbioni, 2011), but even here opinions were mixed about its significance. Although the importance of weather as a factor in the deterioration of earthen structures was clear, not all felt detailed climate-change research was needed. Some thought that enough was already known about climate change to gain a good picture of how earthen heritage might degrade, and others drew attention to the fact that the weathering of earthen structures is rapid anyway, so careful maintenance is an effective approach to the preservation of such heritage.

While acknowledging the wisdom of the comments above, we present a case for more detailed research. The discussions in Mali had an understandable focus on impacts of desertification, and impacts of wind-blown (or aeolian) sand on earthen structures. However, threats to vernacular heritage are much wider. In the years since 2008, we have seen a number of climate phenomena that have been of concern for heritage structures, such as flooding in Pakistan (2010), dry aridity in Central Europe and Russia (2010), and more locally in the UK, flooding, and during a cold winter (2010-11), pipes froze in historic buildings and heavy accumulations of snow caused the roofs of heritage buildings (such as chalk barns) to collapse under the weight of snow.

Earthen architecture has been promoted as an environmentally friendly, responsive and sustainable building material, and the UK and Europe as a whole has seen a revival in the craft sector utilizing earthen-building materials. We have scientific data to show such buildings are environmentally sustainable (such as the various research projects undertaken at the University of Bath by Peter Walker, and at the University of Nottingham by Matthew Hall, amongst others), but we have little scientific data to prove the hypothesis that such buildings are adaptable to climate change. A method of assessing the performance, survival and deterioration of earthen structures in relation to climate parameters is proposed, to enable us to establish a real understanding of earth structures. It is not until such data is collected that we can better understand the performance and survival of earthen structures in the 21st century. This might also require critical reflection on the heritage values of earthen heritage, and how these values may be impacted by physical change.

2. HERITAGE AND CLIMATE

Although the survival of earthen buildings is influenced by local climate, climate change poses a new and pressing threat to this aspect of cultural heritage. Data generated by climate-change scientists indicate that the average rate of warming over the next 100 years will probably be greater than any that has occurred in the period over which civilization developed. Increases in the global averages of evaporation and changes in precipitation are expected, and extreme events, such as heavy rains and droughts, are likely to increase as the climate continues to change. Although changes of a few degrees in temperature are unlikely to have a damaging effect on earthen heritage, changes in the relationship between earthen materials and water seem a potential threat. Extreme rainfall events and long periods of wetting or drought can enhance the rate of weathering of these materials.

Recently, the impact of climate change on Europe's built heritage and cultural landscapes was considered through the Noah's Ark Project (Sabbioni, Brimblecombe, and Cassar, 2010). This project used modeled output extracted from climate models at the Hadley Centre to examine climate parameters (precipitation, frost, wind and wind-driven rain). It also established heritage climatologies (Brimblecombe, 2010a) that looked at salt crystallization, wet-frost, biomass accumulation, and lichen to produce damage and risk maps. The work has identified the meteorological changes critical to built heritage, highlighting factors, such as changes in precipitation patterns, salt damage, freeze/thaw, changes in groundwater levels, and inundation. The project examined materials rather than separate heritage entities. However, the project would imply a range of changes that affect cultural heritage, deterioration phenomena, heritage structures, and infrastructure that could have significant impact on earthen architecture. It becomes apparent that the material properties of earthen heritage make it particularly vulnerable to these threats.

The potential impact of climate change on earthen heritage raises concerns nationally and internationally (for example by ICOMOS and ISCEAH), but detailed studies of the specific effects of climate on earthen structures is largely absent. Only a vague and general picture of impact upon earthen materials can be surmised, such as the dramatic physical loss of landscape components (i.e. structural loss of buildings and archaeological sites as a result of inundation), the acceleration of more gradual decay factors (i.e. as greater presence of fungi and salt), alongside impacts on values and societal relationships with earthen-building technologies related to increased frequency of maintenance cycles. Such general viewpoints can raise awareness, but are hardly a guide to action. These offer little understanding of the mechanisms or rate of damage. It is unclear which fungi or salts might be damaging or where the problems will be most serious. It would be hard to justify expensive and difficult interventions without a better understanding.

3. RESEARCH AGENDA

There are a range of questions that can add to research projects on climate change and earthen-architectural heritage. Such work will need to consider the physical aspects of a changing climate and its impacts with a number of objectives such as:

- Identification of the climate parameters most likely to affect earthen-architectural heritage and highlighting of those most likely to change over the next century;
- Identification of likely mechanisms and damage forms to arise under a changing climate that would most affect earthen-architectural heritage;
- Understanding how each of the separate components of earthen-architectural heritage may be affected by climate parameters by gradual long-term change as compared to extreme events.

These scientific questions cannot be addressed in isolation, so it is important to consider management and social aspects, such as:

- Development of a methodology for documenting and proactively monitoring earthen architecture that will be applicable in an international context;
- Reflecting critically upon the values of earthen-architectural heritage, and how these may be affected by future climate change;
- Making recommendations concerning how tangible and intangible values can be preserved using traditional and modern conservation techniques;
- Development of an understanding of how heritage values of earthen-architectural heritage may be transformed in response to physical change.

4. PROJECT METHODOLOGY

The broad research agenda above is often too vague for an individual research project, which needs to be more focused in its specific objectives. Many projects center on monitoring of the climate and the change to materials at heritage sites. Such an approach leaves us with an immediate question: How is it possible to monitor long-term climate change within the confines of a short-term project? It raises further issues, like the fact that monitoring necessarily addresses the present, while the records of such exercises tell us something of the past. Issues such as these have been addressed in a paper concerned with the problems of monitoring the future (Brimblecombe, 2010b),

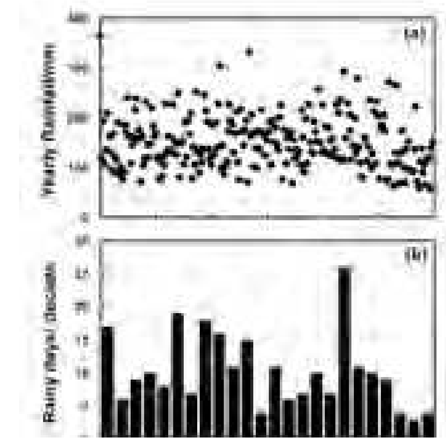

Fig.1 Modelled rainfall in the Timbuktu region of Mali: (a) annual precipitation and (b) the number of rainy days (rainfall>10 mm). Note: the estimates are derived from the HadCM3A2 output for a cell 2.5°×3.75° centred close to village of Araouane on a key Saharan trade route.

but typically, climate-change research has relied heavily on models of the future world, rather than monitoring. This is not without its scientific problems, but has also fuelled public skepticism about the existence of climate change. In addition, specific problems exist for earthen architecture because it is associated with dry climates where there are issues with climate data and how climate models are generated (as precipitation is used to downscale such models).

However, smaller scale projects with a well-defined methodology and relevant monitoring can contribute to a broader set of questions. The example below was derived from some ideas developed for an application to the UK Arts and Humanities Research Council (AHRC)-led Science and Heritage program called Identifying, Modeling and Predicting the Impacts of Climate and Climate Change on Earthen Heritage. Under the AHRC call, projects had to be multidisciplinary, meeting a set of objectives already defined by the Science and Heritage program, primarily the application of scientific techniques to heritage, which in this case is to understand the significance, vulnerability, resilience and conservation of earthen heritage in the 21st century as a result of climate, climate change and extreme climate events. It was suggested that the available climate data would allow the assessment of the results of monitoring of conditions over a period of time that enables the relationship with climate, climate change and earthen-architectural heritage to be explored and better understood.

This project envisaged a series of earthen 'test walls' that would be monitored and compared to climate factors. It was seen as necessary to build new walls for this project rather than use historic walls for several reasons. First, the exact composition and construction of the walls will be a known factor, whereas historic walls may have a particularly complex history of repair and maintenance that may impact the quality of results. Second, temperature and relative-humidity sensors can be embedded into and outside the walls during construction using techniques developed by Dr. Mike Lawrence at the University of Bath (Lawrence, Heath, and Walker, 2009).

New walls were also necessary as the design and location of the walls can be controlled to ensure exposure to climatic effects and facilitate photographic-recording and 3D-scanning. As such, this project envisaged the design and construction of two sets of test walls on the site, composed of cob, adobe, rammed-earth, wattle and daub, turf, and chalk. With one set protected via a simple inverted V-shaped roof capping, while the other will be unprotected. An additional pair of walls will facilitate analysis of the effect of maintenance cycles and alterations. One of these would have been maintained throughout the course of the project, while the other will be coated in a cement-based render, reflecting one of the most problematic and damaging methods used for earthen walls in the UK. To eliminate variation in groundwater movements, the walls would be constructed on concrete-block footings. The walls would also incorporate right angles in order to be resistant to weather in all directions, and this will allow an analysis of the influence of different aspects (windward, high and low areas, corners) and microclimate on the walls.

The project built upon existing research carried out in the UK concerned with the construction and monitoring of test walls (for example, the Scottish ESRP project (undertaken by Becky Little and Arc Architects), alongside experimental archaeology projects, such as Overton Down (Bell, Fowler, and Hillson, 1996). Internationally, a number of earthen test-wall projects have been undertaken, such as those undertaken by CRAterre-ENSAG, and the Getty Conservation Institute (Cooke, 2010); these have primarily been concerned with researching methods of construction, repair and conservation treatment, rather than monitoring conditions in relation to climatic factors.

In addition, it was possible to identify a site that had existing meteorological data from the last 50 years, and a weather station, which records data at sub-hourly intervals. This existing meteorological data can be used to identify longer-term climatic change, as well as to place the project data in a wider context. Finally, the site would have to be located to allow easy access to document wall conditions during and immediately after extreme climatic conditions.

The project required a comprehensive documentation and monitoring system. It was envisaged that the test-wall materials would be analyzed both for construction and on an annual basis, through the collection and analysis of soil samples, thin sections and strength tests in order to detect and quantify change both within, as well as on their surfaces. The surface condition (e.g. physical loss, biological phenomena) of the walls would also be monitored through the use of conventional documentation (drawing, photography, surface-condition assessment), and through repeat 3D-scanning at regular intervals throughout the project.

The documentation of the physical condition of the walls would be supplemented by the continual logging of RH/temperature from sensors embedded within the test walls. These data will be analyzed via WUFI software for calculating the coupled heat and moisture transfer in building components, as well as relate conditions recorded in the walls to long-term predictions. A database would also be developed for logging long-term monitoring attributes (condition reports, climate data, microclimate data) and photographic records.

The analysis of monitoring and climate data collected through the project would enable the relationship with climate, climate change and earthen-architectural heritage to be explored and better understood. Where damage could be expressed in terms of damage functions, the potential damage in the future could be determined by coupling these to the likely future climate at the site.

This project also wished to move beyond the data to carry out qualitative analysis of the test walls, in order to understand earthen-architectural heritage and climate change in relation to the philosophical and reflexive context of heritage values. For example, recording of thoughts and opinions concerning the physical appearance of the test walls provides opportunities to reflect upon and document reactions to the varying conditions of the test walls, to understand how rates of transformation impact upon physical conditions and heritage values of earthen structures.

A key problem for such research is how to transform the very large quantities of data gathered into coherent research outcomes. It is easy enough given modern recording techniques to gather large amounts of data. However, this can become a descriptive end in and of itself. An important element of this research was to isolate key parameters such that they would be useful in understanding the types of change likely to occur into the far future, as well as to provide guidance for the management and protection of earthen-architectural heritage.

5. CONCLUSIONS

Earthen architecture is of significance to a wide range of policymakers, businesses, practitioners and individuals. Earthen architecture has been promoted as an aesthetic, healthy, environmentally friendly, responsive and sustainable building material. There has been a revival in the craft sector utilizing earthen-building materials. The construction industry is also interested in the utilization of earthen-construction materials as environmentally friendly and economically more viable materials (due to reduced carbon-dioxide emissions as a result of the omission of cement-based materials or reduction in firing temperatures) in otherwise more 'conventional' building developments. In the long term, by providing information and a scientific rationale for monitoring earthen structures in relation to climate parameters, this research is of importance to all involved in planning for sustainability in the 21st century, not just from a heritage perspective, but also from the industry concerned with adopting more environmentally friendly materials and technologies, alongside communities and individuals involved in sustainability, local distinctiveness and craft-skill training.

Earthen architecture is affected by climate, and will be increasingly threatened by climate change. If there is a need to adapt to climate and climate change, and plan strategies to minimize harmful effects on important earthen structures, it is required a better comprehension of the mechanisms of weathering. There is a need to need to be proactive, in order to better understand the likely impacts and adaptations necessary to assure the survival of earthen-architectural heritage. It seems unfortunate, given the sensitivity of earthen structures to climate, that there is so little focused research in this area.

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CHALLENGES IN PRESERVING THE WORLD HERITAGE EARTHEN SITE OF CHAN CHAN, IN PERU

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Theme 2: World Heritage Earthen-Architectural Sites, Natural Disasters and Climate Change
Keywords: Chan Chan, World Heritage site, conservation, management plan

Abstract

Chan Chan is an archaeological site in Trujillo, on the north coast of Peru. The archaeological complex is the largest earthen site in the world and has been on the World Heritage in Danger list since being inscribed in 1986, following its classification as a UNESCO World Heritage site.

The aim of this paper is to address the state of the art, regarding the challenges and the current preservation status, and to understand why the site has been on the list for last 25 years. This paper also discusses the architectural and archaeological significance of Chan Chan, its assessment as a World Heritage site, the management-plan development, the conservation state of the site, the conservation practice on site, the conservation philosophy, reasons for conservation failure, key issues emerging from qualitative analysis, and finally, in conclusion, recommendations to consider.

1. INTRODUCTION

Chan Chan is an earthen archaeological site located in the Moche Valley, 5 kms northwest of Trujillo on the north coast of Peru. It is situated 600 km north of Lima. Chan Chan is considered to be the largest World Heritage site built of earthen materials in the world, and the largest pre-Columbian city in the Americas.

The inhabitants of the Moche Valley were the Mochica and Huari, when the Chimú culture arrived around the 9th century AD. In 1100 AD, following the collapse of its economy resulting from "el Niño phenomenon, as well as several tectonic movements" (Castellanos, 2000, p. 69), the Chimu state directed its attention to military activities "to conquer and dominate the neighboring valleys … consolidating Chimu power" (INC, 2000, p. 5, Executive Abstract). It was in 1300 AD that the Chimú culture initiated the dynasty of the Chimor Empire (Briceño Rosario, 2004, pp.13-15).

Chan Chan became the religious and administrative capital of the Chimor Empire during the reign of the ten rulers, reaching its maximum splendor in 1450 AD, with an estimated 35,000 inhabitants living in the citadel (INC, 2000, p. 5, Executive Abstract). This empire extended throughout an area of 1,000 km, on the north coast of Peru (Valle Alvarez, 2004, p. 9) and fell under the Inca conquest between 1462 and 1470. Chan Chan was then almost abandoned as a living city and was again conquered by the Spanish, approximately 60 years later (Briceño Rosario, 2004, p. 15).

According to several authors, the meaning of Chan Chan in the autochthon Yunga language is "City of the Sun" or "Warm City" (Pinillos, 1995, p. 24). At the present time, the complex has an area of 14.14 km²; however, its original area was about 20 km² (Valle Alvarez, 2004, p. 9).

The complex is comprised of nine walled citadels, known as townships or palaces. There are also "thirty-five architectural units and semi-monumental ensembles, six huacas, ceremonial roads and four extensive popular neighborhoods" (INC, 2000, p. 6). The huacas were built as pyramidal-type structures dedicated to sacred ceremonies, related to the concept of transcendence. According to Campana, a huaca represented the idea of an ancestral power, which explains in certain cases the burial of men at huacas (2000, p. 120). Within the citadels, there were autonomous units containing ceremonial squares, temples, reservoirs, gardens, burial places, storehouses of the aristocracy, but also labyrinths and blind alleys (Pinillos, 1995, p. 15). Some authors believe that most of the population lived outside the citadels.

2. ARCHITECTURAL AND ARCHAEOLOGICAL SIGNIFICANCE

The citadels were built in different historical periods with similar architecture typologies. The overall complex emerged as a metropolis, and followed an outstanding method of town

Fig.1 Sector of Audiences, in Tschudi Palace, (credits: Mariana Correia, 2005).

planning. The Early Phase is composed of the township of 'Chaiwac', at the south end of the complex, and the "palace complexes of 'Uhle', 'Tello', 'Laberinto', in chronological succession" (Pinillos, 1995, p.14). In the second phase, named Transitional Phase or Middle Period, the palace of 'Gran Chimú' was built; while in the Late or Imperial Period the 'Velarde', 'Bandelier', 'Tschudi', 'Rivero' and 'Squier' palaces were built. The time period classification of the citadels was based on investigations made by Alan Kolata, who analyzed the "chronological sequence through a study of the adobes of Chan Chan according to their characteristics and uses" (Ibid., 1995, p. 14).

A high degree of control of the construction material and the building method can certainly be discerned related to adobe use in Chan Chan, with more than 17 different shapes of adobes identified at least for the complex walls (Campana, 2000, p. 117). For instance, a specific type of adobe with a truncated-pyramidal shape was applied for the citadels' surrounding walls. These walls had major relevance at the time and were built for defensive purposes. In the case of Tschudi Palace, the citadel wall has a height of 12 m and is 1,500-m long (Pinillos, 1995, p. 28). To ensure strong and thick earthen walls, the citadel's surrounding walls were built wider at their base and narrower at the top. With the increase of height, the wall thickness would decrease, as would the size of adobes. In this way, deterioration was avoided, due to "humidity and the salinity of the earth, and ensured that it [would be] earthquake-resistant" (Pinillos, 1995, p. 15).

Inside of the citadels, there are walls with very significant decoration, such as "raised friezes in which abstract motifs, anthropomorphic and zoomorphic subjects add to the exceptional splendor" of the ruins (World Heritage, 2007, p. 4). The grandness and the enormous scale of the complexes are impressive, in spite of the damaged structures and the great

Fig.2 Different dimensions of adobes at Tschudi palace (credits: Mariana Correia, 2005)
Fig.3 Section of partially destroyed citadel wall (credits: Mariana Correia, 2005)

deterioration of the site fabric. Due to the advanced decay, only Tschudi Palace is opened to visitors, as it is the citadel most excavated and best preserved (Correia, 2009).

3. WORLD HERITAGE SITE ASSESSMENT

In 1986, Chan Chan was listed as World Heritage site, and inscribed on the List of World Heritage in Danger. The criteria chosen to justify its nomination are:

> *"Criterion (i): The planning of the largest city of pre-Colombian America is an absolute masterpiece of town planning. Rigorous zoning, differentiated use of inhabited space and hierarchical construction illustrate a political and social ideal, which has rarely been expressed with such clarity."*
> *"Criterion (iii): Chan Chan bears a unique testimony to the disappeared Chimu kingdom."*
> (World Heritage, 2007, p. 7)

Since then, the Peruvian authorities have developed several conservation actions, which have been focused "on controlling the rising water table levels at the property, as well as site management actions, security concerns and illegal occupations" (World Heritage, 2007, p. 4). However, the criticism of the World Heritage Committee (WHC) has increased concerning the strength of "institutional capacity for implementing the management plan. To date, there is no formal decision making, professional team working full time at the site, there is lack of prioritization in implementing actions and some of these continue to be politically driven" (Ibid., p. 5). The State Party addressed some of the recommendations by creating Supreme Decree (N°26-2006), Emergency Decrees (n°032-2006 and N°001-2007) and Ministerial Resolution (N°0714-2006) specifically related to the Archaeological Complex of Chan Chan (World Heritage, 2007, p. 12).

In 2008, the World Heritage Committee recommended that it was "critical that capacity building and technical training is considered inherently in the implementation of projects. The implementation unit should also consider a broad technical

participatory decision-making process, particularly enforcing collaboration between archaeologists, conservators and architects" (World Heritage, 2008, pp. 82-85). The four-page comprehensive revision of Chan Chan's State of Conservation by the WHC, and its draft decision are a major resolution to force the State Party to undertake more participative and long-term action.

4. ADDRESSING THE MANAGEMENT PLAN

In 1997, the World Heritage Committee required the State Party to produce a management plan for Chan Chan (Castellanos, 2001, p. 111). The Management Plan of Chan Chan was prepared during 1998 and 1999, and published in 2000 as Supreme Decree N°003-2000-ED (INC, 2000, p. 3, Executive Abstract). The plan was assigned to the National Institute of Culture in Peru (INC), through its regional department in La Libertad. It received the contribution of World Heritage Fund, UNESCO's representation in Peru, as well as collaboration of the Getty Conservation Institute (GCI) and ICCROM (Castellanos and Hoyle, 2000, p. 14) and the support of CRAterre-ENSAG. The plan was composed of nine volumes, plus appendices. It incorporated seven programs with 24 subprograms and 140 projects for research, conservation and management of Chan Chan (Castellanos, 2000, p. 79).

A participative and interdisciplinary approach was fundamental to involve different stakeholders and disciplines, which also "provided a better knowledge of the values of Chan Chan and the understanding of its conservation issues" (INC, 2000, p. 2-3, Executive Abstract). This was possible through a broad consultancy of national and local stakeholders and a value-based approach undertaken during the process of creating the management plan. The process was so profound and extensive that it brought difficulties in its implementation. This was due to political reasons, but also due to demanding targets, resources and a wide-ranging plan to achieve the proposed goals.

The WHC/ICOMOS/ICCROM mission undertaken to Chan Chan in February 2007 emphasized that priority should be given to the course of action prescribed in the management plan. The State Party finally took positive actions by creating Ministerial Resolutions and Decrees designating a management plan and administrative director to the site, authorizing the implementation of emergency action at the site and updating its management plan (World Heritage, 2007, p. 12). However, at present, in September 2011, the site still bears a high risk of deterioration and decay.

5. CONSERVATION STATE OF THE SITE

The site is very exposed to cyclical strong rains originating from "El Niño", as well as to floods and to seismic activity, as this region is located "in the earthquake belt of the Pacific Ocean. The last flood was in 1925 and the last earthquake in

Fig.4 Before restoration: Tschudi citadel surrounding wall (credits: Mariana Correia, 2005)
Fig.5 Following restoration: Tschudi citadel surrounding wall (credits: Luis Guerrero, 2007)

1970" (Pinillos, 1995, p. 13). Several of the earthen structures are affected by the direct action of the "combined effects of wind and rare atmospheric precipitation; [but also] the proximity of the water table and the salinity of the soil and air …" (World Heritage, 2007, p. 7). The presence of salts brought by the wind or by the groundwater also affects the particle cohesion of the earthen materials of the walls, resulting in their structural degradation. Moreover, this additionally has an impact on materials that are lost "on the capping layers and [in] both original and restored decorative components …" (World Heritage, 2007, p. 13).

It is important to note that the "best explored and restored palaces (Tschudi, Gran Chimú, Laberinto) present damages in minor scale compared to those still to be restored" (World Heritage, 2007, p. 13). The Executive Abstract also calls attention to the fact that several of the excavated components have been left without protection, which has created serious erosion problems (INC, 2000, p. 23). It underlines that it is possible to recognize some deficiency in conservation interventions derived from reconstruction concepts, which generated structural and stability issues when addressing the original problems (Ibid., p. 23). The lack of continuity of the conservation works and lack of full management-plan implementation caused disruption to previous efforts. This affected the authenticity and integrity of the site and it was one of the main reasons for the WHC draft decision concerning reassessment of authenticity and integrity principles at the site. This will provide justification and definition of priorities of action, to keep the site listed as a World Heritage site.

6. CONSERVATION PRACTICE ON SITE

Chan Chan has had several conservation interventions in the last 50 years. Castellanos considers the existence of two conservation phases (2000, p. 71). The first phase was between 1964 and 1969 and relates to the Tschudi Palace intervention with a "type of highly criticized pastiche … to satisfy the demands of mass tourism" (World Heritage, 2007, p. 8). Castellanos states that this was "largely oriented toward reconstruction for formal presentation" (2000, p. 71). The reconstruction of walls and frieze decorations can be observed in the Grand Ceremonial Plaza at the Tschudi Palace. Morales Gamarra supports the

Fig.6 Grand Ceremonial Plaza with reconstructed walls during the 1960s, Tschudi palace, Chan Chan (credits: Mariana Correia, 2005)

Fig.7 The reconstruction of the surrounding wall done during the 1960s is identified on the exterior of Grand Ceremonial Plaza, Tschudi palace, Chan Chan (credits: Mariana Correia, 2005)

criticism about the arbitrary reconstruction undertaken in Chan Chan (2007, p. 264). After 1974, "a stronger emphasis was placed on … stabilization of structures, through the application of sacrificial renders and capping …" (Castellanos, 2000, p. 71-72). As previously mentioned, capping with soil cement was addressed on some of Chan Chan's earthen friezes (Alva Balderrama and Chiari, 1995, p. 105). Morales Gamarra directed criticism to some UNESCO experts who applied a stabilized mortar of soil-sand-cement as capping (1983, p. 112). As an alternative solution, the use of lime-soil was first proposed for capping and for the stabilization of the friezes, and the use of acrylic emulsion, as well as other chemical substances, such as Polyvinyl Acetate. Morales Gamarra stated that results were not satisfactory as there was recurrent exfoliation due to the high humidity (1983, p. 113).

According to Morales Gamarra, the only satisfactory solution was to use treatments with ethyl silicate, a solution applied by Chiari in 1975 in Tschudi Palace (2007, p. 266). Alva Balderrama and Chiari also confirmed the "good results despite torrential rain in spring 1983" (1995, p. 109). However, the irreversible character of the treatment still does not convince all of the experts (Morales Gamarra, 1983, p. 113).

Also during this second conservation phase, attention was addressed to the reburying of exposed decorated surfaces (Castellanos, 2000, pp. 71-72). For instance, this happened in the Ribero Palace, which was intensively archaeologically excavated and had the different components reburied after conservation measures, but this did not manage to mitigate the acceleration of decay.

Alva Balderrama and Chiari underlined the problem of excavating, backfilling, re-excavating several times and backfilling repeatedly, as it creates an unstable environment to the fragile earthen friezes and also makes them vulnerable to illicit diggers (1995, p. 112). In 1997, more archaeological excavations were carried out at the site, as well as conservation practice to eliminate salts from earthen decorations (INC, 2000, p. 14, Executive Abstract).

A third phase can be considered work after 1998 following the El Niño phenomenon, which greatly affected the site. This phase was partially focused towards preventive conservation. This can be observed through the erection shelters "made of canes and woven thatch, [which] provided a low-cost alternative to mitigate the extensive damage" (Castellanos, 2000, p. 72). In 2007, the WHC/ICOMOS/ICCROM joint mission emphasized that the conservation "interventions undertaken have not addressed priority conditions" (World Heritage, 2007, p. 5). This was also due to the fact that interventions have not been carried out systematically, but "basically on an emergency basis" (Castellanos, 2000, p. 74). Later in 2007, the reconstruction of the surrounding walls of the Valerde Palace started, as well as the Tschudi Palace. The same type of contemporary adobe technology was applied throughout the overall intervention.

7. CONSERVATION PHILOSOPHY

In the Venice Charter, Article 9 states that restoration "is based on respect for original material and authentic documents. It must stop at the point where conjecture begins, and in this case moreover any extra work which is indispensable must be distinct from the architectural composition and must bear a contemporary stamp" (ICOMOS, 2004, p. 37). Additionally, the Cracow Charter (2000) in its Article 4 underlines that "reconstruction of entire parts "in the style of the building" should be avoided. Reconstruction of very small parts having architectural significance can be acceptable as an exception on condition that it is based on precise and indisputable documentation" (Charter of Cracow, 2000, p. 2). The Gran Plaza de Ceremonias in Tschudi Palace was to a great extent reconstructed. In Fig. 7, when comparing new and ancient fabric, it can be observed in the background of the plaza the part that was reconstructed, which is a positive aspect. However, when visiting the interior of the plaza, the lack of physical indication and interpretation material concerning the new intervention, but also the unified image given by the new intervention transmits a false interpretation of being ancient fabric, and it partially contradicts the aforementioned Article 9 of the Venice Charter. This intervention relates with the first phase intervention, mentioned by Castellanos (2000, p. 71).

It is also recognized that throughout the years, different responses have been applied for wall-conservation treatment, as shown in the criteria for intervention, which are inconsistent with international conservation policy. An illustration of this situation is "the current decision of not differentiating the new from the original adobes in walls; or the decision to apply a finishing superficial layer against the old criteria (INC) of leaving the faces of adobes exposed and marked (World Heritage, 2007, p. 14). This was a procedure that allowed the visitor to accurately read the sequences of applied treatments.

Another aspect to consider is: when will the Chan Chan complex be considered a ruin beyond recovery? Brandi studied this issue and associated the response with the recognition of the potential unity of the object (Jokilehto, 2004, p. 232).

It is difficult to identify the turning point of unrecoverable damage. For the recognition of site significance, UNESCO usually requires the assessment of the principles of authenticity and integrity. Both were identified in Chan Chan, when the site was nominated for the World Heritage List. Recently, due to the increase of decay, UNESCO requested a new assessment of "Outstanding Universal Value, including the conditions of integrity and authenticity" (World Heritage, 2008, p. 38).

Chan Chan's cultural significance was established as emerging from the following values: historic, aesthetic, scientific, urban and social. They are a reference for the projects and the development of the work programs, as well as the decision-making management (INC, p. 25, Executive Abstract). The value-based approach recognized in Chan Chan's management plan is related to the Burra Charter and its Article 2.2 in which "the aim of conservation is to retain the cultural significance of a place" (ICOMOS, 2004, p. 64). Fernandes emphasizes that during Chan Chan's PAT 96 course, the site assessment of significance was identified according to different values, as for some conservators, "conservation was a question of values" (Jorge, Correia and Fernandes, 2005, p. 136). This argument is valid considering that in the literature review, the value-driven approach is part of the overall conservation process. However, it should not become its main goal (Correia, 2009).

8. REASONS FOR CONSERVATION FAILURE

In Chan Chan, besides the natural factors affecting the site, there is failure related to the control of pressures affecting the site fabric. State authorities have difficulties in discerning its origin, as there is lack of care and awareness of Chan Chan's Outstanding Universal Significance by a part of the local population.

Several factors affecting the site were identified during the observation field trip to Chan Chan, as well as during the analyses of the reports related to the World Heritage Committee decisions. The factors contributing to failure are construction incursions into the buffer zone, garbage dumping, graffiti, vandalism, motocross rallies, agricultural pressures, plundering of tombs for tourism artifacts to sell, soil extraction for adobe manufacturing, etc. Castellanos also underlines that the "low-income levels of the adjacent communities promote looting and deterioration of the site's structures, which are also increased by uncontrolled access to the site" (2000, p. 73). The World Heritage Committee underlined this, emphasizing the importance for the State Party to define "the limits of the property in order to avoid further encroachment" (World Heritage, 2007, p. 9).

Recognized reasons for failure to enhance the site originate from lack of decision-making and commitment, but also a lack of determination to manage and to continuously conserve the complex of Chan Chan. This can be due to political pressures and weak local decision-making in conservation practice matters, even though there was published legislation answering to the WHC requirements and there was also some "recovery of illegally occupied sectors used for agricultural and industrial activities" (Castellanos, 2000, p. 73). However, according to the WHC/ICOMOS/ICCROM report, there is still a "lack of expertise in conservation and a certain unwillingness to follow the prescribed course of action, already defined in the management plan" (World Heritage, 2007, p. 16).

Failure is also recurrent due to pressure originated from continuous archaeological excavations, without preservation procedures being addressed and conservation interventions being applied. There is additionally recurrent failure to control tourism in the overall complex, with visitors and cars openly accessing any exposed and unprotected remains.

In Chan Chan, several factors are contributing to a negative impact on the quality of visitors' experience at the site. There are insufficient prepared infrastructures for public use, lack of conservation and maintenance measures throughout the site, missing overall site promotion and interpretation material (except some at the Tschudi Palace), "uncontrolled tourism with no visitor management strategies in place" (Castellanos, 2000, p. 73), etc. However, according to the WHC/ICOMOS/ICCROM joint mission, some of the access and parking was improved, but not finalized (World Heritage, 2007, p. 16). If compared with other cultural sites that are not World Heritage listed as, for instance, Huaca de la Luna, the number of visitors is decreasing drastically (Morales Gamarra, 2006). Other reasons for failure are related to a lack of permanent site-conservation policies, lack of implementation of the management plan and of a site conservation unit (Correia, 2009).

9. KEY ISSUES EMERGING FROM QUALITATIVE ANALYSIS

The main concerns are presented below, rising from the qualitative analysis emerging from questionnaires addressed to local and international experts in 2008. The main results embraced the management plan, the site condition and management, and politics.

9.1 Regarding the management plan, the key points arising were:

- Community and stakeholders participatory process: This was a participatory management tool with a strong impact on the content of the plan. There was a great effort engaged in involving national and international stakeholders and consultants. This contributed to a collective and interdisciplinary vision, with solutions based on those consultations.
- Content of the management plan: The management plan was very sophisticated, complete, detailed and considered the comprehensive regional and urban scale with constructive details included.

Fig.8 A sacrifice layer of gravel is used to protect the top of the walls. Audiences sector, Tschudi palace (credits: Mariana Correia, 2005)
Fig.9 Reconstruction of the surrounding wall in Velarde palace, Chan Chan (credits: Luis Guerrero, 2007)

- Size of the management plan: The large size of the management plan was a weakness and brought difficulties to its implementation, as it was composed of nine volumes and more than 100 projects.
- Management plan implementation remains difficult: Implementation remains an issue, as there are limited resources, both human and financial. There are difficulties arising from external pressures, execution of sound and consistent conservation treatments and overall approach to such large site. Difficulties are also due to the Trujillo urban expansion growing towards Chan Chan.

9.2 Key issues that emerged from the site condition and management:

- Not enough conservation professionals: Local professionals have the constructive knowledge, but very few have enough conservation-intervention knowledge. Besides, local professionals do not have access to resources, which can facilitate decision-making.
- Difficulties assessing physical condition: Although there is profound knowledge of the natural variables affecting the site deterioration, there should be more studies and research related to the decay of the physical condition of Chan Chan, especially causes and effects of decay. For instance, the crust formation existing on the top of the walls is prominent and deserves further analysis and examination to detect its origin.
- Monitoring control: The management and control of the buffer zone is an important issue to address. Effective and continuous monitoring should be implemented, as there are some groups from the local community that do not respect the site, and daily cause destructive impacts.
- Important missing actions to address: There is a need to address several important actions at the site, such as recovery of perimeter walls to control erosion, discontinuity of archaeological excavations, enlargement of public-use activities, addressing the urban pressure on the site's surroundings, etc.

9.3 Regarding political issues, the key-points raised were:

- There is competition between earthen sites: There is fierce competition between different sites in the region *(Huaca de La Luna, Huaca Esmeralda, Huaca El Brujo, Chan Chan site, etc.)*. This can affect collaborations, stakeholder's engagement, political decisions, etc.
- Difficulties within the centralized management of INC: The fact that local site-conservation decisions directly depend on the direction of INC, which in turn depends on political power, enforces a lack of decision-making at the site.

10. CONCLUSIONS: SUMMARY OF RECOMMENDATIONS TO CONSIDER

Some of the key issues emerging from site observations and undertaken analysis, crossed with the evaluation of the questionnaire are mentioned below, as well as recommendations to consider:

- Decentralized decision-making: Problems related to political pressures, lack of local decision-making, and lack of long-term continuity on the site's direction and management have a negative impact on the site's degradation and decay. Also, there is a lack of implementation of the management plan and too much centralized decision-making. As a result, in spite of the enormous effort of site teams, the response has been more reactive (and not proactive), and has addressed in particular, emergency issues. An implementation strategy taking into consideration the existing resources could contribute to a more feasible and realistic approach regarding the management-plan implementation.
- It is lacking continuous conservation intervention practice: There is a high pressure for archaeological excavations and not enough conservation intervention protecting the exposed remains. The large extent of the site and the lack of human and funding resources to address preservation actions is an increasing problem. Furthermore, it appears that there is a lack of expertise in conservation-intervention knowledge regarding earthen architecture; continuous maintenance and preventive conservation are non-existent at the site. Also, there are no continuous conservation activities, workshops or systematic intervention reports, as there are in other World Heritage sites in Peru.
- Need to develop conservation standards: There is the need to reinforce site conservation standards and laws to protect earthen heritage. In general, there is neither precise protective legislation, nor earthen site conservation recommendations, as well as there is no site maintenance or conservation plans. To create recommendations for physical stabilization of structures at risk and in decay, as well as recommendations for criteria in conservation intervention, and for intervention methodology regarding the preservation of the property would contribute for site teams to have a consistent and comprehensive approach towards such large site.
- Lack of seismic retrofitting and awareness: In spite of being an area exposed to seismic activity, there is no seismic awareness at the site; neither is there seismic-retrofitting of the earthen structures, or a seismic-mitigation plan.
- Lack of community awareness: There is not enough effort to develop long-term awareness and respect for the site by the surrounding community. This results in the rise of human factors and pressures affecting the site. Also, masons have a tendency to use the site for a source of materials. To involve the local community through awareness-raising, but also through capacity building, can be an effective way for site monitoring.

Chan Chan exhibits a unique and exceptional character sustained by its authenticity and integrity, and expressed by the masterpiece of its town planning and exceptional fabric, both presently at risk. This immense archaeological complex with major threats to its fabric and Outstanding Universal Value needs to be conserved in the long term with criteria, consistency, and perseverance. Appropriate measures should be considered for the management and conservation of the site, before it is too late and Chan Chan becomes a complete ruin beyond any possible intervention.

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RAMMED-EARTH ARCHITECTURAL HERITAGE IN HAVANA, CUBA: PRESENT AND PERSPECTIVES

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Theme 2: World Heritage Earthen-Architectural Sites: Natural Disasters and Climate Change
Keywords: Coastal flooding, cyclones, rammed- earth, preventive actions

Earthen constructions were the predominant typology in Havana in the 16th century, composed of simple earthen walls (earth deposited within a framework of sticks) or rammed earth, sometimes stabilized with lime and covered with guano (palm leaves) or tiles. The five centuries, which have since elapsed, have minimized these typologies. Only inside the Historic Center of Old Havana, declared a World Heritage site, remain very old buildings with rammed-earth walls.

The effects of climate change have had an adverse effect on the architectural and urban heritage, and have impacted negatively earthen construction, which is extremely vulnerable because of its fragility to flooding, heavy rains and cyclonic winds (Casal, 2008). Moreover, given its small current representation in the city, these structures should be properly safeguarded. A study performed overlapped of the lowest-lying areas with different forecasts of weather events (tropical cyclones up to Force 5, combinations of extra tropical rainfalls and migratory anticyclones, cold fronts and the proper periphery of migratory anticyclones). This representation was intended to define the damage area of the urban fabric near the coastline, which included Port Avenue and the old harbor, emphasizing the possible impacts on heritage and historic architecture.

Conclusions and recommendations for further study are formulated, and additional preventive actions proposed, for diffusion among the community (Mitrani, 2006), in order to safely protect valuable heritage of the flood-zone area of the Historic Center.

1. INTRODUCTION

The Historic Center of Old Havana, declared as a World Heritage Site by UNESCO in 1982, is valued among the most precious urban complexes in Latin America and the Caribbean. This is due to the conservation of its urban fabric and variety of colonial and Republican architectural styles, including the original defense system of the city around the port. This shows the unmistakable imprint of stonemasons, responsible for the physical construction of a new world and a new culture involving Hispanics, Africans and Aborigines contributions. Havana, the meeting point of fleets from the Spanish colonial America, is possibly one of the cities where the most dissimilar cultures are represented. The Asian culture was also introduced in the 19th century.

The Historic Center has a great touristic and cultural attraction. It is a compulsory place for visitors to experience the city, including foreigners.

Earthen construction, which was widespread in Havana since the 16th century, declined as a constructive option in the 19th century. Structures were constructed of simple earthen walls (plastic earth deposited within a framework of sticks) or rammed earth in formwork, sometimes stabilized with lime. These were always roofed with guano (palm trees leaves) or terra-cotta tiles. The five centuries that have elapsed since have reduced these structures to a minimum. Some very old rammed-earth buildings remain, often only the outer exterior walls, while the interior was modified with other constructive techniques. The rammed-earth walls were more vulnerable due to their fragility to flooding, heavy rains and cyclonic winds (Casal, 2008). Moreover, considering their current minimal representation in the area, adequate protection is required.

Fig.1 Waves on the Malecon of Havana (credits: Cuba Debate, 2008)

2. CLIMATE THREATS

The average increase of global temperatures is reflected by the increase in the average sea temperature in the Caribbean. In Havana, this change has enlarged and will further extend the frequency and intensity of floods by sea incursion, rain and cyclonic winds, all of which cause serious damage to heritage, especially rammed earth, due to destructive action of strong winds and humidity in different forms (environmental, infiltration, capillarity, and surface erosion) (CITMA, 2011).

A study on the increase in average sea level by the Weather Institute (INSMET) in 2009 estimated that sea-level rise could reach 27 cm in 2050 and 85 cm by the end of this century (1), although when combined with the action of a hurricane, this number could be much higher (CITMA, 2006, p. 2011). So, considering only the height of current waves, which produce light to moderate flooding, more intense and damaging floods are possible in the immediate area of the Malecón (waterfront). In the event of greater wave heights, flooding would logically be even more severe (2) (Mitrani, 2006).

The abrupt changes in moisture content and temperature cause cracks and could possibly lead to the collapse of these ancient structures. When periods of very heavy rains are followed by sunny and dry days, collapses increase in the city, with an average of more than one per day.

3. FLOODED AREA

The coastal area under study was heavily built-up. The immediate access to the channel of the bay, where several swamps were, was later filled in and urbanized. As an example, the current Cathedral Square was originally known as Plazuela de la Cienaga (Swamp Square).

A possible scenario of overlapping floods of lower areas generated by potential weather events (very heavy rains, tropical cyclones, extra tropical rainfalls and combinations of migratory anticyclones, cold fronts and the proper periphery of migratory anticyclones) is shown on the map of Fig.3. If there was a Force 5 hurricane, the combination of events would be the most unfavorable.

The critical flood zone (primary) coincides with the low areas near the initial development part of the city, close to the mouth of the channel that provided access to the bay. The wharfs of the first port are also included in this area. This zone represents very valuable urban fabric in its architectural, historical and heritage components. The outline of this primary urban sector provides an approximation of the original line coast.

To better understand these impact studies, more detailed topographical surveys of the critical area would be necessary. In order to safely identify these limits, specific modeling of the sea incursion on the inner shore of the bay needs to be performed. A review of existing drains to the coast is required, considering the increase in flow by heavy rains, combined with the possible incursion of the sea by an extreme northwester.

Fig.2 Inventory of wall types, and primary and secondary flooded areas in Old Havana; yellow circles reveal rammed-earth construction (credits: Rodriguez, 2011 - Plan Maestro de la oficina del Historiador de la Ciudad de la Habana, Dirección de Planificación Física Ciudad Habana y CITMA Ciudad Habana, 2006-2011)

4. HERITAGE VALUE

The most vulnerable area within the historic center is also one of the most sought after for tourism and with very high heritage significance. Here are found the Cathedral Square and San Francisco Square. In the secondary sector are located Armas Square and the axes of Mercaderes and Ofícios Streets, presenting lower risks of flooding.

The Cathedral of Havana is valued as the best Cuban example of Baroque architecture, in addition to the buildings that outline it, which also hold great architectural and heritage value. Among them, only the Cathedral is placed on an over foundation, which in some ways protects it from lesser flooding. San Francisco Plaza is located opposite the quay for cruise ships, which makes it the maritime gateway to the city (3).

Naturally, the aim is not only to protect architecture, but all art objects, urban landscapes, and other elements of heritage significance in the urban area that must be preserved as well.

N°	Address	Use	Flooding Risk	Heritage value
1	Peña Pobre, 64	Collective housing	High	Medium
2	Empedrado, 215	Building of the Alejo Carpentier Foundation	High	High
3	Cuba, 221	Collective housing	High	Medium
4	Obrapía, 158-160	Museum building	Medium	High
5	Oficios, 53	Hostel building	High	High
6	Lamparilla, 9	Bldg. in repair	Medium	Medium
7	Mercaderes, 257	Bldg. in repair	Medium	Medium
8	San Ignacio, 703	Individual housing	Medium	Medium
9	San Ignacio, 705	Individual housing	Medium	Medium
10	San Ignacio, 709	Carpentry Bldg	Medium	Medium

Table 1. Details of rammed-earth buildings in the flood area (credits: Raimundo de la Cruz, Plan Maestro de la oficina del Historiador de la Ciudad de la Habana, 2011)

5. RAMMED-EARTH CONSTRUCTION

Out of a total of 24 rammed-earth buildings identified around the town, ten of them or 40% of the total are located in the flood zone. Of these, four are located in the most vulnerable primary sector. In each case, research needs to occur, to review if there is lime stabilization, in order to pinpoint the most vulnerable buildings.

The Alejo Carpentier Foundation, originally the residence of the Countess of La Reunion, and the Valencia Hostal, a former residence of Count Casa Moré, is found in the primary flood zone and is of high heritage value. The Museum Obrapía House is equally important, but is located in the secondary sector. In this area, on the Puerto Avenue, the Russian Orthodox Cathedral was built using typical details of gold onion-shaped domes; it has become a new and controversial touristic curiosity.

6. CONCLUSIONS

Different strategies from those established for the historic center are required, aiming at these most vulnerable areas. Moreover, residents and/or users must be sensitized for these special conditions. These strategies should embody two different proposals: one, aiming at the heritage and infrastructure construction located in the primary and secondary flood-zone areas and suitable to their material vulnerability; and another one, appropriate for the remaining buildings and infrastructure in the same area.

6.1 Recommendations

The following are the recommendations for further research based on this study:

- A more detailed topographic survey of the flood areas is required.
- There is a need to study at greater depth the effects caused by climate change on the Historic Center.
- A redesign of the urban drainage towards the coast is necessary, taking into consideration the increasing flow caused by heavier rains, combined with the possible incursion of the sea at the extreme northwest.
- A study of the moisture composition and resistance of rammed earth is needed, taking into account the possibility of an original stabilization with lime, and putting forward suitable protection actions.
- The inclusion, in current and future investment tasks for the area, of a paragraph with the duty to mitigate damage from flooding is required.
- The promotion of discussion and dissemination of this issue to institutions and the population of the area is necessary, in order to incorporate contingency plans that should be drawn up to counteract the various kinds of negative effects from floods.

Notes

(1) According to the estimate by a team of oceanographers, sea-level rise would be 31.14 cm in 2050 and 84.92 cm in 2100.
(2) According to estimates in 2050, 2,550 km^2 would be submerged throughout the Cuban archipelago; this area would reach 5,994 km2 in 2010, representing 2.32% and 5.4% of the land area, respectively.
(3) Formerly the docking area for daily-service ferries to Florida, USA.

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AL-TURAIF DISTRICT OF AL-DIR'IYAH, SAUDI ARABIA: WORLD HERITAGE SITE FACING PERIODIC EXTREME WEATHER EVENTS

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Theme 2: World Heritage Earthen-Architectural Sites, Natural Disasters and Climate Change
Keywords: Al-Dir'iyah, violent rain, sand storms, risk preparedness, disaster response

Abstract

Al-Turaif district of al-Dir'iyah in the Kingdom of Saudi Arabia on the outskirts of Riyadh was inscribed on the World Heritage List in 2010. Al-Turaif site covers approximately 29 hectares with a buffer zone of 238. Nominated under criteria iv, v and vi, the site is an outstanding example of a Najdi settlement, a significant human settlement in a desert environment intimately linked to the adjacent Wadi Hanifah (a dry riverbed), site of the first two Saud States, and connected to the teaching of the Islamic reformer who lived there, Sheikh Mohammad Bin Abdul Wahab.

Dating to the 15th century, the site was deliberately destroyed in 1819 by the Ottomans. As such its current state is that of a mud-brick ruin, extraordinarily evocative both for its size and detail, but also for the beauty of its setting within the Arabian plateau landscape. Located at the crest of the escarpment, the area receives very little annual rainfall. However, when there is precipitation, it typically arrives as violent rain events. There are also periodic sandstorms that "sand-blast" the structures. The site is extremely vulnerable to both of these phenomena, because of the steepness of the topography, the ephemeral nature of the construction material that requires cyclic renewal, and the incompleteness of the architecture, no longer being roofed or having the capacity to shed water.

This paper will describe the significance of the site, its physical nature, and the risks to its survival. It will propose environmental monitoring together with conservation measures that will improve risk preparedness and disaster response. Most of the conservation methods are specific to mud-brick ruins, but the paper will also include the proposed mobilization of civil society as a tool for use in risk preparedness and disaster response that is applicable to heritage sites in general.

1. INTRODUCTION

From 19-20 February 2011, the authors participated in a two-day workshop that included several international experts (1), representatives of the Saudi Commission for Tourism and Antiquities (SCTA) (2), and the Arriyadh Development Authority (ADA) (3). The purpose of the workshop was to review conditions and provide recommendations for the treatment of al-Turaif district (Fig. 1) at the site of al-Dir'iyah on the outskirts of Riyadh along the Wadi Hanifah, which was added to the World Heritage List in 2010.

2. BACKGROUND

2.1 Brief History

It is known that Wadi Hanifah has been inhabited for at least 80,000 years. Although no Neolithic sites have been found at al-Dir'iyah, it is likely they existed. It is also believed that by the 3rd millennium BCE, oasis farming developed in Wadi Hanifah. Written sources attest to settlements in the Riyadh area during the Classical period of the Mediterranean (500 BCE).

In pre-Islamic times, the area around the Wadi was cultivated, and prospered until the decline of the Roman Empire, the advent of Christianity, and the lessening of the demand for incense. As settlements weakened, nomadic tribes rose to power. A centralized government appeared between the 5th and 6th centuries CE, but Christianity was defeated in 634 CE in a battle to the north of Wadi Hanifah.

The Umayyad Dynasty took control of the area in 692 CE. However, after the last Abbasid campaign in the 9th century, the area reverted to local rule. By the 10th century, the region became part of the route to Mecca. In the two succeeding centuries, the area was prosperous, eventually developing the Najd settlements in the 15th century, of which also dates the origins of al-Dir'iyah. In 1446, Ibn Dir', the chief, invited his relatives from the Gulf Coast to inhabit the farmlands,

Fig.1 Al-Turath district in al-Dir'iyah was added to the World Heritage List in 2010 (credits: Pamela Jerome, 2011)

and the Muradah founded al-Dir'iyah. The influence of Islam became stronger with the growth of religious advisors.

By 1600, the population reached its peak. The Ottomans also made an appearance. In the 16th and 17th centuries, two rival clans emerged, al-Muqrin and al-Wataban. The clans migrated to opposite sides of the Wadi, and the chiefs came mostly from the latter clan. This changed when Mohammad Bin Saud (1788-1818) of al-Muqrin assumed power and founded the House of Saud. As urbanization increased, so did the desire for appropriate governance, providing fertile ground for the great reformer, Sheikh Mohammad Bin Abdul Wahab.

Sheikh Mohammad Bin Abdul Wahab, born in 1703 in Najd, studied from an early age the teachings of the Prophet, and subsequently sought to restore the pure principles of Islam. Mohammad Bin Saud officially accepted his teachings in 1745 and the First Saud State was founded in al-Dir'iyah based on sharia law. This changed the course of Arabian history.

Al-Dir'iyah encompassed several villages, including al-Turaif, which by the late 17th century had become the most important town. From 1745-1790, al-Dir'iyah held authority over Najd, and was the seat of the Reform message of Sheikh Mohammad Bin Abdul Wahab until 1810. During this time, Al-Turaif evolved into the center of the First Saud State, with administrative complexes and palaces for the Saudi princes, of which the largest is the Salwa palace with a plan of 10,000 square meters.

Al-Dir'iyah fell in 1818 to the Ottomans, ending the First Saud State, and the following year, al-Dir'iyah was deliberately destroyed. Partially rebuilt, it was demolished for a second time in 1821. Sheikh Abdul Wahab's sons and Turki Bin Abdullah al-Saud ousted the Ottomans, establishing Riyadh as the capital of the Second Saud State in 1824. Al-Dir'iyah remained in ruins (Al-Aidaroos, 2009, pp. 40-49).

Fig.2 A wide variety of historic Najdi architecture is found on the site (credits: Pamela Jerome, 2011)
Fig.3 One of the authors standing next to a high stone foundation for scale. These provide traditional flood protection for the mud-brick superstructures (credits: Pamela Jerome, 2011)

2.2 Significance

Inscription of the site onto the World Heritage List in 2010 was justified under the following criteria:

(iv) an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history

Constructed of mud bricks on limestone foundations, the ruins of al-Turaif are the most impressive of al-Dir'iyah, illustrating homogeneity of scale, some of the finest examples, as well as the variety and extent of Najdi architectural styles, and the appropriateness of the architecture to the harsh conditions of the local climate and topography. They provide a unique example of Najdi architecture.

(v) an outstanding example of a traditional human settlement, land use, or sea use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change

Al-Turaif is an outstanding example of an oasis settlement, demonstrating the organic development between the environment, its resources and the architecture's construction materials.

(vi) be directly or intangibly associated with events or living traditions, with ideas, or with beliefs, with artistic or literary works of outstanding universal significance

Al-Turaif is directly associated with the Islamic reformer, Sheikh Abdul Wahab, who lived and taught there. His teachings brought stability, while his concepts had a major influence on subsequent reformers (Al-Aidaroos, 2009, pp. 53-56).

2.3 Description

Al-Turaif lies on the top of the escarpment overlooking the edge of Wadi Hanifah (4). The urban site, a mud-brick ruin, incorporates 29 hectares with a buffer zone of 238 (Al-Aidaroos, 2009, p. 22). Al-Turaif is extraordinarily evocative in its setting and spirit of place. The textures of the different types and phases of construction, as well as the beauty of the

Fig.4 Textures vary at the site and are an important aesthetic that should be protected (credits: Pamela Jerome, 2011)

landscape and traditional Najdi architecture, also contribute to the remarkable aesthetic qualities of the site.

Thus far, extensive research and documentation have been achieved, including archaeological excavation and the recording of oral histories. Low-impact shoring has been installed to provide temporary structural stability. A management plan (Kingdom of Saudi Arabia, 2009), approved master plan (Lord Cultural Resources, 2008), conservation manual (CRAterre, 2008), and detailed construction drawings have been prepared, the latter not only for stabilization of the site, but also for a series of museums of respectful scale carefully inserted into the ruins, as well as elevated walkways that appropriately isolate the visitor from physical contact with the site (Ayers Saint Gross, 2008).

3. THREATS AND REMEDIATION

Like all exposed archaeological sites, al-Turaif is threatened by the incompleteness of its architecture, no longer having the components that provide it with the capacity to shed water. Although Wadi Hanifah is a dry riverbed in a very arid environment, the site is prone to severe weather events in the form of violent rain (Al-Aidaroos, 2009, p. 85) and sandstorms. In addition, the ephemeral nature of the construction material, requiring periodic renewal of sacrificial plasters, as well as the steepness of the site, make it particularly prone to degradation by either of these phenomena.

3.1 Proposed conservation and monitoring measures

Data on localized climatic conditions need to be gathered at various points on the site through the introduction and use of small weather stations, measuring wind speed and direction, temperature, Aeolian-particulate material (dust), rainfall, relative humidity, etc. These data should then be monitored and compared over time to recognize specific changes, trends and risks (Hurd, 2011, p. 1).

The site will be presented and interpreted to the public. Elevated walkways will lead the public through the site, clearly defining paths. To enhance this experience, a series of low-impact, reversible glazed 'boxes' will be inserted into roofless rooms and courtyards, providing exhibition spaces along with viewing ports, yet excluding the public from physical contact with the interior surfaces of the ruined structures. Use will also be made of restored buildings, which were reconstructed in the past (Al-Aidaroos, 2009, pp. 97-100).

This work must be carried out within the framework of the World Heritage Convention's Operational Guidelines (World Heritage Centre, 2008), in order to maintain both the integrity of the site and the Outstanding Universal Value (OUV) for which it was inscribed under criteria iv, v, and vi. Therefore, all conservation work must safeguard the authenticity and integrity of the attributes that manifest the site's OUV (Cotte, 2011, pp. 1-3). The management plan produced for ADA is general to the oasis of Wadi Hanifah (Burro Happold, 2004), and not the specifics of the World Heritage Site (WHS). A conservation plan needs to be developed that details acceptable interventions for the WHS (Cotte, 2011, pp. 1).

Thus, conservation of the site is the core issue from which all other interventions must proceed. In an email written shortly after the conclusion of the workshop, one of the authors provided the following recommendations for conservation (Hurd, 2011, pp. 1-2):

- Put the conservation and preservation of the monuments as the first concern and root of the process from which the detailed planning of all other aspects of site development originate and spring.
- Recognize the importance of legibility of the interface between the historic remains and new conservation additions and reconstructions. A clear and discrete, but comprehensible, separation layer should be placed between historic remains and new additions. This could be a physical geotextile sheet (5), applied along the interface. Alternatively, the addition of a small proportion of glass microspheres, or even colored beads, in a mortar separation layer can be used, to clarify the interface.
- Value the 'sacred' dirt, containing microscopic data, pollen grains, seeds, animal hair, feces, etc. Samples have already been taken of all contexts, and these should be analyzed and contribute to the detailed archaeological record. This dirt will include wind-blown dust and debris, especially at floor level, fragments of paint and any polychrome decoration, soot and other evidential deposits.
- Appreciate and document the principal qualities of the historic architecture and archaeology by recognizing the subtle textural languages of the structures on site. During the workshop's inspection, at least four types of earthen construction were noted, and no less than four general styles

and textures of plaster finishes; these possibly represent and reflect the period at which a structure was first built. It is important to guard against the use of unified styles of plastering, color and texture. A unified pattern of color and texture will lead to a bland and monotonous appearance. Therefore, each wall, internal and external, of each structure should adopt a texture and color unique to the historic finishes observed in situ.

• Recognize the importance of allowing structures to lose moisture through capillary action and transpiration, especially at lower levels and through road and street surfaces.
• Consider with great care the texture, color and function of road and street surfaces throughout the site.
• Include a full design of road surfaces and dimensions to allow civil-defense vehicles ready access.
• Select appropriate shades of white paint, beyond bright titanium shades, to provide softer more broken shades.
• Reintroduce the technology for the production and application of local lime materials.

Further recommendations from another one of the authors were as follows (Jerome, 2011, pp. 1-2):

• Treat the site with great dignity. Enhance its spiritual qualities; link it to the role of al-Turath Charity Foundation, while permitting the site to provide a meaningful experience for visitors. The site has to be treated with respect because of its symbolism.
• Protect the view sheds. The site is prominently located on the escarpment. There is a sense of discovery while walking through the site, when views across the wadi are suddenly revealed. Development in these view sheds must be carefully controlled so as not to spoil the solemnity of the space, its evocative qualities, and the wonder it provokes. Similarly, views towards the site must also be preserved.
• Solve the technical issues of the new insertions. These appear to be delicate and reversible glass 'boxes', providing not only for interpretive panels, but also for safe viewing of the interior of the ruined spaces. Resolving the water removal issues will be critical to having the least impact on the ruins.
• Provide drainage for the interiors of roofless rooms. Rooms (and excavation pits) that lack roofs require special consideration for the evacuation of water. They have the potential to become 'swimming pools' during a sudden downpour. The base of a mud-brick wall is particularly vulnerable to standing water. Drainage can be accomplished by the introduction of infrastructure (requires archaeological excavation and breaching of original foundations), or by pitching the ground surfaces towards the center of the room and providing evaporative pans. Reburial of excavation pits and reestablishment of floor levels is recommended. Backfilling will assist with clarifying the archaeology, as well as providing proper interpretation of spaces, so that the excavated areas do not leave the visitor with a false impression.
• Establish an endowment for the continued maintenance of the site, but also of the new structures. All buildings require sustained maintenance. For ruins, this is particularly important, because we are dealing with incomplete architecture that has lost its ability to shed water. For mud-brick ruins, this is even more critical, because of the ephemeral nature of the material that requires constant renewal of mud plaster, to act in a sacrificial capacity.
• Respect the materiality and textures of the site. Differentiate reconstructions from original material, and provide consolidation and engineering studies to assure the ability of existing remnants to support new construction. Provide horizon markers between old and new. This is critical for preserving the authenticity and integrity of the site.

3.2 Risk preparedness and disaster response

In 1994, technical studies were executed by ADA, including groundwater monitoring, water resource and flooding (Arriyadh Development Authority, 1994). There has also been an extensive recording of the site through laser-scanning (ATM3D, 2008) and photogrammetric documentation, as well as scaled drawings.

The management plan calls for a Site Management Unit that will be responsible for protection, maintenance and monitoring. The management plan also foresees a staff- and visitor-evacuation plan from fire and smoke, power-outages, and flooding (Kingdom of Saudi Arabia, 2009, pp. 54-55). In historic buildings, since the number of exits will be limited to the existing openings, this may constrain access in terms of carrying capacity at any given time. Staff will be trained to guide evacuation. An infrastructure of piped water has been installed to provide fire-fighting capacity, although it is recognized that in the event of a fire, the use of water could damage the mud-brick structures. Fire extinguishers will also be installed in each used building. In addition, infrastructure has been inserted to provide drainage.

A full risk-assessment survey must be undertaken and continually reviewed, leading to a disaster-preparedness-and-response policy with cooperation between the site authorities, civil defense, and perhaps, with the cooperation of groups within civil society. This assessment should continue to consider the safety of human visitors, but must also address the mitigation of risk to all aspects of the historic structures, including violent rain conditions that could also produce flooding; wind, including sandstorms; and other unexpected climatic activity.

The traditional architecture was designed to withstand the effects of floods by having tall stone foundations. However, the capacity of the recently installed plumbing infrastructure needs to be able to accommodate extreme events, including 100-year floods. In addition, provisional measures may be required, such as temporary backfilling in advance of the 'rainy' season, typically the spring and fall on the Arabian plateau. In general, backfilling of excavation soundings will both clarify presentation and prevent destruction by ponded water.

In terms of sandblasting as a result of sandstorms, the traditional protection for earthen structures involves periodic renewal of renderings that act in a sacrificial capacity. However, as indicated earlier, care needs to be taken not to introduce a single type of mud plaster, because of the existing textural variety at the site, which provides interesting tonalities and aesthetic qualities. It may also be possible to provide vegetative 'fences' at strategic locations to act as windbreaks.

Additionally, risk assessment should investigate damage caused by local flora and fauna while recognizing and accommodating the need to protect and nurture endangered species.

4. CONCLUSION

Earthen-architectural ruins are among the most challenging types of archaeological sites to conserve. The very nature of the construction material makes it readily return to its original constituents, because there is so little alteration of the raw materials (soil, straw, water) during the production of mud bricks. Without the components that provide mud-brick construction with the capacity to shed water, ruins of this type are at great risk. In an urban context such as al-Turaif, this basic issue is exacerbated exponentially. Therefore, effective evacuation of water from interiors and exteriors of buildings is paramount, as is the use of shelter coats. In addition, caution should be taken in the choice of paving materials to permit evaporation, particularly near the base of walls.

Providing for risk preparedness and disaster response is a necessary step that should be implemented with care, as should conservation and management planning, so as not to compromise the subtlety of the aesthetics of the site. The conservation plan must avoid a single prescription for all buildings, thereby respecting the textural qualities of the different construction methods and styles, as well as the variety of sacrificial coatings.

New interventions and additions must be distinct from the original artifact, and where possible, reversible, while complementing the historic environment. Reuse of structures must be planned in such a way so as not to detract from the archaeology, but rather to enhance it. Control over development in the buffer zone and site view-sheds is also an important consideration in maintaining the character and aesthetics of the site.

With the meticulous planning that has been involved thus far in the preservation and presentation of al-Dir'iyah and Wadi Hanifah, in general, the site provides the opportunity to be an exemplary case study for implementation of a variety of protective and interpretive measures for earthen-architectural ruins on an urban scale. With the planned addition of a scientific committee composed of international experts to periodically evaluate interventions to the site, the monitoring process becomes an effective tool for gauging both the efficacy of the work, and also its adherence to international principles and the World Heritage Convention's *Operational Guidelines*.

Notes

(1) Mounir Bouchenaki, Director General of ICCROM; Zaki Aslan, manager of the ATHAR program at ICCROM; Michel Cotte, advisor to the ICOMOS World Heritage Panel; John Hurd, president of the ICOMOS Advisory Committee and president of the ICOMOS International Scientific Committee on Earthen Architectural Heritage (ISCEAH); and Pamela Jerome, officer of the ICOMOS Scientific Council and vice president of ISCEAH.
(2) Prof. Ali al-Ghabban, vice president for Antiquities and Museums; Dr. Ali al-Moghannam, Site Manager of al-Turaif district of al-Dir'iyah; Mohammad al-Aidaroos, Antiquities and Museums consultant; and Bandar al-Malaq, architect.
(3) Abdullah Arrukban, Program Manager, Arriyadh Development Authority.
(4) The restoration of the Wadi Hanifah wetlands, designed by Moriyama & Tashima Planners Limited in joint venture with Buro Happold, won the Aga Khan Award for Architecture in 2010.
(5) DuPont TYPAR range of textile perhaps TYPAR 32.

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FROM THREAT TO OPPORTUNITY: THE CASE OF BAM, IRAN

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Theme 2: World Heritage Earthen-Architectural Sites, Natural Disasters and Climate Change
Keywords: Hazard, earthen heritage, Bam

Abstract

The earthquake of December 2003 in Bam should be considered the worst hazard to befall one of the oldest standing earthen structures of the world. The disaster severely affected its historical and cultural landscape and destroyed a significant amount of national heritage. This heritage was comprised of religious, residential and public buildings, as well as the ancient city of Bam. The tragedy not only ruined the character of the buildings from their core, but also made earthen resources a distrusted category of building materials in people's minds. Subsequently, the culture of building with earthen architecture lost its good traditional reputation with the risk of tragedy in an earthquake. Six years of hard work after the earthquake, which began with the creation of the Recovery Project of Bam's Cultural Heritage (RPBCH), along with the help of other national and international partners, made it possible for conservators, engineers and architects to rebuild the lost trust in the public mind.

In the aftermath of the earthquake, some major opportunities for meaningful progress in conservation presented themselves. The development of new guidelines for crisis management in cultural heritage, valuable identification of Bam's heritage, recognition of different aspects of the existing earthen architecture, assessment of new technology for conserving earthen monuments and learning the techniques to use them in other historic earthen heritage were among the results of capitalization of these opportunities. In addition to these achievements, educating and training the elderly craftsmen, and the combination of scientific methods with traditional methods also helped to gain the trust of residents. This paper reviews these activities and presents the results within a research framework; it identifies good practices in using the opportunities and proposes new ideas to tackle potential future challenges.

1. INTRODUCTION

The earthquake of the 26th of December 2003 in Bam, Iran seemed like an irreversible tragedy and the destruction of one of the biggest earthen monuments of the world. The six years spent after the earthquake from 2003 to 2009 marked a crucial era for conservators of earthen architecture to improve their knowledge on conservation of earthen architecture.

This paper evaluates the damage and opportunities at the World Heritage Site of Bam and its cultural heritage. The opportunities resulting from the earthquake were not only important for conservation and reconstruction of Bam, but also critical for other similar sites. In conclusion to this evaluation, it is important to mention that the knowledge gained was a significant step forward in the conservation of earthen heritage.

2. DAMAGE

The damage to the architectural heritage of Bam can be classified into two main categories: the first category includes the damage to the body and structure of the heritage in the Bam citadel and the structures near the citadel; the second category is the loss of credibility and reliability of earthen architecture in the mind of citizens of Bam, as well as the rest of the country.

2.1 Damage to the structure

The damage to the structure can be grouped into two categories:

- The first category is comprised of the damage to the architectural heritage inside the city of Bam. The earthen houses, the bazaars, mosques, sacred buildings, Ab Anbars (cisterns), and other communal buildings outside the citadel and in the city of Bam are in this group. The percentage of damage differed in various parts of the city, because the earthquake intensity varied in different parts of the city. For example, the intensity was higher around the citadel, whereas in the south of the city, less damage was seen in earthen structures. Some earthen buildings, like the Arsham School, the henna factory, the Ameri house, the Vakil bath, the Vakil mosque, the Haj Abbas bath, parts of the Zoroastrian complex, and parts of the old hospital of the city were heavily damaged in the earthquake, but were still stable. These buildings were well protected during the conservation phases of the recovery project, but did not have the chance to be fully conserved.
- The second category consists of the damage to the citadel of Bam and the buildings inside. The Bam citadel is an ancient city that was fully inhabited until 200 years ago, when the residents of the citadel started migrating to the nearby orchards. The abandonment of the citadel by ordinary people from the early Qajar era in 1785 until the 1940s made the citadel a fortress monument with a military presence as its sole inhabitant. It was during this period that the Bam citadel was listed on the national heritage list of Iran and was, therefore, protected from further manmade damage. The citadel of Bam is a good example of an untouched pre-Islamic Iranian city that stands today. The fortress, the moat, the huge entrance, the bazaar, the residential quarters, the governor's quarters, the surrounding walls and the watchtower were all fully standing before the earthquake of 2003.

At first assessment, the earthquake damage was estimated to be well over 80%. The Bam citadel appeared to be a mass of ruins; however, subsequent analyses and surveys, revealed otherwise. These surveys were based on the comparison of the volume of the earthen structures before and after the earthquake. For example, the volume of the standing outer-boundary wall of the citadel before the earthquake was 168,570 cubic meters. This volume decreased to 151,319 cubic meters after the earthquake. Thus, the volume of destruction was 17,250 cubic meters, or in other words, 10.33% of the wall. This can also be calculated holistically based on the volume of the entire citadel as a complex (the boundary wall, the important buildings described in the pilot projects, government's quarter and residential areas). In this case, around 195,935 cubic meters were destroyed; this amounts to about 23.7% of the entire volume of the buildings (Keramatfar, 2008).

Fig.1 The Bam citadel in 2004 after the 2003 earthquake (credits: RPBCH, 2011)

Fig.2 The city of Bam after the earthquake (credits: G. Amirjamshidi, 2004)

Despite these higher evaluations, it is imperative to note that the remaining structures were not entirely stable and many different varying levels of stability existed. As a result, the rescue plans were prioritized to emergency conservation of the least stable structures and short-, mid- and long-term actions.

2.2 The loss of credibility of earthen architecture

After the tragedy in Bam, the reliability of earthen architecture seemed questionable, both to the ordinary population of Bam, who were used to seeing the citadel as an unmovable background in their daily lives, and to the professional team assembled on site after the earthquake. Some of the published literature states that the majority of the buildings in the old citadel of Bam, which were earthen buildings, were completely destroyed (Mirzai, Farzanegan, Majedi Arkani, and Nasrollahzadeh, 2003, p. 15). It was also stated that rural earthen houses located in central Iran are relatively vulnerable in massive earthquakes of over 5.5 Ms (Moghaddam, 2003, p. 8). In addition, it is important to note that from the public's point of view, earthen structures were considered to be the cause of death and destruction.

There are no accurate records of the number of earthen structures in the city of Bam before the earthquake, but the total number of adobe structures with vaulted roofs, fired-brick structures with flat roofs, steel structures and concrete structures were estimated to have been around 20,000. In the earthquake, these buildings were damaged with destruction rates between 80 and 100 percent (Papoli Yazdi, 2010, p.56). In

Fig.3 The first international workshop in Bam after the earthquake (credits: RPBCH, 2011)

the process of identifying the buildings that were worth listing in the city of Bam, surveys and field studies were carried out. Sixty-four eligible buildings were discovered as the result of these studies. Most of these buildings were public buildings, such as bazaars, hospitals, schools, mosques, Imamzadehs, baths, etc., while historical houses formed only a small percentage (Ekhlaspour, 2005, p. 213).

Only a small percentage of the city of Bam's 100,000 inhabitants were living in earthen houses at the time of the earthquake. Perhaps surprisingly, the wealthy families of the city were all in this minority. These families lived in earthen mansions surrounded by gardens that substantially contributed to the perceived image of the city.

A survey after the earthquake showed that most people in Bam preferred conserving the heritage using pre-earthquake methods. In this survey, while 85% of the population of Bam expressed their interest in rebuilding the city with its pre-earthquake character and identity, there was an overwhelming desire for adding equipment and enhancing the resistance of the buildings against earthquakes. The opposing minority believed that the earthen architecture was not strong enough against earthquakes (Golpaygani and Einifar, nd, p. 76).

This trend of opposition against living in non-reinforced earthen buildings went beyond the public and the engineering society. Governmental organizations regulating the building and construction work in Iran, with the Iranian Construction Engineering Organization at their lead, adopted more stringent guidelines in assessing the habitability of earthen buildings. This was mainly due to the weakness of earthen structures against earthquakes, and thus the earthquake in Bam ultimately resulted in a decrease in the credibility of earthen architecture in the public's opinion.

3. OPPORTUNITIES FOR IMPROVEMENTS IN THE CONSERVATION OF EARTHEN ARCHITECTURAL HERITAGE

Although the earthquake in Bam caused severe physical damage to the tangible heritage, as well as significant damage to the credibility of the intangible cultural assets of the area, it provided unique opportunities for practitioners to enhance conservation techniques used in earthen architectural heritage. These opportunities include:

3.1 Crisis management for cultural heritage

The importance of the city and citadel of Bam for Iranians was such that an hour after the earthquake, the Iranian Cultural Heritage Organization, which was legally responsible for the support and preservation of historical heritage, formed a crisis headquarters. These headquarters were active for four months and helped to appoint the new management team for the site, clarify duties, and develop an emergency-work program. The crisis headquarters was comprised of seven work committees. Among these, the international-relations committee was responsible for coordination of the international-relief effort and actions undertaken by global organizations and international institutions.

The efforts of this committee resulted in an international workshop that was held on 17 April 2004 for four days. In this workshop, 38 international experts collaborated with 23 Iranian experts, 31 members from the Iranian Cultural Heritage Organization and representatives from national and international organizations from countries like Canada, France, Germany, Italy, Peru, Spain, UK and the USA took part. Representatives from UNESCO and ICOMOS also attended the workshop. The final convention resulting from the workshop contained short-term, mid-term and long-term conservation plans that significantly supported the rescue effort that was orchestrated as a joint international collaboration. It is noteworthy that these efforts formed the first experience for this kind of rescue activity and crisis management in the history of conservation in Iran, and can be considered as good practice in heritage rescue efforts in the world (Mokhtari, 2005; 2008; Momenzadeh, 2005).

3.2 Rediscovery of the Bam cultural landscape

Before the earthquake, Bam was culturally recognized for its glorious citadel only. It is as if the rest of the cultural heritage in the region was completely overshadowed by this magnificent building. Sir Aurel Stein, for example, ignored many of the treasures surrounding Bam as if blind (Stein and Hobson, 1937) (1).

Archaeological studies that were carried out from the first day after the earthquake started to reveal thousands of hectares of valuable historical landscape with numerous sites, some as near as just one kilometer from the citadel. The archaeological artifacts around Bam had remained undiscovered for millennia

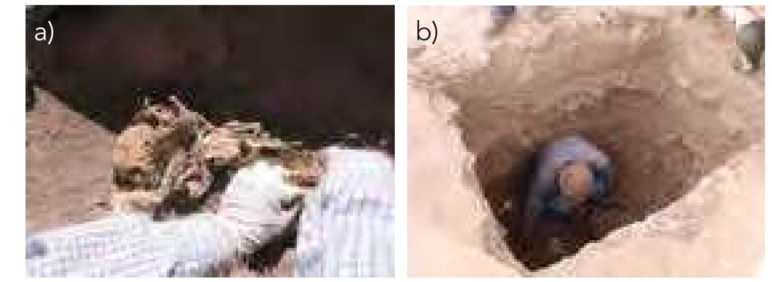

Fig.4 (a) Excavation at the Bam citadel (credits: RPBCH, 2011)
(b) Excavation of roads at the citadel (credits: G. Amirjamshidi, 2004)

and the site only started to attract its deserved attention when the area was inscribed as World Heritage (Adle, 2006).

The archaeological data generated from the activities after the earthquake, revolutionized the knowledge about the history of Bam. This data indicated that the citadel of Bam is only one of the ancient cities in the region, and numerous large cities dating from the Achaemenids to the pre-Islam dynasties existed nearby. In addition, the largest qanat (2) was discovered in the Bam fault (Zareh, 2008). Tools built by Neolithic humans were discovered in and around the citadel as well as in Tal-e-Aatashi 30 kilometers east of Bam. This showed that Bam was populated as long ago as 7000 BCE. Undoubtedly, the studies of the 280,000 pieces of pottery discovered in the debris in Bam will further enhance the knowledge about the history of the southwestern Iran and its culture in the pre-Islamic era. These discoveries resulted, indirectly, from the earthquake in 2003.

Similar studies were also carried out in fields such as archaeological ethnology, anthropology and geology resulting in a wealth of information and rediscovery of the Bam cultural landscape.

3.3. Enhanced awareness of the values in earthen architecture

The Bam earthquake and the subsequent rescue effort, which was conducted in an atmosphere of national and industrial collaboration, raised awareness for the many aspects of earthen-architecture conservation for practitioners and interested parties.

Most importantly, the attention of the international conservation community was drawn to the fact that the majority of the Iranian architectural heritage is built from earth. As Iran is located entirely in a seismically active area, more vigilance and prudence is necessary in the conservation of the built monuments. The importance of this awareness becomes more prominent when attention is paid to the fact that Iranian earthen architecture guards the bulk of the historical data and archaeological documents in the country. This invaluable archaeological evidence was found after the earthquake, during the excavations (Shidrang, 2005; Sajjadi, 2007). The only way to preserve, study and rediscover this historical data is to conserve the earthen buildings that contain and embody this knowledge. Bam has been an integral example in this process

Alignment of earthen architecture with human nature, limiting the waste of energy in heating and cooling of buildings, local sourcing of building materials in earthen architecture, and the economy of construction in earthen buildings are among the other values that were reconsidered as a result of enhanced awareness at Bam.

3.4 Technological discoveries in conservation of earthen heritage

Many of the conservation approaches that were adopted in the six years' worth of rescue activities after the earthquake in Bam were being tried for the first time.

The majority of these approaches relied on the basis of introducing construction-engineering knowledge into the conservation effort. Before the experience in Bam, the conservation approaches for preservation of earthen architecture was based on traditional methods of the past. These traditional methods included the elimination of damaged elements and adding new adobe structures. In Bam, it was no longer acceptable to remove original materials or to replace unstable elements with newly constructed artifacts, as this would severely affect the authenticity of the heritage. Therefore, new methods for stabilizing the remaining structures were needed. These methods included introducing engineering practice into earthen structures.

The first step was the establishment of the earthen material-studies laboratory in the site with the support of CRAterre. This laboratory analyzed the building materials, including the adobes used to construct the citadel. In addition, the laboratory performed mechanical tests on the materials to ascertain their properties. The efforts undertaken in the laboratory resulted in the development and building of authenticity-based adobe with maximum tensile strength (Hadian 2005; Ejrai, Esrafily, and Rasekh, 2005; Esrafily, Ejrai, Farahbakhsh, Asadollahi, Rasekh, and Hadian, 2005; Ahmadi, 2005; Esrafily, Ejrai, Rasekh, & Hadian, nd; Amirjamshidi, Fodde, & D'ayala, 2012) provide an overview of materials used before and after the earthquake in the conservation of Bam's citadel.

The next steps concerned with reinforcing standing earthen structures after the earthquake. Three activities were undertaken in parallel:

- Collaboration was sought from international institutes with expertise in the subject of adobe structural strength. The interested parties were each assigned a project: Dresden University of Technology undertook work in conservation of the Sistani house; the Italian Ministry of Cultural Heritage and Activities commenced work on Tower 1; CRAterre in France assumed responsibility for the second gate; and Politecnico di Milano and the University of Padua from Italy became jointly responsible for the Mirza Naim house conservation. These projects were envisioned as pilot projects.
- Soil Engineering Services (SES), consulting engineers,

were invited to perform studies on injection grouts. National universities with relevant expertise were also invited, to assume the responsibility for pilot projects. Among these, only Isfahan University, which had previous experience in reinforcing historical buildings, was charged with the conservation of Tower 32.

- A national engineering group was formed at the site from structural and civil engineers with experience in analysis of seismic areas. The Payambar Mosque, the warehouse adjoining the Sistani house, and the Tekkiye (3) were chosen as pilot projects for this group.

These steps were taken to gain experience and develop the necessary technology to reinforce and stabilize the standing adobe structures and to control the lateral forces in these structures to eliminate the weaknesses.

The collaborations between the international community and the young Iranian experts resulted in the following:

- Development of techniques for reinforcing materials and structures of earthen architecture.
- Design and construction of the necessary tools for implementation of the above techniques (e.g. grout-injection tools, levers for moving structures, etc.).
- Study of materials and additives required for reinforcing earthen buildings at the foundations, load-bearing elements and coatings.
- Education and training of experts and craftsmen.
- Use of local materials to reinforce earthen structures.
- Study of the use of structural-modeling software for application in conservation of earthen architecture.

Consequently, useful expertise in reinforcement and stabilization of adobe structures was generated as a result of the rescue efforts in conservation of the Bam cultural heritage. This expertise is not only useful in the continuation of the conservation work at Bam, but is also good practice applicable to other similar sites around the world.

3.5 Attempts to revive the culture of earthen architecture

In a conference after the Bam earthquake, Dr. Ghalibafan, a major structural engineering figure in Iran, said, “Engineering in Iran has abandoned earthen architecture”. Bam’s earthquake greatly affected people’s faith in earthen architecture and its benefits; the majority of the population thought of earthen architecture as the main reason that the death rate had been so high in the earthquake, even though buildings made from other materials were also destroyed. At the time, the society of engineers in Iran were of the opinion that buildings using modern materials could have been designed to better withstand the earthquake but, in their mind, earthen buildings would never have been able to resist earthquakes of such magnitudes.

This lack of attention by engineers could have had devastating effects on the future of earthen architecture in the country, and hence there was a need for some effort in reuniting the engineering disciplines with earth as a building material. The path towards this reunion has been precarious, but lessons learned from the conservation of Bam after the earthquake has created new hope. The efforts in building more earthquake-resistant earthen structures and reviving the culture of building with earth have given rise to a new horizon for these buildings in Iran and throughout the world. In the six years after the earthquake, the following activities where undertaken in Bam in this regard.

Fig.5 World Heritage logo at the entrance of the citadel (credits: G. Amirjamshidi, 2011)

3.5.1 Education and training of craftsmen

The recovery effort after the earthquake created a unique opportunity for earthen-building techniques to be taught to a new generation of young professionals. A number of expert professionals in the field, who had been in Bam at the time of the earthquake, had unfortunately perished in the disaster, and thus the number of experts had dwindled. During the six years of the project, the remaining professionals were heavily encouraged to mentor new students, and as a result of this program, newly trained young professionals learned the techniques to use and pass on to future generations. For example, in the production of khesht (adobe), the project started with a single professional. He was originally placed in a group with two assistants, who later became experts in their own respective groups. In 2009, there were six groups active in khesht production, each with one expert and two apprentices, and thus the number of professionals in this trade, traditionally called kheshtmal, had risen from one to 18 in six years.

3.5.2 Educating students

Aside from professionals who were working full-time or temporarily in different parts of the Bam project, university students interested in khesht and earthen architecture were involved through many student projects during the six years. In addition to the students from the Universities of Bam, Kerman, and other Iranian cities, some projects were completed with students from Italy, Germany, and France. All of these projects were aimed at reviving earthen-architectural culture.

3.5.3 Involvement in other earthen architectural projects

During the tim that the post-earthquake reconstruction efforts were being carried out, two other earthen architectural-construction projects were completed. The first was the construction of a sample earthen structure by CRAterre in the Iranian Housing Foundation (Bonyad-e-Maskan) exhibition. The second project was the building of two sample projects by the Nader Khalili Foundation in the city of Baravat. In a period of time where earthen architecture was mistrusted by the public, perhaps undeservedly as a result of the Bam earthquake, the Bam Recovery Project Office had the responsibility, as the guardians of this ancient method of construction, to utilize every opportunity to maintain the core competences required for gradual recovery of the practice. The office, therefore, participated in both of these projects by supplying the craftsmen, labor, and, in the case of the CRAterre project, the required materials. This participation was in line with the goal of reviving the culture of earthen architecture in Bam.

3.5.4 Construction of an earthquake-resistant earthen-architecture unit

Investigating methods for retrofitting earthen buildings in villages around Bam was another useful step in preserving the culture of earthen architecture in Iran. Consequently, the Bam Recovery Project carried out a joint effort with a postgraduate researcher from the University of Kassel, Germany to build a sample earthquake-resistant khesht building. The resulting structure was reinforced with organic fibers and resins, and was finished in 2007 (Nejati, 2008).

3.5.5 Other attempts

Other attempts to revive the culture of earthen architecture included: publishing reports, participating in related seminars, and organizing meetings with Bam’s City Council and culturalheritage enthusiasts.

3.6 Establishing the heritage zones of Bam and its cultural landscape

Prior to the earthquake, many houses were built in the vicinity of the ancient city of Bam and the citadel without appropriate consideration for heritage. The destruction resulting from the earthquake gave rise to a unique opportunity to put in place boundaries and limits for construction. In the city of Bam, a maximum height of 10.5 meters was set for all building construction to protect the cultural landscape. Many properties had been occupied based on dubious legal foundations around the citadel. After the earthquake, the conservators could put in place rules to disallow the same thing from happening again. Another example is the street to the south of the citadel and the surrounding gardens and orchards, which had been put in the care of the municipality of Bam before the earthquake. The responsibility for these areas were given to the Bam Recovery Project as a result of the zoning for inclusion in the World Heritage listing; this opportunity allowed significant steps to be taken towards the conservation of the cultural landscape in Bam.

Fig.6 New students learning from the professionals (credits: RPBCH, 2011)

4. CONCLUSION

Natural disasters, such as earthquakes, result in irreplaceable damage to earthen architecture. The experience in Bam showed that despite the devastation that is left in the wake of such events, many unique opportunities for radical rethinking of conservation approaches can also appear. Exploitation of these opportunities could allow some good to come out of an otherwise horrendous event and provide some degree of consolation. The six years of conservation after the earthquake in Bam are a good example of such capitalization of opportunities with the support of the national and international communities. During this period, Bam was not only a reconstruction site and a historical heritage-conservation project, but also a leading world-research facility for developing and testing new ideas in preservation of the earthen-architectural heritage.

Notes

(1) Stein stayed for three days in Bam, from 20 to 23 April 1932, but did not manage to see any of the archaeological sites that he intended to visit.
(2) Wells connected with underground tunnels, a popular method of irrigation in arid areas of the Middle East.
(3) A stage for traditional religious theater.

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DOCUMENTING EARTHEN-ARCHAEOLOGICAL SITES – THE ISCEAH GLOSSARY OF DETERIORATION PATTERNS

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Theme 3: Documentation, Conservation and Management of Archaeological Sites
Keywords: Damage, decay, earthen sites, terminology

Abstract

Traditional and contemporary earthen construction can be identified in most European countries. The ecological and sustainable advantages associated with European earthen-building traditions make it a relevant material for construction nowadays. However, despite recent technology, earthen heritage remains fragile and threatened. This is why the protection of this unique heritage and the diffusion of contemporary earthen architecture in Europe deserve to be further acknowledged and supported.

In that aim, a European project was implemented in 2006-2007 making a state of the art of earthen architecture in Europe, particularly in France, Italy, Spain and Portugal. In order to complement these results at the scale of the European Union and to ensure a widest dissemination, a new project "Terra InCognita – Earthen Architecture in Europe" was launched in November 2009 for a period of two years. The aims of the research project were challenging: a scientific publication gathering the contributions of authors from the 27 European Union countries; an updated European cartography concerning traditional earthen techniques; a scientific exposition and a photography exhibition, a European label, as well as a comprehensive website (www.culture-terra-incognita.org). The research project also initiated the launch of a European network during a symposium held in Marseille (4-6 May 2011).

This paper presents the results of the Terra InCognita project, as well as a reflection concerning the relevancy of these kinds of initiatives, as they can contribute for the advancement of knowledge regarding earthen heritage, as well as the establishment of strategies to protect earthen heritage.

1. INTRODUCTION

1.1 The need for a glossary of deterioration patterns

The need to document earthen architecture and its deterioration has been an issue since the development of the scientific approaches to conservation. The start date for earthen architecture is often considered to be 1966 with the establishment of ICCROM's scientific program through a partnership between the University Museum, Philadelphia and the Italian Archaeological Institute in Baghdad and Turin (Carter and Pagliero, 1966). Documentation has been an issue highlighted at many of the Terra conferences, since their initiation in 1972 (Hughes, 2002; Matero and Cancino, 2002; Cooke, 2010a).

ICOMOS-ISCEAH International Scientific Committee for Earthen Architectural Heritage supported the compilation of the document, as consolidating both vocabulary and terminology would be of great help for practitioners and academics. At present, there is no similar tool that deals with earth, as a building material. As such, the current initiative is the response to a growing need for a standardized approach for documentation of deterioration patterns, particularly in light of the growing interest in the conservation of archaeological sites. There is also recognition of needs for both research-led documentation of earth structures alongside more rapid documentation of earthen architecture, given the assumed complexities of its environmental susceptibility and given the likely impacts of climate and climate change.

Moreover, the professionalism of 'documentation' as a discrete technical discipline allied to, but not necessarily undertaken by, archaeologists, conservators or earth building specialists – and particularly the one undertaken by technicians (such as 3D-scanning) – can present difficulties in managing data that can have relevance for conservation planning. This is in the context of a growing trend throughout archaeology and conservation to establish norms and procedures, and some of these have been undertaken in different contexts by ICOMOS.

2. BACKGROUND AND OTHER INITIATIVES

A number of different initiatives have been undertaken for a glossary of deterioration patterns of earthen architecture. There exist a number of institutional approaches (such as ICCROM, CRAterre, and GCI), alongside with project-based approaches (such as Ancient Merv and Ajina Tepa) or individual-based approaches. Many of the ICOMOS-ISCEAH group members are able to bring their own experience and approaches to the debate. The key to this debate is to separate 'personal preference' terms from more analytical terms, which are more suitable for an 'international' glossary. Even this approach is also complex (see discussion below).

These 'earthen building' approaches exist alongside with those undertaken in a similar context but for different materials (such as stone and fired brick). Given the scale of past and present initiatives, it was clear that there was a need to review past process, and understand what does and does not work effectively. At present, the current stage is still collating glossaries and approaches for understanding, whether they are of practical applicability to real-world cases.

2.1 Examples

The development of standard approaches to documentation was a component of the influential Getty Conservation Institute's Fort Selden Test Wall project and its various of-shoots (Agnew, 1990; Caperton, 1987; 1990). Similar approaches were used at Casa Grande and other sites from the University of Pennsylvania students (Matero, 1999). Other approaches were developed specifically in the context of UNESCO projects, such as Ajina Tepa in Tajikistan (Fodde, Watanabe and Fujii, 2007) and Burana in Kyrgyzstan (Fodde, 2008), as well as other research projects, such as Ancient Merv in Turkmenistan (Cooke, 2008) and Hili in Abu Dhabi (Cooke, 2010b).

Additional examples of glossaries from non-earthen materials include the ISCS (ICOMOS International Scientific Committee for Stone) stone glossary and the damage atlas for fired brick (Franke and Shumann, 1998). It took seven years to compile the ISCS document on stone and develop a hierarchy of terms to describe deterioration patterns observable by the naked eye, but with some variation, such as 'mechanical damage'. The ISCS stone glossary only contains terms related to stone material as an individual element within a built object or sculpture. As a consequence, the terms do not relate to the description of the deterioration of a stone-masonry structure as a whole (ICOMOS-ISCS, 2008, p.6). This is an important aspect to consider when narrowing down and refining our approaches to the ISCEAH glossary.

	Advantages	Disadvantages
B/W photography	Clarity of image Ease of reproduction	Limited palette to demonstrate
Colour photography	Clarity of image Accurate record	Difficulties of reproduction
B/W line drawing	Clarity of drawing Ease of reproduction Establishes drawing convention	Limited palette to demonstrate
Colour drawing	Clarity of image Accurate record	Difficulties of reproduction
Point cloud (static or 3D)	Accurate record	New technology, not all familiar with technique Difficulties of reproduction

Table 1. Comparative analysis of advantages and disadvantages in using graphic methods (credits: ICOMOS-ISCEAH)

2.2 Problems and issues

Language is the greatest complexity when developing any glossary – each person has his/her own terms to describe what is seen, and as individuals, each one knows precisely, to what they are referring to. Furthermore, the expansion of earthen materials across different continents, together with different and local specialism's make the task immensely complex – this being the difference between personal terms of reference and those more suitable for an international glossary. Just one example of a characteristic deterioration pattern affecting earth structures can demonstrate this - capillary action takes place at the base of the building, often creating a zone of damage cut into the base of the wall. Even by a single practitioner this can be variably known as: undercutting, basal erosion, wall-base cavities and coving, amongst others.

Other issues are made complicated for earthen architecture, as different types of earth construction are more or less liable to demonstrate particular deterioration patterns. This is similar to how different geologies demonstrate different deterioration patterns for stone deterioration.

Methodologies for graphic portrayals of the glossary have also been discussed (particularly by William Remsen and Pamela Jerome). These include black-and-white or color photography, black-and-white or color line drawing, and use of point-cloud data (from 3D laser-scanning) (Table 1).

How and in what ways, the illustrative support is developed, largely depends on how the glossary will be used and disseminated. There are advantages and disadvantages in the different methods depending on print/online distribution – with perhaps a rather idealistic aim that this could eventually be a hand-held or smart-phone application. For the time being focus has been on black-and-white line drawing, alongside color photography (Table 2).

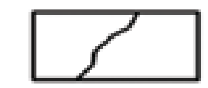
Term and drawing convention	Definition	Representative photograph
Crack and deformation (ISCS)		
Cracking 	Fractures of variable length and orientation, greater than or equal to 0.40mm in width, with or without associated planar displacement of the finish, and differentiated by depth and pattern. (MV)	 Fig.1 - House of Beit Seif and Khalfan Bin Abdallah Al-Zhahiri, Al Ain, UAE (credits: E. Fodde)
Structural crack Seismic crack Masonry crack 	Crack through a load-bearing wall. Structural cracks appear especially on single structures that are left exposed to the elements and to improper drainage. Earthen walls are sometimes not properly connected and are therefore free to move individually. Crack thickness in the order of cm. It also applies to seismic structural diagonal or shear crack, to through wall cracks, with variable thickness.	 Fig.2 - Buttress-wall disconnection (corner crack) in rural Peruvian highlands (credits: D. Quiun)  Fig.3 - Acllahuasi of Pachacamac, Lima, Peru (credits: J. Vargas-Neumann)

Table 2. An example of a page from the ISCEAH glossary

3. DEVELOPMENT OF ISCEAH GLOSSARY

Following on from the discussions at Terra 2008, the archaeology scientific sub-theme of ISCEAH, focused on establishing a glossary of deterioration patterns. This immense project just begun to be tackled and the momentum is complex. To date, the authors have not progressed, as much as they would have hoped.

We have reviewed a number of glossaries used by our members, and looked in more detail at how and in what ways the ISCS stone-glossary approach could work for deterioration patterns of earthen architecture. We have attempted to fit terms from our various glossaries (in particular the Mesa Verde glossary developed by Frank Matero) into a hierarchy of terms (as used in the ISCS stone glossary). What is presented in the table is an early attempt to create a glossary. This has been done in reference to the authors individual approaches to site documentation, and with reference to particular documents – Franke and Shumann (1998), ICOMOS-ISCS (2008) and Matero (n/d), alongside earlier work at Casa Grande (Cancino, 2001) and GCI work at Mogao Grottoes (GCI, 2004). The approach comprises three types of information (the term, and black-and-white drawing convention, the definition, and a representative color photograph). This utilizes the hierarchy of terms from the ISCS stone glossary: crack and deformation, detachment, features induced by material loss, discoloration and deposit, and biological colonization.

4. CONCLUSION

ISCEAH needs now to consider how, and in what ways, the ISCS approach needs to be tailored to earthen materials. It is also relevant, to consider other earth-specific terms that need to be added, and those less relevant that can be omitted. The group would like to further define and develop approaches to the glossary, and this paper become an important opportunity to review progress and develop a strategy for completing the project.

Within ISCEAH, this project will also be evaluated to determine how it contributes to other initiatives, such as the atlas of earthen architecture. There is perhaps an interplay here, between identifying a number of sites that could be used to test-run approaches, to review and to evaluate the glossary.

It is likely that in the future, a great variety of terms will be included, in order to incorporate the concepts of the growing number of specialists involved in conservation, including archaeologists, engineers, architects and conservators. Other categories will also be considered, such as seismic damage, and damage caused by inappropriate repair. In addition, further languages also need to be contemplated, such as Spanish, and French, beside the English.

This paper aims to demonstrate the ongoing commitment of ISCEAH to develop new approaches and the understanding of earthen architecture. The initiative will continue to be developed in the following years.

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PROTECTION OF AN EARTHEN-ARCHAEOLOGICAL SITE: A COLLABORATIVE EFFORT BETWEEN COMMUNITY AND EXPERTS, CHILE

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Theme 3: Documentation, Conservation and Management of Archaeological Sites
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The prehistoric village, Tulor 1, is located about 10 km southwest of San Pedro of Atacama in northern Chile. It is the oldest sedentary archaeological site in northern Chile, whose chronology dates back to 2250 years ago. It was excavated by archaeologists from 1981-1985. At that time, it was clear that the site was undergoing an accelerated process of deterioration, resulting from the advance of a large dune that originally covered it that currently was in the process of withdrawal. Studies were made to find a solution to the natural processes of destruction affecting the site, and it was concluded that the active and irreversible damage is caused by the condition of the environment in which it is located.

Research has shown that the best way to preserve the site was to keep it in a "buried" state. In order for that to be achieved, it was necessary to stabilize the top of the earthen walls, which had been irreversibly degraded, by designing "capping" solutions and binding based on satisfactory studies with more than 20 years of permanence. Moreover, the study of the grain size of the dragged material allowed determining of the minimum particle size necessary to cover the site with a thin layer of sand with similar features, preventing it from being carried away by the winds forecasted by the weather station installed in situ. In addition, and because it is a site whose management and care is in the hands of a small indigenous community, it was necessary to raise awareness of the site's fragility, and to provide technical training for indigenous community to be able to perform the work of supervision and future maintenance.

1. INTRODUCTION

Culture and cultural heritage are living concepts, constantly changing according to societies where they belong. Similarly, the definitions of conservation and restoration have undergone significant changes over recent history; changes that directly affect the materials used in an intervention, the technology applied and, above all, the chosen criteria.

The prehistoric village of Tulor is located in the immediacy of the ayllus of Coyo and Tulor, about 10 km southwest of the town San Pedro of Atacama in northern Chile. The environmental framework is established to the east by the colossal Andean highlands, to the west by the mountain range of the Cordillera de la Sal, which ends northwards to merge with the eastern edge of the great Salar of Atacama. In its surroundings remain active dunes, on which are found scattered shrub species, maintained by subsoil moisture. The chronology of occupation of the site ranges from 800 BCE to 500 CE that is, the settlement would have originated about 2,250 years ago. Some experts have considered it to be one of the best-preserved archaeological sites of the Neolithic period (Barón, 1986).

The site is located on the large area of alluvial deposits of the San Pedro River. The village itself is built on a site of clayey soil. Geological theories hypothesize very different environmental conditions to the present ones of the entire area, theorizing that probably there was a greater availability of water resources, and thus the existence of more vegetation and wildlife than currently. However, fluvial activity, which depends on the climatic cycles of the High Andes, produced over time, sharp changes in the course of the River San Pedro, which moved further away from the Tulor sector.

Dryness drastically deteriorated environmental conditions, making the site uninhabitable and forcing its occupants to emigrate from the territory in which the village was located.

A slow process of desertification began, leaving the ground bare. Strong windstorms dragged the salty sands from the Cordillera de la Sal, forming active dunes that gradually covered the entire site, which also preserved it. It remained in this condition approximately 1,700 years until, in the early decades of the 20th century, the dune covering the site moved southeasterly, revealing the first structures, which was reported by Priest G. Le Paige, in 1957 (Le Paige, 1957-58). For its historical and heritage value, as well as its fragile condition, it was placed by the World Monuments Fund, on its Watch List for endangered cultural sites around the world.

Fig.1 Stallite image from Tulor site (credits: Google Earth)

2. HISTORICAL FEATURES

The main feature consists of 23 circular structures built of earth kneading in situ. Of these structures, linked walls were developed creating passages that connected with enclosures of various mixed forms. In total, 106 structures of different geometry were recorded, evidencing a cellular growth. The enclosures are reached by regular door openings and others are simple openings cut in the earth walls at different times. This indicates that there was a lot of activity and change of use of the buildings during the long period of occupation. Archaeological evidence shows that the enclosures had various uses and functions related to everyday activities occurring therein (Bahamondez and Muñoz, 1997).

3. FIRST ACTIONS OF CONSERVATION

In 1982, an area was chosen, 30m distant from the last vestiges of walls of the site, to construct a polygon for testing, which consisted of exact replicas of the structures number 2 and 3, with their linking walls. A hypothetical roof was also added to recreate the conditions inside the rooms. Here it was possible to accomplish various types of measurements and tests with conventional conservation materials, as well as with various consolidants. The research station on site, included meteorological-measurement equipment that allowed recording the prevailing environmental conditions at the site (Muñoz and Bahamondez, 1990).

Between 1984 and 1989 research was conducted, in order to find a solution to reduce the devastating degradation process to which the site was being impacted. The deterioration observed in Tulor was due to multiple agents, causes and mechanisms. Usually, their action is interconnected, which undermines their identification and subsequent isolation. The main problem was the actively irreversible damage, due to the environmental conditions of the location where the archeological site is located. From the foregoing, it was concluded that it would be necessary to stabilize the tops of the irreversibly degraded walls by designing 'capping' solutions (Morales, 1983), along with the application of consolidating materials that would provide greater resistance against weathering in the most exposed areas.

4. CURRENT PROJECT

The development of the Tulor project was possible through the financial contribution from the Regional Government of Antofagasta through CONAF (National Forestry Corporation) and the University of Antofagasta. The activities carried out between 2009 and 2010 consisted primarily in the design and implementation of solutions to stabilize and to protect the top of walls of the structures, using a technique studied for over 20 years. The analysis of the current condition of the solutions implemented in the years 1989-1990 showed that they have maintained their ability to protect the walls despite the time elapsed, efficiently withstanding the harsh environment of the place.

The first aim was to mitigate the visible and irreversible damage to the structures due to the environment where the site is located. The second target was to train the community of the Ayllo Coyo on issues related to the conservation and management of the environment near which the site is located and cultural remains. This training also incorporated the staff of CONAF, which is currently working in the surveillance of the area of San Pedro of Atacama. Finally, a seminar on the subject of Tulor was convened and attended by relevant people in the cultural field and that related to the theme of the site, Tulor 1.

5. EXISTING CONDITIONS

The first conclusion drawn was that the built remains of the village, on the one hand, are being discovered faster than initially was planned, due to the rapid displacement of the dune that covered them for centuries. This situation induces two opposite effects: on the one hand is the discovery and damage to the remains of structures located to the north, with the consequent degradation and/or disappearance of walls; and secondly, the gradual filling of structures that were excavated during the archaeological research over the years 1981 to 1985, and left exposed to weathering (Llagostera, Barón and Bravo, 1984).

The latter effect, the natural filling of the structures in the last decades, was initially found to be safe and beneficial. However, on the contrary, it constitutes another deteriorating effect that had not been foreseen beforehand. The sand particles that drift with the wind swirling at an average height of the half-buried walls have produced erosion of the structures at the base of the parts that are exposed.

6. AGENTS AND DETERIORATION MECHANISMS

The obvious fact that the site is being slowly rediscovered as the dune advances has proved that, in this situation, structures are more vulnerable to damaging agents, for which there is not nowadays a definitive solution. For this reason, it is necessary to maintain the site in its buried condition. Therefore, it was required to determine the proper characteristics of the filling

Fig.2 Replicas of two village dwellings built as a conservation prectice site (credits: Monica Bahamondez)

and surface covering materials, so that this will not be dragged by the prevailing winds common in the place.

The deterioration observed in Tulor is due to multiple agents, causes and mechanisms. Often these are interrelated, making it rather difficult to identify and isolate them. When classifying the agents of deterioration as intrinsic and extrinsic to the structures themselves, among the former is undoubtedly the raw earthen material used for building the structures, which is highly vulnerable to atmospheric factors. Extrinsic agents include strong and steady winds that drag particles impregnated with soluble salts; a certain amount of summer precipitation, because of the winter in the High Andes; and finally, large temperature differences between day and night, which create severe variations in relative moisture. All of the aforementioned agents act simultaneously, with the exception of the human factor, which is currently controlled (Bahamondez and Muñoz, 1997).

Undoubtedly, the dune that covered the village for over 1,500 years, which is currently in retreat, is the main cause of their destruction. Already in the 1990s, it was determined that the settlement had taken the shape of the dune, which due to its advance dragged sand, leaving the walls at the surface. These, in turn, were soon swept away by the abrasive wind. To this, other damaging agents described below are added.

6.1 Moisture

Although the village is located in one of the driest places on the planet, there are summer rains known as the Bolivian Winter, manifested between the months of December and March. On the other hand, evening relative humidity is close to 100% throughout the year, and the high hygroscopicity of the salts and of the raw earthen material, develop a process to a greater or lesser extent of continuous solubility and re-crystallization of salts on the top of the walls. This process has been confirmed to occur at the surface or immediately below it, depending on the temperature reached by the wall in the hours following wetting. This permanent migration of material, and the regular formation and re-solubility of large crystals within the pores, causes serious micro-structural deterioration, manifested as a progressive lack of inter-particle cohesion or surface dusting.

This phenomenon means that, under a seemingly hard and solid (but extremely brittle) surface, there is a layer of clay, which does not have any structural capacity and, in fact, favors the deterioration process, which cyclically repeated will slough off material from the top of the wall. Cyclical moisture issues are the great enemy for conservation of earthen-built archaeological structures.

6.2 Temperature

During the year, in the Salar of Atacama, high temperatures can be noted during the day, and very low ones during the night, the latter well below the freezing point of water. The effect of this temperature gradient is verified in that part of the wall that is exposed to the weather, provoking at the interface of the "wall buried/wall unearthed" significant differences in thermal expansion, which ultimately translate into a sum of tensions that may culminate in the generation of multiple micro-fissures, cracks and subsequent detachment of entire areas.

Moreover, a wall with a high percentage of liquid water inside is exposed to severe mechanical alterations from the time when the temperature drops below the freezing point. Indeed, the water passing from the liquid to solid (ice) state increases its volume by producing, within the pores, tensions that can irreversibly fracture the structure. This phenomenon occurs mainly at thermal interfaces.

6.3 Wind

The Tulor village is located in a degraded and bare plain in the northern sector of the great Salar of Atacama. It is constantly buffeted by strong winds, which carry a considerable amount of dragged material (brackish soil, sand, and pebbles).

This material, depending on its volume, specific density and hardness, impacts the top of the walls through sandblasting. In addition to this effect, the weakened, by the aforementioned agents, wall is likely to experience progressive deterioration, reaching the extreme circumstances of its almost total destruction. This situation is obvious in semi-unearthed remains of structures around the village of Tulor.

In the first assessment visits, this phenomenon was evident as it was possible to observe the effect of erosion on different structures, which were well documented. Even structures built on the test grounds showed severe damage to their bases as a result of erosion by the winds. From the foregoing, it was concluded that it was necessary to stabilize the top of the walls that had been irreversibly degraded by designing 'capping' solutions (Morales, 1983; Muñoz and Bahamondez, 1990; 1992-1993; 1993)

Fig.3 Removal of salt-contaminated first coating layer. (credits: Monica Bahamondez)

7. PROJECT DEVELOPMENT

7.1 Selection and physicochemical characterization of the earthen material

The first activity consisted of research and testing of the behavior of different soil types in the area (Teutonico, 1998). The possible choices were varied, and finally a type was chosen from an alluvial deposit located at a distance of 60 m to the southwest of the replica houses very similar to that used in the original earthen construction. The raw earthen material selected for the reinstatement of the top of the walls was sent to the laboratory of the National Center for Conservation and Restoration (CNCR) DIBAM for characterization and understanding of its properties. With this result, the archaeological site began being capped, by selecting a homogeneous clay layer, from which material was extracted and collected for use.

7.2 Interventions at the tops of the walls

Two types of techniques were established to condition the walls for intervention. The first related to the remains of the underground walls, in which it was necessary to clear its sides in order to carefully observe the original forms, having as reference the most prominent features at the surface. The second had to do with those tops of the walls that emerge beyond the surface. In this case, the intervention was focused on the frailty of the walls' tops, due to the causes described herein.

7.3 Preparation of the tops of the walls

Considering the current condition of the top of the walls, the extent of damage caused by the exfoliation of layers and efflorescence of salts, of the first step was to remove material irreversibly degraded and unrecoverable. This task was achieved through the careful work of constant evaluation of the materials affected in varying degrees by erosion and salinity. The removal of the damaged layers was limited to the level of the depth of loose saline material that no longer had the ability to adhere to the wall. The tops of the walls were cleaned until the original material was found, which still retained in good condition and consolidation. With a sound substrate, it would be possible to reintegrate new patching material.

7.4 Preparation of the earthen material

The earthen material selected from the location adjacent to the archaeological site, as aforementioned, was extracted by layers and prepared for use by grinding and pulverization. The raw material required for use in the 'capping' solution had to meet special conditions. These relate to the plasticity of the earthen material, which should adapt to the top of the wall, in very different moisture states from that of the material to be incorporated. Should there be much difference between them, there would be and uncontrollable contraction rate and cracking would result in the new layer. In this case, detachment would be inevitable. The solution to this problem is to manage the plastic limit of the earthen material. The right mixture is achieved through careful allocation of the quantities of water and sand, in addition to the amount of wetness at the top of the wall.

The materials used in this procedure complied with the specifications given by the project. The technique, already mentioned as a 'capping' solution on walls built of earth, technically corresponds to a continuous coating of the wall surface to be preserved. One of the main objectives is to serve as 'sacrificial layer' to protect the surviving parts of the original wall. This layer was designed to cope with the various types of damaging agents and to also avoid increasing salt migration to the original parts of the walls. The damage to this capping will not be a great loss, as it is not the original material and, therefore, easily replaceable.

7.5 Integration of a sacrificial layer ('capping' solution)

After removing the unsound material from the tops, the walls were cleaned and the sound parts were stabilized; this was followed by a gradual wetting process in preparation for 'capping'. As mentioned above, this "capping" material in a wet and plastic condition is different from that of the original tops of the walls. The "capping" mixture was prepared by the combination and adjustment of the right proportions of sand, earth and water, taking into consideration the differential behavior in unlike parts of the tops of the walls by the range of types and amount of salts in their structure.

To connect the "capping" mixture to the walls, wooden mallets were produced of ideal size, shape and weight, so as to incorporate the new material using a compressed technique. This allowed the application of the low-moisture capping mixture to better adapt to the tops of walls, which is in a different state of moisture content. Through this process, the moisture content between the wall and the "capping" mixture was standardized, permitting the covering of the tops of the walls, significantly reducing the risk of incompatibility, as well as cracking. The implementation of the capping mixture occurred manually only, by tamping with wood mallets the raw earthen material until optimum condition was reached.

After drying, the eventual appearance of fissures was to be expected. When this occurred, the coating required stabilization through a local reimplementation of the mixture in low-wet condition to those specific areas. Once the earthen "capping" completed its drying process, and when environmental conditions were favorable, consolidation treatments and waterproofing of the coating could be consecutively applied (Schwartzbaum and Seymor, 1983). These processes should not occur in extreme thermal gradients of temperature. If possible, temperatures are required to be moderate and should always be above the freezing point.

The variables to be controlled during the implementation of the different products are unique to the specific site conditions of Tulor, and these were specifically established by the laboratory analyses. The aim of this application was to increase resistance to erosion and to restrict water absorption that carries a certain amount of saline solutions.

Fig.4 Part of the community team of workers in charge of site management (credits: Monica Bahamondez)

7.6 Leveling enclosures

As already extensively described, the wind with sand traveling at high velocities over the surface of the walls is one of the most aggressive agents for the site destruction. The other type of erosion, detected in recent years, is produced on the vertical walls in their lower sector, where abrasive sand swirl occurs, moved by the wind following the circular shape of the enclosures.

To mitigate the effects of this agent, the accumulated sand was leveled naturally within enclosures, filling the low parts and berming higher ones. With this procedure, it was possible to protect the foundations of the walls by evenly leveling the filling within the enclosures. However, this filling can also become windborne and, therefore, abrasive. To maintain a steady and constant filling, a layer of 3/8" gravel was placed. This material, because of its size and weight, cannot be mobilized by high winds; thus, the foundations of the walls that are exposed are protected.

8. CAPACITY BUILDING OF THE COMMUNITY

The work described above was jointly conducted between professionals and members of the local indigenous community. The latter is the most interested party in preserving the site, since it has become an important source of income. Moreover, it is important that they have knowledge on how to maintain the site, repairing small damaged areas and, above all, that they are able to detect conservation problems to promptly notify the appropriate authorities.

Hence, theoretical situations were presented where the indigenous community was introduced to the theme of cultural heritage and associated values. At this point, there was an interesting exchange of information between experts and trainees, as most of the latter had grown up near the site and listened to the stories of their parents and grandparents about it. At the same time, explanatory meetings were also held for local tourist guides, who daily carry dozens of tourists to the site. They were informed on the nature and intent of the work beingcarried out, and the methodology applied.

9. CONCLUSIONS

This paper aims to provide detailed insight on the conservation work implemented to the earthen structures of the Tulor site, accomplished between the months of December 2008 and November 2009. Apart from planning and the previous experience of the experts involved, many surprising factors were found here, as is typical of any planned work of conservation/restoration.

The priority given to the conservation work is justified, as the site was in the process of destruction. In such conditions, appropriate actions intended to mitigate the process are acceptable, although there is still a significant amount of scientific information that has not yet been addressed in this field.

Finally, the participation of the local community is highlighted, which worked carefully on the site, and who also rapidly attained the knowledge conveyed during the training sessions in the field. It is further understood that the work performed is not the definitive solution to the problems the site faces, but certainly, will inhibit the degradation processes. The greater or lesser success of this project will depend on the persistence of the community to perform the maintenance work to which they have committed and to which they have been trained.

Notes

(1) The village is almost entirely covered by the dune, except for the excavated structures. The top of the walls are the parts exposed to weathering, which, as the dune advances, are swept by the wind that carries sand, causing irreversible damage to the site.
(2) The function of covering of the top of earthen walls is to protect the original material and to serve as a sacrificial element to weathering agents.

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CONSERVATION OF RAMMED-EARTH STRUCTURES: THE HISPANO-COLONIAL ARCHAEOLOGICAL SITE OF SANTA FE LA VIEJA, ARGENTINA

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Theme 3: Documentation, Conservation and Management of Archaeological Sites
Keywords: Conservation, protection, museography, interpretation

Abstract

The archaeological site of Santa Fe La Vieja in Argentina preserves the urban and architectural material record of the first settlement of the city (1573-1660). All archaeological structures excavated since 1949 are of rammed earth, and correspond to the lower parts of the walls and foundations of the Council (Cabildo), three churches and dozens of houses.

Since the first excavations, the site was recovered for research and museum use, and various forms of protection and conservation were applied. Due to the loss of the original roofs and the vulnerability of the construction material to the action of environmental agents, the broadest and most controversial issues of design and erection of shelters to protect archaeological structures are questioned.

In the case of Santa Fe La Vieja, from the time the remains of rammed earth walls were excavated, it was necessary to protect them from environmental agents, especially intense and frequent rainfall in some periods of the year. In parallel, the transformation of the site into an Archaeological Park has created demands for visitor access inside the protective shelters, as well as to guarantee its museological treatment. Finally, the inclusion of shelters in the context of a landscape with a strong presence of nature is another issue that should be taken into account when designing protective measures.

The paper discusses conservation actions taken to date. The shelters that have been protecting the archaeological structures are evaluated, and current projects, which aim to achieve better protection, are presented.

1. SANTA FE LA VIEJA: BACKGROUND AND PROBLEMS OF THE SITE

1.1 From city to site and archaeological park

The Santa Fe La Vieja Archaeological Park (SFLV) corresponds to the site of the first settlement of the city with the same name in Argentina, which was founded in 1573 and lasted until around 1660.

In a region populated by hunter-gatherers, the Spanish transplanted their construction techniques to meet the demand for housing and institutional buildings, using earth and wood as building materials. The urban plan refers to the typical grid layout used from the Spanish colonization of South America, which follow the model from Lima (Calvo, 2004, pp. 113-117).

When the city moved 80 km to the south, the founding site was definitively abandoned. During the colonial period, the former enclave was part of a rural area sparsely used. In 1867, the foundation of an agricultural colony of European immigration generated a new and stable occupation; at that date, the area of the old urban plan became agricultural land (farms).

In 1949, Agustín Zapata Gollan started archaeological excavations on land belonging to one of those farms, which uncovered the vestiges of the old town . The excavations lasted for several years and exposed the urban architectural material record the first settlement of Santa Fe (1573-1660) and the structures of its main buildings: foundations and lower parts of walls from dozens of houses, three churches and the Cabildo (Zapata Gollan, 1971, pp. 80-81). A significant number of rammed earth wall structures were not excavated; instead, their location was recorded and they were kept buried to ensure a better conservation.

All archaeological structures are constructed of ordinary rammed earth. Although the French pisé was also used, no evidence of such construction was recovered, possibly because of the methods used during the archaeological excavations.

Fig.1 Santa Fe La Vieja (credits: II Air Brigade of Parana, 1980)

Fig.2 Archaeologist Agustín Zapata Gollan with the remains of rammed earth walls of a house he excavated (credits: Ethnographic Museum in Santa Fe, near 1952)

1.2 Site management

Since the first excavations, the site was recovered for research and museum use. In 1950, the provincial government acquired the land through an expropriation law, and since then has adopted a management structure that has incorporated the necessary facilities for conservation and exhibit.

From the beginning, the Department of Ethnographic and Colonial Studies (DEEC), currently under the Ministry of Innovation and Culture of Santa Fe, has been in charge of the management of the property. The site was declared a National Historic Monument in 1957, so both the nation and the state have joint jurisdiction of its guardianship.

The Archaeological Park covers more than 60 hectares, and its management involves research, conservation, and educational touristic use. Over seven decades different planning forms have been tested, with three recognized stages:

1. From 1949 to 1980, actions were taken to resolve the various emerging issues; these were not part of a comprehensive plan.
2. From 1980 to 2002, the Conservation Plan of Santa Fe La Vieja site was defined with the participation of specialists required by the Organization of American States, which for two decades set the tone for intervention in three areas: architecture, archeology and bio-anthropology.
3. Since 2003 with funding from the Federal Investment Council, a team of professionals in six specialties was convened to develop the Management Plan, which currently serves as a tool for decision-making within the management of the site.

1.3 Physical scale of conservation concerns

For its size and complexity, the site presents challenges for heritage conservation at very different scales:

- Territorial scale: Fluvial erosion affects the integrity of the area over which the ruins of Santa Fe La Vieja were established (1).
- Urban scale: Closely linked to the previous one, the integrity of the old urban plan depends on the relation with the riverbank.
- Architectural scale: Refers to the conservation of rammed earth structures.
- Artifact scale: Related to the conservation of excavated objects in relation to the structures.

For reasons of thematic relevance, this paper only addresses the question of the conservation of archaeological structures. First, a characterization of the structures was carried out, and then, the protection and conservation measures that have been adopted in the management of the site since 1949 are discussed.

2. ARCHAEOLOGICAL STRUCTURES

2.1 Typological features

The structures respond to three distinct architectural typologies:

- Houses, whose main bodies are made up of rooms (living rooms and bedrooms) arranged in a row, which define built-up structures inside the plots parallel to the streets, but recessed from the front property line and perimeter boundaries. Forty-nine excavated houses are preserved.
- Churches, single naves without transepts, of which three of the six churches that the city had are still preserved: San Francisco, Santo Domingo and La Merced. On one side of the first church excavated was the cloister of the convent.
- A Council (Cabildo) comprised of a series of rooms with a similar scale to the domestic architecture, but differing in location at the front of the plot.

2.2 Technological features

The geological composition of the area (levee of the river) offers an almost pure mixture of sand and clay, ideal for the construction of rammed earth, with a composition of between 25% to 30% of clay and 75% to 70% of sand (Rodriguez Camilloni, 1980, pp. 19-20). All excavated structures thus far are of ordinary rammed earth and there are historical records documenting the use of this system since the early years of the city.

The foundations and lower parts of the walls remain. Its thickness depends on the type of building, which can vary between three-quarters of a measuring rod in the houses (approximately 60 cm), up to one-and-a-half measuring rods in churches (approximately 120 cm). The original roofs were of straw or terra-cotta tile, and only fragments of the latter associated with the archaeological structures are preserved.

3. CAUSES OF DETERIORATION

3.1 Rain and wind erosion

SFLV is located in an area of subtropical climate without a dry season, and with rainfall reaching 1,100 mm per year, and winds with an average of 12 km/hour.

3.2 Biotic agents

Anthropic: In addition to incorrect interventions, discussed later, the use of the old urban plan as arable land, which occurred between 1867 and 1949, led to the razing of the walls that had survived the environmental conditions.

Wildlife: One of the main problems are rodents (anguyá or tucu-tucu), which dig underground passages that affect the walls. Attempts to control their presence have been unsuccessful, and are constrained by the rules for wildlife protection. Wasp nests and anthills have left their mark on the surface of rammed earth walls, but this is a more manageable problem through allowable insecticides.

Forestation: Before starting the excavations, many tree species had grown on the walls or very close to them, resulting in the infiltration of roots within the rammed earth and the development of cracks and landslides. In the early days after the excavations, improper reforestation was carry out that did not take into account the type of roots of the species planted. In recent decades' plant growth has been controlled, and the growth of trees that had grown in inappropriate places has also been eliminated.

3.3 Incorrect interventions

The excavation of these rammed earth structures allowed retrieval of the record of an early Spanish-Colonial urban site, but the decision to leave it uncovered for display, adopted from the beginning, generated much deterioration. In some structures, excavations below the original floor level affected the stability of the walls remnants. In churches, the construction of the first shelters involved the introduction of foundations very close to the original rammed earth walls.

4. RAMMED-EARTH PROTECTION

The degree of authenticity of Santa Fe La Vieja can be assessed as exceptional, considering these are archaeological structures built in earth. It is known that this type of vestige is highly vulnerable in archaeological contexts. Therefore, its conservation has presented great challenges. From the start, the criterion of maintaining as much as possible its physical condition, as the main element carrying authenticity has prevailed. Therefore, different methods have been sought to protect the rammed-earth from deterioration agents.

4.1. 1949-1980 Time period: shaping the SFLV archaeological park

While the first excavations were carried out, the remains of rammed earth were covered with straw applied directly to the top of the walls. The next immediate step was to replace the straw with aluminum sheets. Two methods coexisted in this time period:

- Aluminum plates were applied directly to the top and bent down to cover the vertical parts of the walls. Despite the instability of the system, the structures supporting these protections have been monitored and confirmed the preservation of the wall to be in a good state.
- Gabled roofs, also of aluminum sheets, supported by very low structures did not prevent wind erosion, nor have they kept away rainwater. For those reasons, they were replaced.

In terms of the three churches (San Francisco, Santo Domingo and La Merced), two types of solutions that occurred over time were adopted:

- Enclosures with brick walls, sliding windows, and a wooden structure covered with aluminum sheets were erected. They existed until 1973.
- New structures were built by 1973, similar to large sheds that consisted of reticulated metal structures, brick-wall enclosures and sheet-metal roofs. On the exterior, concrete irrigation ditches were built to manage rainwater.

In 1976, Humberto Rodriguez Camilloni assessed these protective structures (Rodriguez Camilloni, 1976, p. 24), and made the following evaluation:

Negatives:

- The structures are "shocking in the environment of the ruins because of their design and construction materials."
- They convey a false idea of spatial feature characteristics that the churches had.
- The indoor system for the circulation of visitors obstructs "the visual perspective from their respective entrance". This defect was corrected in 1988, when all cross walkways were removed, keeping only the perimeter ones.
- In the case of San Francisco church, the shed covers only the church, isolating it from the attached cloister.
- Inside Santo Domingo and La Merced churches, the supports for the walkways are anchored into the ground too close to the walls, and the walkways themselves are located almost directly over them.

Positives:

- These structures have effectively protected the rammed earth remains. Three decades after Rodriguez Camilloni formulated

Fig.3 Protective shelter for the church of San Francisco built in 1973 (credits: Luis Maria Calvo, 2005)

Fig.4 Protection of the Gonzalez de Ataide house according to the prototype designed by H. Rodriguez Camilloni (credits: Jorge Anichini, 2005)

this assessment, it is recognized that the wall structures have survived in reasonably good condition.

4.2 1980-2003 Time period: valuing SFLV

The recognition of the importance of the site at the American level promoted the technical backing of the Organization of American States (OAS). This was accomplished in periodic missions between 1976 and 1987, resulting in the Conservation Plan of Santa Fe La Vieja (1980). The three main action guidelines included architectural restoration by architect Humberto Camilloni Rodriguez, who also coordinated the integral aspects of the Plan, archeology and bio-anthropology (linked to more than 200 exhumed skeletons within the churches).

Rodriguez Camilloni also assumed the problem of rammed earth wall conservation and the proposal for protective shelters. Already in 1976, he warned that the deterioration observed in many ruins could have been avoided by covering them after excavation. He proposed this alternative as the best recommendation for some of the 49 ruins excavated by Zapata Gollan (Rodriguez Camilloni, 1976, p. 21).

As for the conservation of the rammed earth, he noted that applying coatings based on transparent resins to the foundations and walls in order to waterproof the rammed earth it could not be considered "as a substitute for the new protective structures" (2). "The main problem is presented by the difficulty of penetration that will be evidenced sooneror later by the foreign substance, resulting in its eventual detachment and further damage to the surface of the original material. For the moment, at least, it seems that no better substitute for the conservation of rammed earth or adobe has been found than a suitable permanent maintenance program" (Rodriguez Camilloni, 1976, p. 21). This recommendation has always been taken into consideration, and the remains of rammed earth in Santa Fe La Vieja have been preserved as a result of this experience.

The need of introducing shelters in archaeological contexts is an issue largely debated and assumed as an inevitable option in same cases (Jerome, 1995, Schmid, 1998).

With regard to shelters in Santa Fe la Vieja, each ruin should be considered as a separate problem, adapting to each the prototype (Rodriguez Camilloni, 1987, p.9), whose proposed design consisted on:

- A semi-open pavilion, equipped with a gabled roof with side gutters and downspouts connected to the general drainage of the site.
- A perimeter fence consisting of fiber-cement panels that serve as windbreaks but allow ventilation, by leaving open spaces at the bottom and at the top.
- The perimeter fence also provides surfaces for mounting explanatory signs and graphic reconstructions of the ruins.
- The course for visitors is accomplished on one side of the ruins (it can also be around the perimeter), and consists of a tile floor directly placed on the existing floor.

The purpose of these structures is to nullify the main causes of deterioration (wind action and rain erosion), to control the access of visitors, and in turn to allow a museographical display. For two decades the Conservation Plan was the guideline for all actions that were undertaken at Santa Fe La Vieja. In the 1990s, six protective structures were built following the prototype designed by Rodriguez Camilloni, one for the Council and five for the houses (González de Ataide, Fernandez Montiel, Paez, Cifuentes and Garay).

4.3 Since 2002: management plan for SFLV

In 2002, given the need to update the diagnostic and management tools, the DEEC convened a team of specialists to design a Management Plan for the Santa Fe La Vieja site. It was coordinated by Dr. Maria Graciela Viñuales, a professional with vast experience in the field of heritage conservation, as well as an earthen architecture specialist. Additional knowledgeable experts covered interpretation, architectural and environmental design, cultural tourism, bio-anthropology, archeology, marketing and management, and financing.

The Management Plan acknowledges that the archaeological structures of raw earth with higher conservation issues should be reburied, aiming to ensure their future survival. However, this recommendation has found huge obstacles as there is no availability of earth with similar characteristics, and the site's soil cannot be used because it is protected as an archaeological site.

Considering specifically the protective shelters, the Management Plan includes a new proposal, whose design was under the charge of a group of professionals from the Faculty of Architecture, Design and Town Planning of the Universidad Nacional del Litoral. The team was led by the architect L. Müller and the architect J. Arroyo.

The effectiveness of shelters built according to Rodriguez Camilloni's prototype was recognized in terms of rammed earth conservation. The new design draws on its strengths and adds new premises that seek to overcome and improve the relationship of the shelters to the landscape.

The "architectural interventions are carefully oriented to generate less physical and visual impact on the site, understanding through the materiality and languages characterized by the criteria of lightness and contemporaneous, the own contingent condition of the intervention (aware that it occurs over a place filled with stories from long ago), while intrinsically belonging to the time of its completion" (Arroyo and Müller, 2011, p. 104).

As protection against weathering, an enclosure is proposed that, similar to the shelters, to ensure adequate control of the rain and wind, but at the same time allowing for permanent ventilation to maintain a balance of the internal and external conditions of temperature and moisture content (Arroyo and Müller, 2011, p.107).

In 2007, the project was developed, based on:

- An independent system of columns and beams holding the roof and the vertical enclosure panels.
- Vertical walls shaped like lattices that allow ventilation, composed of phenolic-plywood panels with treatment for weather protection.
- Roofing with a minimum slope, composed of sandwich-like panels superimposed over rigid-foam insulation and finished with a ceiling.

5. CONCLUSION

Since the first excavations, there has remained the interest in safeguarding the ruins of the ancient city of Santa Fe and to limit the actions to those that are essential for in-situ conservation of rammed earth structures, respecting the authenticity of the excavated remains. There have never been interventions directly to the remains of rammed earth foundations and walls. They have not been altered with reconstructions, nor extra elements for their consolidation, conservation or presentation have been added. This has avoided any falsification, reconstruction or addition of missing parts that could distort and compromise their authenticity. Therefore, the original materials of the walls are as they were found, without alteration to their composition, texture or color. This gives an exceptional degree of authenticity, in which the physical evidence, in-situ location, forms, and materials maintain the evidence of how they were built.

From the onset, the criteria adopted were to protect the archaeological remains from atmospheric agents with shelters. These used the technology and design that was considered the most appropriate for that time. These protective shelters do not bear directly on the walls. Their inevitable presence in the landscape should be assessed based on the absolute need to preserve earth remains, and a respect for the decision taken at the outset, to exhibit the archaeology to the visiting public. However, it should be noted that ultimately, these shelters are reversible interventions, which can be removed if at any time it is deemed possible to preserve rammed earth without them.

Notes

(1) Until 1949, river erosion resulted in the loss of a third of the layout of SFLV. Between 1979 and 1987, defensive protection was implemented. Now, new defensive work greater size and duration is about to commence.
(2) This refers to a technical report by A.V. Elmo (Buenos Aires, 1979). In 1987, Rodriguez Camilloni reemphasized the overall incompatibility of applying transparent coatings based on resins to rammed earth remains (Rodriguez Camilloni, 1987, p. 8).

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THE STABILIZATION, CONSERVATION AND PRESENTATION OF MONUMENTAL MUD-BRICK ARCHITECTURE: THE SHUNET EL ZABIB IN EGYPT

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Theme 3: Documentation, Conservation and Management of Archaeological Sites
Keywords: Decay, stabilization, presentation

Abstract

The Shuneh is a large mud-brick structure in Abydos, Egypt constructed for the funeral of Khasekhemwy, the fifth Pharaoh of the 2nd Dynasty. It consists of two parallel walls that enclose an area approximately 60 meters by 110 meters. The inner, or enclosure wall, is 5 meters wide at the base, and the battered walls originally rose to a height of approximately 14 meters. Portions of the inner wall remain at a height of 11 meters. Approximately 7 million earth bricks were used in the construction.

The overall conservation project is to stabilize the structural geometry of the Shuneh, conserve the remaining fabric, which consists of architectural elements such as pilasters, doorways, and original finishes, and present the Shuneh as a ruin that evokes the character that has evolved over 4,700 years. The primary factors of decay are wind erosion, animal and insect infestation, and the intervention of man, who utilized the large mud-brick walls as a Coptic community in the first centuries of the first millennium CE, resulting in the partial collapse of some of the walls.

The major stabilization consists of restoring or repairing portions of walls that contribute to the structural integrity, rebuilding foundations that have been undercut, reattaching plasters, pilasters and other features, and capping the tops of walls, all with mud bricks made on site.

1. INTRODUCTION

The conservation of the Shunet el Zebib is an initiative of the Institute of Fine Arts, New York University, as part of the University of Pennsylvania Museum – Yale University – Institute of Fine Arts, New York University Expedition to Abydos, David O'Connor, Co-Director, Matthew Adams, Associate Director/Field Director. Major support for the project has been provided by the American Research Center in Egypt (ARCE), using funds provided by the United States Agency for International Development (USAID) and administered through its Egyptian Antiquities Project (EAP), Egyptian Antiquities Conservation (EAC), and Antiquities Endowment Fund (AEF) grant programs. Additional support has been provided by the World Monuments Fund and Egypt's Supreme Council of Antiquities (Crosby, 2000).

The conservation of the Shunet el Zabib (or Shuneh, if mentioned by itself) began in 2000, with a site visit by a team of architects, a structural engineer, and the assistant project director. The purpose of the site visit was to collect information about the conditions and the values of the Shuneh for a comprehensive conditions-assessment report, which would lead to treatment plans for the conservation of the structure. The conditions-assessment report identified the overall conditions, including the major problems that were causing deterioration and loss. The reports also documented the primary character-defining features of the Shuneh that were to be preserved. Generally, these characteristics are the overall geometry and the color and texture of the exposed mud bricks. The site features, such as the large sand embankments, and architectural details, like plaster and pilasters, are other important characteristics that are to be protected. Reports resulting from the site visit emphasized that the Shuneh is a ruin and it is to be preserved as such. The subsequent development of the treatment specifications one year later was designed to protect these characteristics (Crosby, 2000, pp. 4-12).

The large mud-brick enclosure at north Abydos known today as the Shunet el Zebib was built near the end of the 2nd Dynasty (ca. 2750 BCE) to serve as a cultic enclosure for King Khasekhemwy, last king of the dynasty. It represents half of a two-part funerary complex, the other consisting of his underground tomb, located some 1.5 km to the south of the enclosure at a part of the site known as Umm el-Qa'ab. The enclosure was the last and largest of a series of royal cult enclosures at Abydos that, insofar as presently available evidence indicates, begins at the start of the 1st Dynasty, corresponding to a dramatic increase in scale in royal tomb construction at Umm el-Qa'ab. All the kings of the 1st Dynasty, as well as the last two of the 2nd, were entombed at Abydos, and it appears that each also built a corresponding enclosure. Given that the royal tombs

Fig.1 Shunet el Zabib, the funerary enclosure of Khasekhemwy from the north, with mud brick walls 11 meter high (credits: Anthony Crosby, 2001)

were underground features located in the desert relatively far from ancient habitation, and that for the most part they do not seem to have been marked above ground by any large-scale built feature other than possibly a tumulus of sand and gravel, the Abydos enclosures, situated on a low desert terrace near and overlooking the ancient town of Abydos, probably should be seen as representing the primary monumental statement of royal presence and power for each king (O'Connor, Adams, Remsen and Crosby, 2006).

2. DESCRIPTION, CONTEXT AND CONSERVATION ISSUES

2.1 Physical description of the site and structure

The Shunet el Zabib is located 10 kilometers west of the Nile and 2 kilometers from the western edge of the Nile Valley. It consists of two parallel mud-brick walls that enclose an area about the size of a football field, or approximately 110 meters by 60 meters. The interior walls are the largest being 5 meters wide at the base and some are still 11 meters high. It is estimated that these interior, or enclosure walls, were approximately 12 to 13 meters high originally. The exterior or perimeter walls were smaller being approximately 3 meters thick and perhaps about two-thirds as high as the enclosure walls, or approximately 6 meters high. Both the enclosure and perimeter walls were battered, or tapered from the base of the wall to the top. There were four entrances into the enclosure, the northeast and the southeast ones being the most significant. Niches, defined by pilasters, were constructed on the exterior surfaces of the enclosure walls, those on the east being slightly more complicated than those of the north, south and west. The entire surfaces were plastered with gray clay and finished with a thin coat of white gypsum plaster.

The original construction of the Shuneh was consistent and appears to have been the result of one building episode. Mud bricks were laid on a bed of sand, probably compacted, and the walls constructed to a height of approximately one meter at which point, a layer of reed was placed; this may have been for the purpose of adding a minimal amount of horizontal reinforcement. The layer of vegetable matter was also placed to terminate a leveling course. The construction continued for another 1 to 1.5 meters at which point another leveling course was defined by another layer of reeds, which were not woven but placed loosely on bedding mortar. The process continued until the top of the wall was reached. The walls are battered at an angle of approximately 2 degrees and the coursing of the interior and exterior wall surfaces is alternating headers and stretchers with header courses beyond the surface mud brick. The bricks are relatively small, 27 cm by 13 cm by 9 cm, which is common for this early period (Spencer, n.d, p.5).

2.2 Conditions of the microenvironment

The average annual precipitation is less than 25 mm. Mud rills formed by a rain in 1996 remain on wall surfaces indicating the lack of subsequent rainwater sufficient to erode the rills. No measurable rain has occurred during our work seasons. The average high daily temperature during the summer months of May through August is approximately 42° C, but extremes can be considerably higher. Daily highs of greater than 50° C were experienced while working on site and mud-brick wall surface temperatures of 60° have been recorded. The area is a relatively low risk for seismic activity.

The relative humidity during site work in the spring averages approximately 25-35% for the daily temperature highs and 60-65% for the daily lows. The relative humidity corresponds to the daily temperature gradients; hence, the absolute moisture content of the air during this time of year does not vary significantly. Prevailing winds from the north off the Mediterranean are relatively cooler than the hot and dry winds from the south and west. Winds speeds above 6 - 10 meters per second are not uncommon and can reduce work efficiency during cooler temperatures. Wind speeds of 10-20 meters per second can cause work to be shut down because of blowing sand and unsafe scaffolding.

Presently, the water table is approximately 6 meters below the existing grade, as measured in the well at the Dig House. Without having access to hydrological information it is impossible to predict the corresponding current water-table level at the Shunet, although there is certainly no evidence of a significantly higher water-table level at the site. However, an increase in irrigation could possible result in a higher water table in the future. To actually affect the lower walls of the Shunet, the water table would have to be within a meter of the existing ground level and that is not probable.

In order to accommodate the battering of the walls and also to level courses, several conventions were employed. Bricks were often laid perfectly flat, but at an angle to the wall plane, reducing the overall horizontal dimension, Header bricks were also laid vertically or at an angle between horizontal and vertical for the purposes of leveling; this is a practice often found in Egyptian brickwork (Spencer, n.d, p.114).

2.3 Factors resulting in decay

The most significant problems were the large losses of wall sections that put the adjacent walls at risk. In some cases, the construction of the Coptic cells resulted in the removal of as much of 3.5 meters of a 5-meter thick wall. The cells eventually collapsed and additional loss of mud-brick walls occurred. Large sections of mud bricks adjacent to all of the four entrances had collapsed, leaving the adjacent walls free standing with only the northwest corner intact. Wind, rain erosion and insects had also caused significant loss, the latter resulting in holes and small voids in the walls, some of which are as deep as two meters. Animals often enlarged the holes, as well as creating their own. Large animals, such as jackals and foxes, have made dens in the walls, significantly undercutting them to a depth as much as 3 meters.

In addition to these external or extrinsic causes that results in loss and deterioration, there were also intrinsic problems. The original mud bricks were made with chopped straw and other organic matter, such as manure, which served as a food source for insects and fungi. After nearly 5,000 years, most of the organic material had been eaten, leaving a substantive amount of the mud bricks significantly weakened. The other intrinsic problem was that of the actual brick-laying pattern, which used only header courses, or bricks laid perpendicular to the wall axis for the majority of the mass masonry. Because the bricks of the Shuneh are relatively small, it is impossible to lay the bricks as header courses without having many joints lining up vertically, or "stacked" in such a large structure. This results in weak points that can develop into a vertical structural crack as stresses develop.

Fig.2 Large sandbag buttresses were constructed in 2001 to support the east enclosure wall (credits: Anthony Crosby, 2006)

3. INTERVENTION

3.1 Emergency stabilization

The first stabilization action was the construction of large sandbag buttresses along the interior of the east enclosure wall in 2001. This entire wall section is much lower than the other enclosure walls, but had been severely undercut by animals and 19th-century invasive archeological excavations. Many sections of this wall were in immediate danger of additional loss. One large structural crack was identified as characteristic of the failure pattern of the entire wall, and it was cleaned and repaired with mud mortar and horizontal reinforcement.

In addition to emergency stabilization for the Shuneh, issues often arise that require emergency bracing and shoring during archeological excavations. Specifications have been prepared for these emergencies utilizing site scaffolding.

3.2 Conservation priorities

The conservation-implementation phase actually began in the spring of 2004, continued with a second field season in the fall of that same year and continued with three additional conservation seasons. Site work was delayed after the spring of 2006 season and did not resume until spring 2009. The sixth field season in 2009 was followed by a seventh in spring 2010 and an eight in 2012.

Conservation interventions during the first several seasons concentrated on some of the highest priorities that had been identified in earlier reports. The highest priorities included the infilling of a large missing portion of the north wall, the construction of a mud-brick "buttress" at the east end of the north wall, the initial stabilization of two collapsed Coptic cells in the west wall, the stabilization of the south end of the west wall, and the infilling of the holes and voids that had been caused by insects and animals. Part of the first season also consisted of working out many logistical and technical details of the site work. The mud bricks are

Fig.3 The west enclosure wall showing the completion of the stabilization of two collapsed areas where Coptic cells existed (credits: Anthony Crosby, 2006)

manufactured near the Shuneh and are transported the several hundred meters to the actual work site, as they are needed. Each new mud brick is stamped with the project identification 'PYIFA'. The mud bricks are made with only natural sand and soil, as is the mortar, and include no additives. The selection of a suitable material for horizontal reinforcement and for the attachment of new masonry to the existing Shuneh masonry was made and implemented in areas where reinforcement was required. The material selected is a high-density polyethylene (HDPE) in the form of an open grid.

Because of the structural problems, it was impossible to leave features of the Coptic cells, such as the plastered walls and floors, exposed. They were protected before the cells were completely infilled by placing a separation layer of clean sand. If the infill is ever removed, the features of the cells can be recovered. Where necessary, the existing plasters in the cells were stabilized prior to covering them.

3.3 Details of conservation interventions

The Shuneh conservation work consisted of 1) filling holes and voids; 2) reconstructing missing portions to stabilize existing walls; 3) constructing missing features such as doorways; 4) capping all walls; and 5) conserving surface features.

During the process of planning the interventions, original Shuneh mud bricks and the available soil for new mud bricks and mud mortar were analyzed (Harrison, Amione-Martin, and Keift, 2005). In addition, testing was done on site to determine the strength of the mud bricks utilizing field techniques and compared with the specific analysis and with the actual overburden of new masonry. The strength of the original mud bricks was estimated to be low, but the masonry system with much stronger mud mortar appeared capable of supporting the overburden of the new masonry (Crosby, 2005, pp. 26-28).

3.3.1 Small holes and voids

Filling small holes and voids are primarily not structural, but are an important part of the project. Insects and birds have created and then expanded the holes, and filling them discourages but does not completely stop damage. These holes and voids are filled with mud bricks, replicating the adjacent coursing patterns and wall texture.

Fig.4 East enclosure wall showing the process of constructing the mud-brick foundation system (credits: Anthony Crosby, 2010)

3.3.2. Structural stabilization

Structural stabilization generally addresses two conditions – tall unsupported walls, the unsupported ends of which separate over time from the wall mass, and large cavities in walls that leave upper portions of walls unsupported. At every unsupported end wall, large structural cracks were documented, often a series of vertical through-wall cracks, becoming less severe the farther away from the end. To provide stability, a portion of the adjacent missing wall is reconstructed as a buttress.

The most severe conditions of unsupported upper walls has resulted from the construction of the Coptic cells and their eventual collapse and the loss of foundation sand from the east enclosure wall from mid-19th-century archeological excavations. These conditions have required the greater interventions in the form of replacing much of the loss materials from the Coptic-cell collapse and the construction of a mud-brick foundation system along the interior of the east enclosure wall.

The large collapsed areas were partially reconstructed with mud bricks following the same coursing as the original. The reconstruction of a collapsed Coptic cell was not completed flush to the existing wall, but recessed to indicate that a cultural feature existed. Geogrid was used as horizontal reinforcement at the approximate same vertical spacing as the original reed mats.

Mid 19th century excavations extended along the east wall were approximately 3 meters deep – they were never backfilled. Sand began to move from under the wall into the trench, and the lower mud bricks followed the sand into the excavation trench. A new foundation is being constructed to provide the missing support for the east wall. It extends out from the original wall plane approximately 1 meter and extends 1 meter below the original base of the wall. The new sections are completed between the sandbag buttresses, and once completed, the buttresses are removed and the two sections are connected with a continuation of the foundation.

Fig.5 Aluminum wedges attached to stainless-steel cables used to attach geogrid to mud brick walls (credits: Anthony Crosby, 2010)

Fig.6 Comparison of mud-brick protective cap and existing wall top (credits: Anthony Crosby, 2005)

An important addition to the original field procedures was the development of a system to mechanically tie the new mud bricks to the existing original Shuneh bricks. In areas where the new mud bricks are entirely under compressive loads, no mechanical ties are necessary. However, areas where the repair is relatively thin, or where there may be some tension stresses between the old and the new, a system of mechanical ties is required. In all cases, regardless of the anticipated loading, the new bricks are 'keyed' into the coursing of the existing masonry to improve structural integrity.

Initially, a system was developed utilizing stainless-steel threaded rods, toggles and eyebolts to attach the geogrid to the wall mass. Holes were drilled into the historic masonry and the rods with toggles were inserted into the holes. When pulling the rods, the toggles opened and locked into place. The eyebolts on the exposed ends were then attached to the geogrid. While it provided the attachment necessary, it was time consuming and required the direct supervision of the conservation architect. Between seasons three and four, another more efficient and effective system was selected.

The new mechanical ties are similar, but much simpler in design and installation. They consist of aluminum wedges attached to stainless-steel cables. Holes are drilled and the aluminum wedges are driven into the historic mud bricks. Tension is put on the cables and the aluminum wedges are set perpendicular to the axis of the drilled holes, locking them in place. The cables are then attached to the geogrid. These proved effective as they can be installed with minimal supervision and provide adequate pull strength of > 140 kilos.

3.3.3 Protection of tops of walls

It is estimated that the tops of the walls, unaffected by more traumatic loss, have eroded approximately 3 meters, vertically, over the 4,700-year life of the structure. The upper most exposed mud bricks are friable and will continue to erode, albeit, extremely slowly, because of the lack of significant rainfall. While a lower priority than the reconstruction of missing structural elements, capping using unstabilized mud bricks is one of the important treatment interventions. The tops of the walls are prepared by removing loose, friable materials and new mud bricks are placed in the general contours of the existing walls. The contouring of the cap and the distribution of additional loose soil result in a character that evokes the character of the pre-treated wall tops.

The important structural stabilization of the walls at the original gateways into the Shuneh presented an important presentation issue. The missing mud-brick sections had to be rebuilt to support failing end walls and the decision was made to include an opening into the Shuneh through the new masonry. After much deliberation a decision to partially restore the west gateway to its historic appearance was made. The existing footprint of the gate was known from archeological evidence and additional research to determine the appropriate height and other details was undertaken. The results from the combination of research and physical evidence is a gate opening approximately 3 meters high with exposed beams and lintels; the proportions are based on the royal cubit. The wall surfaces immediately adjacent to the opening are restored to their original plane, but immediately blend to the color, texture and wall planes of the existing mud-brick masonry of the Shuneh.

3.3.4 Plaster stabilization

During the process of excavating areas that needed to be structurally evaluated, original plasters were often exposed and required conservation treatments prior to the backfilling of the excavated areas. The extent of the conservation intervention included reattachment of completely detached plasters, injecting mud grouts to provide additional support for partially detached plasters, and applying mud beads at exposed edges. We have also completed a partial survey of existing plasters, identifying the extent of the plaster and their conditions. This is important work that will continue in future seasons.

3.4 Summary of conservation interventions

At the completion of the 2010 fifth conservation-implementation season, over 400,000 mud bricks have been laid. This is approximately 65% of the estimated total to complete the major structural stabilization. More importantly, the construction details have all been worked out, presentation issues have all been resolved, and the masons and laborers are thoroughly trained and completely capable of executing most

Fig.7 The west enclosure wall from the north after completion of the west gateway stabilization and restoration (credits: Anthony Crosby, 2010)

of the conservation treatments. In addition, the presentation solutions have been developed and incorporated into the conservation specifications with the completion of the partial restoration of the west gate. In future seasons, the work will continue with the stabilization of the remaining tall walls, the filling of voids and the stabilization of the other gateways. Eventually, all of the walls will be capped with a sacrificial layer of mud bricks. The sacrificial bricks will ultimately erode, but in the meantime the original bricks beneath will be protected.

During the process, much has been learned about original construction practices and materials. While the entire structure was plastered and finished with a thin gypsum plaster, some color was also used as splashes and drips of terra-cotta color paint have been identified. No structural wood remained in the Shuneh, but wood would have originally supported the opening of the gateways. Structural wood has been embedded in the mass masonry at other sites, but this practice did not exist in the Shuneh (Nicholson and Shaw, p. 89). However, tamarisk wood has been found in walls of the Shuneh that was used for scaffolding. Tamarisk wood is mentioned in ancient Egyptian texts, but not specifically for this purpose (Nicholson and Shaw, 2000, p. 345).

4. CONCLUSION

The conservation approach that has guided the project from the beginning is to protect the existing Shuneh as a ruin, while structurally stabilizing endangered masonry elements, reducing or mitigating the causes of decay, and evoking the basic characteristics of the structure and the immediate site. Presentation issues are important to the overall goals and no actions are undertaken without considering the overall effect on the character of the structure.

The conservation methods have remained basically the same as originally designed, but some important modifications have been made and these changes are incorporated into the conservation specifications at the end of each field season. Some of the important changes are specific to material use and some simplify the original specifications to reflect the reality of local site conditions. The same crew of masons have worked on the project from the first season in 2004, having come to the project with sound masonry skills, and have learned how to incorporate those skills on the often specific requirements of conservation. They are skilled at their profession, sensitive to specific issues, adept problem-solvers, and self-directed. No task is too difficult and no challenge is too great.

We recognize that conditions can change, which will require future changes to the treatment approaches. Just as the specifications have evolved during the project, some modifications in the future will be necessary to respond to conditions, new threats, and new conservation treatments materials and approaches. One example is an increased threat by birds that has developed during the project. Birds have increased on the site and the damage they cause will continue to increase as more grain crops are grown in the immediate area.

Birds roost and lay eggs in cracks and small holes in the Shuneh and they feed in the fields. As more food is available, the population will continue to grow. Presently there is no existing long-term solution to this problem. Small holes that provide nesting are being filled, but more will be excavated by the birds on a continuing basis.

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TRADITIONAL BUILDING TECHNIQUES OF THE HELLENISTIC PERIOD IN THE KHABUR VALLEY, SYRIA: THE CASES OF TELL HALAF AND TELL BEYDAR

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Theme 3: Documentation, Conservation and Management of Archeological Sites
Keywords: Building techniques, rammed-earth, adobe, Hellenistic period.

Abstract

The present paper aims to provide an overview of the building materials and techniques employed by the communities that settled in Khabur Valley, Syria during the Hellenistic period. The research was conducted under the recently established collaboration between the Tell Beydar Archeological Project and Syro-German Excavations at Tell Halaf. It focuses on a region in the dry plains of Northern Mesopotamia that reveals how the local communities, facing scarce natural resources, were able to adapt to the strict environmental setting while relying exclusively on earthen architecture. Construction shows the use of both rammed-earth and adobe, either together in different parts of the same building, or independently and related to specific functions. Finally, the analysis of the building techniques of this region could shed some light on the degree of interplay between the local and Hellenistic influences.

1. INTRODUCTION

Tell Halaf and Tell Beydar are situated in northeastern Syria at the headwaters of the Khabur River, in the northern part of Mesopotomia. Tell Beydar, mostly known as a reference for studies of the 3rd millennium BC, due to the presence of a large fortified city with several temples, palaces and the oldest written texts of northern Mesopotamia. It is also the site where a significant community was established during the Hellenistic period. Recent archeological campaigns have exposed a great variety of buildings, ranging from a complex palatial structure, revealing careful planning and high construction standards inspired in the ancient Mesopotamian tradition, to small and perishable architectural units that seem to have been improvised and poorly maintained (Lopes, Cabral, Tomé, Vaz, and Costa, 2011).

Tell Halaf is one of the oldest settlements in northern Mesopotamia, with occupation levels of the Neolithic Period (6th-5th millennium BC), the Iron Age (1st millennium BC) and the Hellenistic period (3rd-1st century BC). The site gained prominence with the appearance of a large number of sculptures that decorated the palace of the Aramaean prince Kapara (ca. 925 BC). The statues were excavated by the German diplomat and scholar Max Freiherr von Oppenheim, during his campaigns of 1899, 1911-13 and 1929 (Baghdo, Martin, and Novák, 2009, pp. 7-8). Besides the large number of basalt sculptures, extensive adobe structures, which are an example of traditional architecture in Mesopotamia, came to light in the area of the citadel (Martin, 2009, pp.13-26). The adobe architecture of this site can be observed from the Neolithic to the Hellenistic period.

The Hellenistic adobe architecture, in particular, is of great interest because it has not been explored in detail in the region, and as a whole and has been largely neglected by researchers. For this reason, it is considered that it is of worth to investigate traditions and building techniques of the Hellenistic period in the Khabur region (Katzy, 2015, pp. 27-28).

This paper was based on a cooperation between the Euro-Syrian Excavations at Tell Beydar, a joint mission of the European Centre for Upper Mesopotamian Studies and the General Directorate of Antiquities and Museums of Damascus, in cooperation with the University of Coimbra, and the Syro-German Excavations at Tell Halaf, a joint mission of the General Directorate of Antiquities and Museums of Damascus and the State Museum of Berlin, in cooperation with the Eberhard-Karls-University of Tübingen, Ludwig-Maximilians-University of Munich and the Martin-Luther-University of Halle (Katzy, 2015, pp.42-48; Katzy, 2012, pp.185-193).

Fig.1 Northern Mesopotamia and Khabur Valley (credits: Elisabeth Katzy, 2011)

2. THE USE OF CLAY IN THE TRADITIONAL BUILDING TECHNIQUES OF THE KHABUR VALLEY FROM THE NEOLITHIC TO THE END OF THE ANCIENT NEAR-EASTERN EMPIRES

Building in the Ancient Near East has always meant building with local available, naturally occurring materials. The design of the resulting architecture was therefore, heavily influenced by the available materials. One of the oldest building materials known is earth. It was in the Khabur Valley - as elsewhere in Mesopotamia – by far the most important and most widely used material (Schmid 2009; Miglus, 1999; Moorey, 1994).

The advantages of clay lie in its capacity as a ready-made, strong adhesive and cohesive blend, which is inexpensive and available nearly everywhere. Its suitability as a building material depends on whether it is argil-rich, argil-lean, argil-meager or a silty or sandy-clay. The quality may be influenced and improved by tempering with sand or gravel, as well as by the addition of fibrous materials like chaff. However, cohesive earthen materials, such as clay, solidify only by drying. Therefore, it achieves a lower hardness than other materials that have undergone chemical or physical processes (Minke, 2004).

In the ancient Near East, air-dried and fired bricks were made from earth. Rammed-earth was used to make floors, walls, ceilings and roofs. Earth also served as a mortar and as a plaster. Especially in walls and roofs, the favorable climatic attributes of the earth came into play. By its ability to absorb moisture, earth has a balancing effect on the indoor climate, which is perceived as pleasant, because the perception of warmth depends on the relationship between relative humidity and temperature. Another positive effect is the thermal absorbability, meaning the ability to delay the passing on of external temperature fluctuations to the interior space. This is a great advantage in areas with large day-night variations in air temperature. In addition, earth has a high fire-resistance, acts to detoxify bacteria-enriched air and is compatible with lime and wood (Moorey, 1994).

2.1 Adobes

In the form of unburned bricks, earth was used in Mesopotamia for the construction of foundations, rising brickwork, vaults and a variety of installations. Earth used for production was quarried in the area, as well as probably partially taken from previous buildings. The earth was tempered to different degrees, with sand, gravel and chaff to achieve greater stability and to reduce the degree of shrinkage during the drying process of the bricks. The bricks were produced in rectangular wooden molds and dried in the air until they reached their full stability. When the walls were laid up, the bricks of one layer were set in a way that the perpendicular joints were shifted to those of the subjacent layer by half a brick's length (Miglus, 1999; Moorey, 1994).

2.2 Fired bricks

Fired bricks were used when high resistance of the material was required, whether due to increased mechanical stress or due to exposure to water. Usually this was the case for courtyard pavements, drainage gutters, wet-room floors and thresholds. In buildings of the Neo-Assyrian period, they are also frequently observed in the base area of the brickwork. A great resistance to weather and moisture, and an increased viability characterizes fired bricks. These features are provided by firing them at temperatures of 900 to 1400°C. To stem the shrinkage of the clay during drying and firing, dimensionally stable temper materials, such as sand, must be added (Miglus, 1999).

2.3 Mortar and plaster

Earth was also used as mortar and plaster. The manufacture of mortar is similar to the raw mixture used for bricks. It is only the smaller amount of chaff and the finer grain of the mineral aggregates that is different. If the mortar was used for plastering the walls, we have to differentiate between single-layered plaster on the one hand and multi-layered plaster composed of one or several layers of floated and finish coats. The amount of chaff in single-layered plaster and floating is similar to mortar, while the grading curve of the mineral supplements usually ran finer. Finish coats are made even more fine-grained and contain very little, or often, no chaff at all (Miglus, 1999; Moorey, 1994).

2.4 Rammed-earth

Most of the ground floors were also made of rammed-earth – apart from the supporting structure of flat slabs – and probably also the assembly of most of the ceilings and roofs. Typically, the floors were laid in the form of irregular heavy portions of rammed-earth and, occasionally, the rammed-earth was tempered with chaff or straw. Alternatively, the natural soil or the building waste of previous buildings was simply leveled and covered with a thin layer of fresh clay. Ceilings and roofs normally consisted of a wooden supporting structure, a layer of reeds, palm leafs or twigs to provide a compact surface, and a clay puddle up to 50-cm thick (Miglus, 1999; Moorey, 1994).

3. THE DEVELOPMENT OF ADOBE MASONRY

The best indicators for the development of techniques in earthen architecture are the forms of the bricks, the masonry bonds and the varieties of foundations. The oldest known buildings made from adobes in the Khabur Valley are from Tell Bouqras, which lies on the west side of the Euphrates, 5 km south of the mouth of the Khabur and dates to the 7th millennium BC, the transition period from Pre-Pottery to Pottery Neolithic. Continuous longitudinal walls determine the spatial structure of the houses. Despite variations in the floor plan, a basic rectangular shape, which consists of three rooms and three adjacent cells, can be observed. The walls were built without foundations on the leveled ground. The floors in the interior were raised by infill of rubble, up to 50 cm. The walls were made with bricks of different sizes, but the most commonly occurring shape was 54 by 27 by 7 cm, placed in alternating layers of stretcher and bonder bricks.

In an approximately 800-sqm trench on the northern slope of the citadel of Tell Halaf, several tholoi of the Halaf period were uncovered. Among other things, Rundbau 5 dates to the middle of the 6th millennium BC, has an inner diameter of about 7 m and features a rectangular annex to the south. All the walls of the building stand on a 4 to 5-cm thick lime floor, which also forms the floor of the building. The walls of the tholos have a thickness of 60 cm, and those of the dromos, 40 cm. In exceptional cases, joints can be recognized on the carefully constructed adobe walls, which is why the exact dimensions of the earth bricks could not be determined. At a later wall, which dates to the end of the Halaf period, however, a format of 30 by 25 by 5 cm was ascertained (Becker, 2012, pp. 11-20). This was a very common shape at this time, as a comparison with Tell Sabi Abyad shows, which lies further to the west at the Balikh River.

Little is known about the architecture of the 5th and 4th millennium BC in the Khabur region. Therefore, we jump straight into the 3rd millennium. As can be seen in Tell Mozan, for example, the domestic architecture of the Early Bronze Age is marked by small rooms and slender, mostly one-brick wide walls. The usual brick dimensions of this time in Tell Mozan were 15 by 15, 40 by 15, 40 by 25 and 50 by 40 cm. Deep foundations are very rarely observed at this time. The adobe walls of the houses in Tell Bderi are thus found in most cases, directly on the natural soil, and only sometimes were they slightly cut into the ground or erected on the stumps of older walls. Walls were usually built in a masonry bond with adobes of rectangular shape. However, this was not done consistently, because the brick sizes sometimes vary even within a single wall. Bricks were found with shapes of 40 by 30, to 50 by 52 cm (Koliński, 1996).

At this point, it is worth mentioning three places at the southern tip of the Khabur Delta. In Tell Djassa al-Gharbi, a private house measuring 7.50 by 5.25 m was uncovered. The walls use the brickwork of an older building as its foundation. The main walls of the later house are made from adobes measuring 48 by 32 cm. The partition walls use smaller adobes of 32 by 12-15 cm. All walls were laid in alternating stretcher and bonder layers. In Tell Abu Hafur, House 2 was built in a very similar technique. In Tell Rad Shaqrah, adobes of 48 by 32 cm size were also found. Therefore, it can be mentioned that in general, very different brick forms and construction techniques characterize the 3rd millennium BC.

During the Middle Bronze Age, the first half of the 2nd millennium BC, the workmanship of the masonry bonds can predominantly be described as good, even though it sometimes varies from case to case. The sort and quality of foundations differ from case to case, but usually the walls stand on adobe foundations that have mostly the same width, as the walls. In Tell Shagar Bazar, rectangular forms, like 37 by 17 by 9 cm or 38 by 30 by 8.5 cm, were preferred for the bricks, but there were also square bricks with 38 cm in length. In Tell Mohammed Diyab, square bricks of similar size – 37 by 37 by 7 to 8 cm and 39 by 39 by 9 cm – were found. In Tell Mozan, the rooms are larger and the walls stronger than in the Early Bronze Age. Another innovation in the domestic architecture of northern Mesopotamia, which can be found there, were foundations made from rammed-earth (Pfälzner, 2001).

During the second half of the 2nd millennium BC, the Hurritian and Middle-Assyrian periods, adobes were used in foundations and in walls, and were exclusively square. In Tell Brak, for example, bricks in the shape of 39 by 39 by 10 cm were used. Therefore, they were slightly larger than usual at this time in northern Mesopotamia. While in the other regions of Assyria, foundations were now more frequently made from stone, foundations in the Khabur region were often still made from rammed-earth like in Tell Brak, or from great adobe terraces, like in Tell Bderi.

A view of the Neo-Assyrian period shows a previously observed tendency to a standardization of shape and size of adobes. However, along the Khabur, besides square bricks with the typical Assyrian linear dimension of 37 cm, larger bricks were also used. Thus, in the Rote Haus in Tell Sheikh Hamad, bricks with linear dimensions between 39 and 41 cm, and a height of about 13 cm, were found. Square bricks measuring 40 by 40 by 10 cm were found in the so-called Hilani in Tell Fakhariyah. Also in Tell Sheikh Hamad, several vaults could be identified; the vault bricks have the same shape as the wall bricks but with only 9 cm thickness, they are much flatter and lighter. Such special vault bricks are known in northern Mesopotamia since the 2nd millennium BC. All walls of this period are more or less built with a regular masonry bond, standing on adobe foundations, which mostly reaches down to bedrock.

Fig.2 Tell Beydar: adobe and rammed-earth walls in Field C (credits: Ricardo Cabral, 2010)

4. CONSTRUCTION COMPONENTS OF THE HELLENISTIC PERIOD IN THE KHABUR

Tell Halaf during the Hellenistic period, is part of a very long architectural tradition developed on the site, since the Neolithic period onwards (Katzy, 2015, pp. 25-28). Tell Beydar remained largely unoccupied from the 3rd millennium BC, and the contrast between the different architectures is quite clear.

The building techniques, in general, are common to many sites in and outside of Upper Mesopotamia, with foundations, and sometimes baseboards made of stone, and walls constructed with adobes, rammed-earth, or both. Although adobe masonry still predominates over rammed-earth, recent research has shown that the use of rammed-earth was not limited to repairs, as it was also used in the ground floors of large, multi-roomed buildings in Tell Beydar. Interestingly, the use of rammed-earth masonry is absent in Tell Halaf.

4.1 Building materials

As is common in most regions that nowadays rely on earthen architecture, building materials had, during this period, mostly a local or regional provenance. Indeed, apart from the wooden beams that were used in some of the flat-roofed buildings, every other material that was used for construction could be easily collected on site or in the near vicinity. In the case of Tell Beydar, for instance, the earthen material seems to have been extracted depending on the kind of soil required, either from the site itself or from the nearby Wadi Awaj, which provided clay-rich alluvial deposits. Reeds or canes, even if they do not appear in the archeological record, were certainly used for roofing, as they also can be found along the wadi margins.

Basalt, an integral part of many walls and foundations, could have easily been obtained a few kilometers to the west of Tell Beydar, as there are several naturally occurring outcrops on Ard es-Sheik, a plateau formed by quaternary basalt. The use of basalt, even if mostly restricted to foundations, baseboards and wall corners, can also be found in bases for posts, hinge stones for doors, and several other objects. Wood, on the other hand, would probably have to be brought from a farther location, such as the mountains of Jebel Sinjar or Jebel Abd-el-Asis, or even on the margins of the Euphrates, where suitable trees could also be found (Martín Galán, 2003a). The local scarcity would have made it the most valued resource. This would also result in a high degree of reuse and recycling of the wooden components (either in new construction or for combustion), which, in turn, could explain its relatively low level of representation in the archeological record of the region.

4.2 Adobe masonry

The standard adobe at Tell Beydar is square and can vary between 42-43-cm sides to larger 44-45-cm sides, in some occasions. Both types have a height of about 12 cm. In Tell Halaf, however, the rising masonry in adobe is significantly smaller (35 x 35 cm or 37 x 37 cm, and 8 cm in height) and is made of relatively fine clay, without the addition of straw, and sometimes with small stones or ceramics. In Tell Beydar, there are two different kinds of adobes – grey and reddish - according to the clay of which they are made. The clay used for the grey adobes would have been extracted from the surface of the site and, therefore, containing large quantities of ashes and organic material from human activities. These adobes seem to be more resilient to the weather conditions than the reddish-clay adobes. The clay for these adobes could have been obtained from the margins of the nearby Wadi Awaj, being more plastic in nature and easier to work with. Both of these bricks were often combined in the same wall, a technique that has also been observed in 3rd millennium BC architecture. The Hellenistic adobes are, in general, of poor quality when compared to those of previous periods. Furthermore, the remains of the buildings are frequently located just beneath the surface, a fact that also contributes to its degradation.

Walls are made by combining whole bricks with half bricks that are a rectangular shape with a small side of 20-22 cm. While in Tell Halaf, walls often consisted of two or three rows of bricks, 75-110-cm wide, there is a greater variability in terms of wall width in Tell Beydar, with walls ranging from one-brick wide to four-bricks wide (reaching a width of 1.80 m) in the Hellenistic Palace (Martín Galán, 2003b), the largest building of this period on the site. All walls were built with a regular masonry bond.

4.3 Rammed-earth masonry

The rammed-earth technique, not yet demonstrated in Tell Halaf, is used in Tell Beydar for several purposes. Indeed, in recent years, several large multi-roomed buildings entirely made of rammed-earth have been unearthed. The walls of these buildings are made of extremely compact rammed-earth of grey color with widths ranging 60 to 90 cm. So far, it has been very difficult to discern the length of the lifts used. Rammed-earth was also commonly used for small dividing walls and repairs.

A combination of rammed-earth and adobes has also been shown in a few walls. In this case, the adobe courses were laid on top of the rammed-earth, with a thick layer of ashy mortar in between. The uniformity of the preserved height of other rammed-earth walls suggests that this combined technique was more frequent than previously thought.

4.4 Foundations

The use of foundations is limited to some of the buildings, usually the thick-walled ones. In some cases, as in small walls, partitions or fence walls, these are erected directly on top of the ground. In other cases, such as in Tell Halaf, the foundations of two buildings have been erected directly on top of the partially leveled building structures belonging to the Neo-Assyrian period (Katzy, 2015, pp. 29-31).

Foundations could have been made with dry-stone basalt or limestone with the stones combined with earthen mortar, or with adobes only. While the first type of foundation is very rare in the case of Tell Beydar, in the second type of foundation, a more common technique, large uncut stones were laid out in consecutive horizontal rows spaced at 20 cm and rising, in some cases, about 50 cm or more above the ground level. The stones are usually positioned in pairs. The earthen mortar is typically very similar to the rammed-earth blocks used for walls and is frequently mixed with a few pottery shards and small pebbles. When bricks were used, these were placed in a more irregular and less careful way than in the upper part of wall, usually making this type of foundation slightly wider than the wall itself. The depth of the foundations varies considerably, from about 20 cm to almost 2 m (in the case of what seems to have been a large terrace wall that was built on the southern slope of Tell Beydar).

4.5 Wall coatings

For the plastering of the walls, earth plaster, wet clay, or white lime plaster (or whitewash) were used. The manufacturing of earth plaster is similar to that of the raw mixture used for the bricks; both have the same ingredients but the earth used in the plaster was sieved and refined, making it smoother and easier to apply.

Fig.3 Tell Halaf, buildings CH1 (left) and CH2 (right) (credits: Elisabeth Katzy, 2010)

4.6 Floors

Floors could be composed of simple rammed-earth surfaces, rammed-earth with small pebbles, and white lime plaster. These floors are often superimposed with new floors, forming a floor succession that steadily rises in height above the ground level. Door thresholds are sometimes paved with a flat basalt or limestone or with adobes. This type of door entrance is comparable to entrances of buildings of the Neo-Assyrian period at Tell Halaf and in the whole Khabur region.

5. CONCLUSION

By the end of the 1990s, there was little interest in the Hellenistic period of the Khabur Valley and, therefore, of the Hellenistic architecture in the region. Only with the increasing excavation activity and employment of new excavation methods (as opposed to the excavations that took place in the beginning of the 20th century, where only more ancient materials were collected), more and more Hellenistic material can be distinguished, such as ceramics, small finds, and also Hellenistic architecture. A major problem of Hellenistic architecture is the often very poor conservation conditions in which they are found.

In this sense, the recent excavations at Tell Halaf and Tell Beydar allow, for the first time, a systematic study of the Hellenistic period with architectural and archeological material that was previously neglected. The presented examples of the architecture from these sites show that the Hellenistic buildings were erected entirely in the local Mesopotamian tradition, thus with no connections to the Greek-Hellenistic building tradition, neither in material, nor in construction.

Fig.4 Tell Halaf (credits: Elisabeth Katsy, 2010)

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THE RESEARCH WORK OF THE LANDSCAPE GROUP OF ISCEAH – IDENTIFYING AND DISCUSSING CASE STUDIES

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Theme 4: Conservation and Development of Human Settlements and Cultural Landscapes
Keywords: Cultural landscapes, earthen-architectural heritage, human settlements

Abstract

This paper intends to present the ongoing research efforts that the earthen-architectural cultural-landscape group, one of the five scientific research groups within ISCEAH (International Scientific Committee on Earthen Architectural Heritage), is undertaking. After the last Terra Conference, in Mali, 2008, the group committed to identifying and defining the boundaries, various building technologies, configurations and typologies of earthen cultural landscapes. The methodology includes the selection of case studies by members and the creation of a graphic spreadsheet containing data based on research and fieldwork. Important aspects, such as archaeological, historical and contemporary uses of earth, present-day threats, changes in use, socio-cultural issues and efforts towards sustainable development are under discussion. The paper presents the themes discussed by the group, theoretical considerations and practical concerns identified by the case studies, and key issues of earthen-architecture cultural landscapes that provide a foundation for future work.

1. INTRODUCTION

Within the International Scientific Committee on Earthen Architectural Heritage (ISCEAH), there are five broad areas of scientific research. Earthen-architectural cultural landscape represents one of these, alongside archaeology, living cultures, techniques and seismic problems.

Over the past few decades, there has been growing professional and academic interest in earthen architecture, particularly related to building technology and sustainability. Of interest to a growing group of architects, engineers, materials scientists, and cultural historians are not only the historical and archaeological significance, but also contemporary use and reuse of earthen architecture. Growing appreciation for the use of earthen architecture is evident in modern notable attempts to privilege earthen vernacular and emphasize its ecological benefits and sustainability. For example, the experiments of New Gourna (1953), by Hassan Fathy, in Egypt and the Eco House (1991-1992), by Sverre Fehn, in Sweden, and the presence of earth-building networks throughout the world demonstrate the modern respect for and interest in this kind of architecture by distinguished architects. Furthermore, earthen architecture and its conservation today constitute a distinct field of education underscored by numerous specialized programs.

UNESCO defines cultural landscapes, as distinct geographical areas "represent[ing] the combined work of nature and of man…." (Article 1, World Heritage Convention, 1992). The conservation of earthen-architectural sites has begun to integrate larger geographic and cultural contexts in response to the growing trend of cultural-landscape identification and protection (Fowler, 2003). Cultural landscapes incorporate overarching geographic and topographic features, regional cultural aesthetic and traditions, and human interaction with the built and natural environment to establish earthen-architectural cultural landscapes. Examples of World Heritage nominations mandated by UNESCO, within this category are the Cliff of Bandiagara (Land of the Dogon) in Mali, and Bam and its Cultural Landscape (1), in Iran.

During the Terra 2008 Conference in Mali, the earthen-architecture cultural-landscape group presented a paper entitled, "The Conservation of Earthen Architectural Landscapes – A Preliminary Reflection and Review of Concepts" (Kanan, Correia and Hurd, 2011). Since the conference, the group has been committed to identifying and considering the characteristics and significance of earthen cultural landscape, and more specifically, the role that this heritage could play in local sustainable development. This process has involved debate about what constitutes earthen cultural landscapes, such as the percentage of visible or buried landscape comprising earthen architecture, in addition to the nature of its physical or administrative boundaries. These considerations are informed by previous academic and professional work concerned with approaches to cultural landscapes and earthen architecture.

The present paper aims to examine aforementioned characteristics and concerns of earthen-architecture cultural landscapes in view of the hands-on experience and ongoing discussion of the ISCEAH landscape group.

2. A METHODOLOGY TO DEFINE AND IDENTIFY EARTHEN-CULTURAL LANDSCAPES

2.1 The conceptual approaches to defining Earthen-Cultural Landscapes

The diverse forms of earthen-architectural heritage constitute unique typologies of cultural landscapes. In some instances, there is a clear visual boundary to the landscape; in others, it is more difficult to define clearly the extent of the earthen cultural heritage and the landscape in which it lies.

The concept of the cultural landscape embraces complexity and privileges the integration of heritage components into an interwoven backdrop imbued with social value (Kanan, 2010). The landscape is typically represented by the interaction of culture and nature, but also incorporates overlaid traditional living cultures and practices (e.g. religion-cultural ties of a community to its natural environment) (Cosgrove, 1998, pp. 64-66; Cosgrove and Jackson, 1987, p. 96; Sauer, 1941, p.10). Perhaps the best example of the intangible human relationship with the natural landscape is the Uluru-Kata Tjuta Cultural Landscape in Australia.

Cultural landscapes also comprise diverse manifestations of these interactions between the physical and the socio-cultural, between humanity and its natural and built environment, and therefore present a significant range of forms, physical layouts, and use patterns. For example, for earthen cultural landscapes, there is a relationship with the 'earth' as a building material, both the practical reasons why materials are quarried and reused (such as ease of access) and more socio-cultural significances as the material is used and reused. These processes reflect a complex relationship to memory, place, traditional or historical practices, and evolving values (Hayden, 1997, pp. 15-17; Lowenthal, 1985, p. 377; Schama, 1995, p. 18).

Considerations of earthen cultural landscapes fit well within this evolving rhetoric, highlighting the essential aspect of integrated conservation approaches that safeguard the character and related significance of entire landscapes. These approaches expand on previous practices that decontextualized and isolated earthen sites. This is particularly important for earthen architecture as the concept of 'site' and its boundary is made all the more complex by the ever-changing nature of the material undergoing physical changes over time. For example, when an earthen structure begins to erode, undergoing the typical patterns of deformation, walls may slump eventually forming characteristic mounds or tells – and these can continue to change over time, particularly in response to climate impacts (Cooke, 2010; Rosen, 1986). Therefore, the 'boundaries' and 'limits' of earthen-architecture sites are difficult to define, making the concept of earthen cultural landscape of particular importance.

The broader concept of earthen cultural landscape assists in the inclusion of environmental settings and related socio-cultural values in conservation and valorization efforts. These types of integrated conservation approaches that preserve identified sites and their contexts can also privilege planning for local sustainable development (Loulanski, 2006, pp. 54-57; Tweed and Sutherland, 2007, pp. 63-64).

Nonetheless, the question of how to define earthen-architectural sites as having distinct heritage value still remains. To this end, it is necessary to determine criteria and characterize earthen cultural landscapes in order to develop a methodology for their identification.

2.2 The methodology for identifying Earthen-Cultural Landscapes (ECL)

After Terra 2008, the principal research undertaken by the cultural-landscape group evolved around defining ECL and identifying key examples around the world. The long-term goal of the work is to develop clear criteria for these landscapes and compile an exhaustive list by geographic region.

Currently, group members continue to identify case studies from different countries and cultures based on their professional experience. ISCEAH members have already studied in depth some of the landscapes included, while others are less familiar to the group and rely on existing documentation and the data of collaborators. There are potential new cases already indicated by collaborators. In Latin America, for example, three are sites, such as Biribiri, in Diamantina, Brazil, and the pueblos of Susques and Rinconada, in Argentina. According to a recent discussion with the architect Jorge Tomasi, the two pueblos can be considered earthen cultural landscapes due the type of relationship with nature, such as ritual actions and construction/architectural production. The social-cultural significance of space is emphasized as the management of the space is based on very limited resources, scarce fields and water, and symbolic control of the space where the people had their ancestral roots.

Case studies are compiled on a spreadsheet that includes descriptions of each ECL, theoretical and practical approaches to understanding and protecting the sites, and necessary consideration for mitigating threats, such as changing land use, encroaching development, natural disasters, and climate change. As with all heritage assets, changes in use, composition, context, and climate of these landscapes threaten their physical fabric, layout, and their socioeconomic context and value. These can conflict with conservation efforts and the potential for sustainable development.

Moreover, the sites are considered in the light of professional

Members Case Studies	Cultural/ Geographical Territory	Significance/Criteria	NEW topic Risks/natural disasters/climate change/social problems?
This section includes the name of the member presenting the case study and sometimes the name of the collaborator, the identification of the case and country, as well as a general map of the location.	This section presents a brief overview of the geographic, socio-cultural, and physical context of the case.	This section highlights the principal criteria and often includes the historical development of the landscapes, architectural typologies included therein, and other aspects of cultural and significance.	This section was added after a meeting in 2010 to underscore the most urgent threats to the landscapes in the hope of identifying regional, categorical, or other patterns.

Fig.1 Spreadsheet to identify case studies (credits: Landscape group of ISCEAH)

interest in earth as a building material over time, highlighting the archaeological, historical and contemporary uses of earth. The components used to describe the case studies are:

1.Identification (name, location, administrative level of protection, etc.)

2. Value/significance (historical, architectural, archaeological, technological, ecological, religious, spiritual, sustainable, living, etc.)

3.Authenticity/integrity (preserved intact, altered, original, transformed)

4.Geographic/topographic characteristics (arid/desert, oasis, tropical, subtropical, mountainside/hillside, valley, riverine/lakeside, coastal, mesa/plains, etc., including notable natural components of the environment)

5.Landscape use: living (daily use, seasonal use, ceremonial use) v. non-living (archaeological); agricultural practice; sustainable use of local resources

6.Landscape settlement: urban (densely populated, integrated community) v. rural (low density/isolated structures, potential for stronger relationship with natural landscape and agricultural/livestock activities)

7.Landscape visual aspects: percentage of visual landscape or buried landscape comprising earth/physical or administrative boundaries of landscape

8.Historical development of the settlement (regions, socio-cultural territories, ethnic groups, etc.)

9.Building tradition and components (earthen and mixed techniques, typologies, morphology and layout, spatial organization, etc.)

10.Associated intangible heritage: continuing building traditions, sustainable-resource technology (wells, canals, agricultural practice, hunting), crafts and jewelry, religious festivals, gastronomy, rituals, traditional knowledge, etc

11.State of conservation (good, satisfactory, signs of deterioration, advanced deterioration, threatened, etc)

12.Risks/threats (weathering, inappropriate interventions, pollution, tourism, inadequate planning, neglect, etc.)

13.Other observations/comments

2.3 Classification and categories of the case studies

Categories of earthen-architectural heritage are also being defined, and general typologies described. The next phase will be to refine these categories and organize the case studies accordingly. The landscape group further aims to identify representative case studies for major geographic and cultural regions, but the collection of studies is not yet sufficient for a representative sample of each region. Based on the descriptive methodology described above, ISCEAH landscape group is developing classification criteria and earthen landscape typologies.

3. THE ANALYZED CASE STUDIES

3.1 General criteria and significance of the case studies

Currently, twenty-one case studies have been compiled onto an informational spreadsheet. Analysis of the case studies compiled by the group highlighted some key regional characteristics and threats.

3.2 Specific issues/differences and criteria between the analyzed case studies

There are a number of specific issues raised by the case studies. In some cases, the historic socio-cultural significance of the landscape is integral to its modern sustainable development and identity. Such examples are important not only to earthen-architectural heritage, but more broadly as examples of sustainable living-cultural communities. For example, Dauphine in France and Liang Cun and Luxi Tulou in China are significant examples of traditional sustainable-living communities that represent an important ECL.

Another point is connected with the conceptual criteria. It is important to remember that by applying the concept of cultural landscape, by using methodological identification and analysis, significant fundamental values of cultural heritage, otherwise obscured, are revealed (demonstrating the inadequacies of the concept of 'site') for the preservation of the past and the future sustainability of earthen-cultural landscapes.

Identifying the physical boundaries and full extent of significance of some sites, for example, requires applied research and adherence to accepted criteria for ECLs. This is particularly true in the case of sites with little or no extant historic fabric apparent above ground. The Vale of Pickering site, for example, has required thorough mapping of the archaeological anomalies below ground through integrated excavation and remote sensing (over the largest contiguous landscape ever surveyed in Europe). This approach resulted in an informed understanding of the significance and cultural boundaries of the entire landscape despite the absence of extant fabric and visual markers of the site above ground.

Members Case Studies	Cultural/ Geographical Territory	Significance/Criteria	Risks/ disasters/ climate changes / social problems?
Natalia Jorquera/ Chile 	Rural Villages of the Central Valley of Chile. Regions of Valparaiso, O'Higgins, Maule e Bio-bio 	The most typical example of the Spanish rural Colonial architecture, which is, at the same time, an example of vernacular architecture. The villages represented the way that Spanish used to colonize the territory, using the localbuildings territory, using the local building techniques. This particular architecture characterized the agricultural landscape of the central Chile.	• The great seismic activity. The last earthquake (February 2010) destroyed most of the factories and houses of the central Chile, all built with adobe. • Most of this architecture was already in a state of decay due to the loss of the local traditional knowledge. • Lack of legal protection.

Fig.2 Example of a case study (credits: Landscape group of ISCEAH)

4. OTHER KEY ISSUES AND HIGHLIGHTS EXTRACTED FROM THE CASE STUDIES

When analyzing the collection of case studies to extract essential data, key issues and highlights appeared that could help to define more precisely earthen-cultural landscapes, as well as describe main typologies and create categories. Some of the issues were already considered in the previous paper presented at Terra 2008 (Kanan et al., 2011).

4.1 Building tradition, technology, function, social/ community life

By reading all these cases, the following characteristics were identified:

- The cases present a number of diverse building traditions adapted to their specific environments.
- Earthen-building technology tends to be particularly responsive to its environment, even in very hostile conditions, and reflects an understanding of the local environment, topography, climate, geomorphology, etc.
- Certain earthen landscapes present sophisticated solutions and complex structures and typologies that perfectly respond to challenging geomorphologic settings, like the Casas de Acantilado cliff dwellings of northern Mexico or hygrothermal requirements in a semi-arid climate, like the corbelled earthen-dome villages of northern Syria.
- In some cases, previously developed traditions are revived and recreated in new adaptations responding to local environmental conditions.

For example, in the Wadi Do'an, Hadhramaut region of Yemen case, there are *"outstanding clustered mud-brick tower houses for defense and elevated for flash floods, dry-stone flood channels for irrigation"*. In Ladakh, India the *"building technology developed with a deep understanding of the climate/landscape and the availability of local materials"*. In Dauphine, France, *"earthen architecture [was] based on [a] revived building tradition"*.

The range of historical earthen techniques associated with the landscape gives it a recognizable identity, for example, the cases of rammed earth in Dauphine, France, the adobe landscapes in the central valleys of Chile, the earthen towns in the southwest of Sardinia, Italy, etc.

The assortment and variety of building functions and architectural solutions reflect the diversity of the landscapes they occupy. The cases present different building functions that contribute to the diversity of forms and architectural solutions associated with the landscapes. There are communities of multiple buildings, single buildings, fortified villages, monastic complexes, multiple stories, etc.

Notable examples of diverse building function associated with the earthen architecture and the landscapes include Ladakh, in India, with a range of heritage typologies, such as Buddhist monastic complexes, fortified settlements; and the impressive

Fig.3 Left branch of Wadi Do'an, Hadhramaut, Yemen (credits: Pamela Jerome, 2009)

Fig.4 Disket Monastery in the Nubra Valley, Ladakh, India (credits: Tara Sharma, 2010)

multiple buildings/communal living of Liang Cun Tulou, in China.

The complexity of program and form is a function of the concept of cultural landscape, which, by definition, is multi-phase and free from chronological breaks. This identifies significance in the landscape through time, where areas within the cultural landscape may be used, abandoned and reused at different times. This is perhaps best demonstrated by the sequence of cities at Merv, Turkmenistan, where settlement shifted across the landscape over time.

4.2 Archaeological, historical, and technological relationship with the environment, type of settlement, configuration, morphology, etc.

The cases presented demonstrate connections between cultural significance and the natural environment (including the topography, the climate, geology, etc.) of the regions. The location of the settlements in terms of topography varies from flat plains, hilltops, slopes, and valleys. The cases reflect traditional knowledge to adapt to all of these types of setting, developed with sophisticated and careful solutions to building, preventing natural disasters, and responding to climate, winds, etc. Some are in remote areas, perhaps perceived today as potentially hostile environments, but in the past, given the history of climate and climate change, may have been optimum environments.

Other case study sites retain their traditional way of developing agriculture, like Wadi Do'an in the Hadhramaut region of Yemen, Serro in Brazil, Sorraia Valley in Portugal, and Dauphine in France. For other case-study sites, cultural/spiritual connections and symbolism are integral, highlighting the connection between intangible heritage and physical landscape, for example, sites such as Ladakh and Liang Cun.

The morphology and boundaries of ECLs are also variable. Whilst many conform to topography or environmental catchments, others are associated with cultural territories, or are economic and cultural centers along historical routes.

4.3 Threats/risks

The greatest threat to earthen-cultural landscapes is the complexity of identifying and protecting landscape-scale heritage assets. Most statuary heritage-protection systems remain influenced by the 'site' or 'artefact' bias of early heritage and conservation doctrines. Moreover, in most ECLs, there are a multitude of stakeholders, and across a large landscape area, this can amount to hundreds, thousands and many more 'voices' to be heard in planning for sustainable conservation and development.

Within those cultural landscapes, large-scale social change affecting the use, abandonment and collapse of traditional lifestyles has a significant impact on the sustainability of earthen heritage. Even the slightest changes (such as in agricultural-cropping regimes and/or increased use of pesticides) can impact the use of earthen structures. Other urban changes, such as sanitation development or water use, can similarly impact these sites.

Changes, as a result of climate and climate change impact the sustainability of ECLs. Though the impact of many of these changes, it is still relatively speculative. We can see the effects of cumulative change in climate, and the devastating consequences of extreme climate events. Case-study sites are still being collected to demonstrate these threats, with obvious examples likely to demonstrate desertification, and flooding (amongst others).

5. CONCLUSION

Up to this point, the work is progressing through the involvement/commitment of the members. The group is producing valuable research that undoubtedly represents an essential methodological step forward and further conceptual development since the work began in 2008. The research has immense potential to be developed and disseminated, to increase the identification of new cases of ECLs, to rediscover new significance and perspectives, and to optimize the roles of the landscape group in the evolution of the greater concept of cultural landscapes.

For the results, the landscape group thanks the effort of ISCEAH members who gave their time and attention to this collective work. However, further progress needs to be achieved to accomplish the established objectives of producing additional research, practical results, and to find ways to be more active. It is vital to increase research and to identify additional collaborators, institutions, and educational programs interested in participating. For that, ICOMOS-ISCEAH needs to define strategies and aims.

The group aims to expand the research work and engage professionals, along with encouraging young professionals, to join the landscape group. As the work gains substance and progresses, more case studies will be identified and additional reflection required. The identification of potential case studies through reading new papers and contact with researchers and professionals is making it possible to see further possibilities for the work and survey via heritage professionals networks. Other questions that the group must begin to address are in regards to the measures of protection for the conservation and safeguarding of this specific type of heritage, while raising community awareness and integrating local involvement.

Notes

(1) The site was almost entirely destroyed by a large earthquake in December 2003.
(2) Flash floods, such as the 100-year flood that occurred in October 2008, are a major risk.
(3) Since the year of 2000, a new conscious and action plan for the valorization of local resources in the region of Dauphine are changing the situation.
(4) The last earthquake (February 2010) destroyed most of the factories and houses of central Chile built with earth.

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CONSERVATION OF EARTHEN ARCHITECTURE IN THE HUMAHUACA QUEBRADA OF JUJUY, ARGENTINA.

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Theme 4: Conservation and Development of Human Settlements and Cultural Landscapes
Keywords: Conservation, sustainable tourism, earthen architecture, Humahuaca Quebrada

Abstract

This paper presents the results of a project, whose main purpose is to develop a Manual of Architecture and Earthen Construction for the inhabitants of the Humahuaca Quebrada (Ravine), located in the Jujuy Province of Argentina. This manual is intended to be the guidelines for earthen-heritage conservation, and to impart recommendations for new earthen construction. The Quebrada is a territory where earthen architecture is found. This is one of the reasons why it was designated a World Heritage Site by UNESCO in 2003. The project also aims to identify vernacular technologies, in order to properly guide their recovery and insertion into legislation, taking into account that it is a territory affected by earthquakes and geological risks. The methodology considers the collection of bibliographic data, field surveys, interviews and workshops with local people and organizations, and the design of the manual, including recommendations for recovery and development of earthen architecture in the Quebrada.

Places and structures were selected, taking into account popular, state and NGO buildings, to identify the changes in autochthonous patterns and their characteristics. The main features, the architectural and construction facets of some of the studied construction, is described, as well as the features corresponding to their cultural value. Significant aspects of the impact of industrial technologies on local traditions are described, and proposals for conservation and development of earthen architectures in the Quebrada are submitted.

1. INTRODUCTION

The area under study comprises a part of the Argentine territory, known as Humahuaca Quebrada, in the Province of Jujuy, in northern Argentina. The Humahuaca Quebrada was declared Cultural Landscape of Humanity in 2003 (Nicolini, 1981; Reboratti, 2003; Boschi and Nielsen, 2004) for the values of the natural and cultural environment, which frame an exceptional occurrence of settlements, archaeological sites, Indian villages (today civilian villages in development accelerated by the impact of tourism), railroad populations, as well as villages and rural houses, farms and pens for agricultural livestock. It encompasses a 150 km long Andean valley that goes from Barcena and Volcan up to Tres Cruces, including the established gorges and valleys or mountainsides that define the natural landscape of the Quebrada.

This area is designated as a Level 2 and Level 3 seismic hazard area, according to the national zoning of the National Institute of Seismic Prevention (INPRES-CIRSOC 103, 1991). The natural environment of the Quebrada is known for its dry and cold semiarid climate, with significant conditions that are reflected in the architecture. There are sloping territories that determined the location of settlements, the landscape and the orientation; an almost daily presence of cold southern winds, though dry and warm in August; low rainfall, but sometimes violent storms, along with high sunlight exposure all throughout the year; extreme variations between day and night temperatures; natural phenomena responsible for disasters, such as extraordinary swelling of rivers with flooding, mud and rock slides, and earthquakes. The same causes influenced the uniqueness of settlements; they defined the architecture and partly characterized the use of traditional materials and construction techniques.

As for the architectural and technological forms (Nicolini, 1981, SCA-IAIHAU UNT, 1982; Rotondaro, 2001, 2006; Paterlini, Villavicencio and Rega, 2006), the inhabitants of the Quebrada developed criteria, throughout centuries, that denote a deep knowledge of building their habitat, such as the careful selection of a site for a settlement, of the construction emplacement, the organization of houses without breaching the natural topography, or the use of the urban plot, setting aside a third of it to farm, as a productive unit. In particular, the dweller has retained techniques and procedures related to construction and the architecture using

Fig.1 Self-construction of a domestic housing using adobe, and terracotta tiles on hollow reed in El Perchel, Argentina (credits: Rodolfo Rotondaro, 2009)

Fig.2 *Quincha* depot in an agricultural sugar plantation near Route 9, close to Maimará, Argentina (credits: Rodolfo Rotondaro, 2009)

natural materials, predominantly raw earth, stone and plants. It was accomplished through the natural transmission of knowledge and techniques among construction craftsmen over generations.

However, recent decades have witnessed profound economic, cultural and productive changes that are affecting and impacting on traditions with centuries of history. The local know-how of strong cultural significance is being modified and, in some cases, lost or supplanted by other forms of architecture. Nonetheless, in recent years, a process for recovery of traditional technologies is being generated based on the demand for current construction (mainly adobe).

The objectives of the project are the following:

- Identify construction techniques and materials in the vernacular and popular architecture of the Humahuaca Quebrada, by surveying built structures throughout, accompanied by interviews with construction artisans.
- Identify advances in construction procedures carried out in the architecture of the last 10 years, through on-site surveys and interviews of architects, engineers and technicians working in the region.
- Be acquainted with the progress of the construction industry in the matter.
- Propose new guidelines for buildings, by optimizing the use of materials and construction techniques.
- Develop an Earthen Architecture Construction Manual devoted to the inhabitants of Humahuaca Quebrada, through which guidance and instruction on how to build in the region is bestowed.

Within this territory, rural and urban human settlements are considered, as well as buildings in the territory that act as support for productive, tourist and religious activities. The project was led by one of the authors and funded by the Ministry of Science, Technology and Productive Innovation of Argentina. The counterpart is the Ministry of Tourism and Culture of Jujuy, through the Management Unit of Humahuaca Quebrada.

2. NATIVE ARCHITECTURE FROM HUMAHUACA QUEBRADA

The autochthonous architecture and construction technology in force represents one of the enduring cultural traits, and characterizes the identity of Quebrada local populations. Their patterns are part of the system of people's knowledge, which, despite the impacts generated by the emergence of urban industrial models, are maintained and still orally transmitted at a family level, while continuously adapting it to the changes that occur from the 'globalized urban culture'. Autochthonous technology is also an important practice from the perspective of cultural sustainability, based on several factors: the use of natural resources that can be recycled without generating pollution, and produced with much less energy than industrialized materials. In bioclimatic terms, these are a better response to the quebradeño arid environment; and are kept alive as customs, ethnicity and knowledge transfer mechanisms with cultural meanings at the household and community levels.

2.1 Housing

The self-constructed housing is one of the clearest manifestations of the architecture of the Quebrada native lands, which continues and is mainly built of adobe and covered with hollow reed and terracotta tiles. The houses are compact clusters of rooms, L - and U - shaped, sometimes in a row, with patios facing east, northeast and north. The courtyard has multiple functions and connects the interior with the 'outside' of the house. The population of the area performs almost all activities outside the house, which is evidenced by the varied equipment installed around the housing and in the territory. The kitchen is usually a smaller room, with smoke vents or a fireplace at one end. It is common to also use the bedrooms for storing utensils, objects, wool blankets, materials and other household goods.

Fig.3 House fence of stone and clay over an irrigation ditch outside Iturbe, Argentina (credits: Rofolfo Rotondaro, 2009)

Fig.4 Hamlet and small church in La Cueva, Argentina, constructed of adobe, stone and clay, earthen plasters, and terracotta tiles roof (credits: Rodolfo Rotondaro, 2009)

The growth of housing is solved by aggregating modules, following the shape of the settlement, or by adding new ones.

2.2 Domestic and productive equipment

Quebrada housing is a series of auxiliary buildings that comprise the peri-domicile: fences, stables, chicken coops, basins, reservoirs, ovens, stoves, orchards, water well, irrigation ditches, ritual tables, and pillars. Fig. 2 shows a structure of *quincha* (Quebrada hollow reed and earthen plaster), a depot for *quebradeño* farmers in the Maimará area consisting of two rooms with walls and roofs of the same construction type, used as storage space for seasonal agricultural products, which are marketed in the Quebrada. The supporting structure is made of *poplar* wood, a species abundant in areas with water.

The use of local materials and autochthonous techniques is also observed, in a clear and effective way, in the boundaries of domestic, agricultural or grazing areas. The fences are built with stacked stones; blocks cut from the floor or *champas* (grass); stones and earthen mortar; adobe masonry; rammed-earth; stone, clay and adobe; and different variants according to the practices of the self-builder.

2.3 Small hamlets and adobe churches

The configurations of small settlements and rural villages are adapted to the topography and are mostly built with local materials – mainly adobe, terracotta tiles, clay, stone and wood from the area. Almost all settlements include small chapels and churches, also predominantly built with local materials. In regards to churches, the influence of shapes, patterns and spatial organization of building elements are notably of colonial origin, imitating the most important churches in the urban centers of the Quebrada.

3. RECENT EARTHEN ARCHITECTURE

Recent earthen architecture includes all state and private buildings over the past century: service infrastructure, urban and rural health, education, public works and housing facilities. These employ raw earth with timber, stone and vegetation, and embody various forms.

3.1 Religious architectural heritage

There is, in the Quebrada, a very rich and official historical and architectural religious heritage (CNMLH, 2000) from colonial inheritance. Some buildings are over three centuries old, and endured various conservation interventions (which also includes other earthen buildings, such as mansions and historical centers). Most of these were built with stone, adobe, wood and straw or terracotta tiles on the roofing, taking into account local self-builders and building systems. They have also incorporated innovations to improve problems and detected pathologies, such as impermeable layers, multiple layers on the roofs and plastering; reinforcements and beams; chinking and stone plinth with reinforced lime mortar, among others. The main churches are the Volcán, Tumbaya, Purmamarca, Maimará, Tilcara, Huacalera, and Humahuaca Uquía (Nicolini, 2000).

3.2 Adobe railway housing

The railway that joined the provincial capital, S. S. Jujuy, with the city of La Quiaca was built between 1906 and 1908, and was characterized by more than 20 houses built entirely or partially of adobe walls. Regarding the latter, and according to up-to-date railway plans, these were built of stone at the foundation, and adobe-masonry walls, such as the ones at the Yala railway station; or adobe and fired brick, as is the case at

Fig.5 Housing for railway staff of Tres Cruces railway station, in Argentina (credits: Mónica Ferrari, 2009)

Fig.6 Cultural Community Center with plastered adobe walls in Iturbe in the northeast of the Quebrada, Argentina (credits: Rodolfo Rotondaro, 2009)

the locomotive depot of Humahuaca. Generally, these houses have been characterized by the use of typologies that are often repeated, in which the juxtaposition of modules either in L- or U-shaped alignment prevailed. Of these, the most widespread, totaling 10 examples along the railway, consists of a six-module row, with a prominent volume of two modules on its axis (kitchen and bathroom), and galleries at their front and back. These refer to railroad staff housing, or traffic staff housing of the railway stations of Senator Pérez, Humahuaca, Iturbe, and Tres Cruces, taking into consideration the Quebrada.

3.3 New earthen architectural housing

An increase in private housing is seen that proposes new architectural models and reflects a clear attempt to generate new versions of earthen architecture in Quebrada. In many cases, these incorporate field implementations and adaptations that mimic popular architecture. The production from professional studies accompanies this construction in permanent and of temporary housing, incorporating innovations, such as plastering and surface treatments, roof materials and the appropriate design for seismic prone areas. New design in housing is also witnessed in state buildings in different areas of the Quebrada, which have been developed by government agencies, such as municipalities, Institute for Housing and Urban Development of Jujuy, Ministry of Public Works of Jujuy, National Institute of Industrial Technology (INTA), and Presidency of the Nation.

3.4 Schools and buildings with community and cultural functions

Some earthen built structures are produced by multi-disciplined management methods and shared efforts among governmental agencies (municipalities, departments and ministries) and community organizations. This applies to some isolated rural schools, in places where their maintenance and additions depend on local efforts (e.g. Huachichocana); micro-regional and effective community halls; and cultural centers of regional relevance (such as the child cultural center of Tantanakuy in Humahuaca). The technology used varies from the local native use of adobe walls with earthen plaster and lime paint, and terracotta tiles on woven reed or timber; up to other innovations, such as the use of soil-cement and soil-lime, Trombe wall, square adobe, interior reinforcement with reeds; and stabilized earthen plasters; etc.

3.5 Construction of the tourist industry

In the last two decades, particularly in the last one, departing from the growing interest generated by the Quebrada after being declared a Cultural Landscape, new hostels and hotels have been built. These used construction technologies of stone, wood and raw earth, generating a great visual impact in some cases. In addition, there are several structures of small size and scale in urban centers and subsidiary ravines. In some situations, these were due to local family initiatives, and in others, they are an important business investment. The resulting structures are changing the hotel architecture that characterized the Quebrada for many decades: colonial-style buildings, some with whitewashed adobe walls, or with conventional urban architecture, of stone, concrete and terracotta tile.

3.6 Buildings with 'alternative' architecture: between the autochthonous and the 'modern'

There are other varieties of construction and interventions in the Quebrada that refer to the possibility of alternative architectural and technological proposals, in-between the intrinsic architecture and the newer one, which seeks to convey the image of 'regional', but is at the same time modern. These are produced in different areas and with different aims, either by community-based organizations, NGOs located in the

Quebrada but external to it, or entities that develop scientific and technological research (such as national universities, CONICET and the National Agency for Scientific and Technological Promotion). Though a minority, these models occasionally generate significant impacts that are replicated in popular areas by technicians and professionals involved in this region. They disturb the interchanges between traditions and the impression that Quebrada presents.

Within this pattern are included construction prototypes of modified autochthonous techniques, such as mixed roofs with layers of stabilized earth, passive-solar energy and adobe walls, coatings with stabilized earth, compressed earth blocks, prototypes of suitable housing for Quebrada, multipurpose halls using mixed construction technologies, and others.

4. CONCLUSIONS

4.1 Coexistence of different architecture and technologies

The autochthonous constructive methodologies and architecture remain predominant in rural areas and more isolated areas of the Quebrada and transverse valleys, where building types identified with local natural resources and the transfer of knowledge from parents to children are still valid. Thus, in hilly areas more stone is observed; where there is grass, cut blocks are used as flooring; where there is wood or cane, more quincha and half-timbered houses are found. As a rule, in all areas of the Quebrada, adobe and stone walls, terracotta tiles and straw roofs are the most used and disseminated building type. There are also the local variations in shape, size and finishes. In urban and semi-urban areas, there is additionally the presence of autochthonous patterns, but adapted to the urban fabric (in grid or not), with changes in formal types, implementation and orientation. Here, the definition of the construction system and the selection of materials are characterized by the coexistence of different patterns, and thus, ethnic typologies incorporate non-ethnic elements and materials. Even in central areas, there are houses and other buildings using stone, adobe and wood; reed and terracotta tiles on rooftops, although with tile edges; cornices; arches; colonial fences; industrial doors and windows; stone, brick, and ceramic veneers, and other elements.

There are two other approaches to the architecture and technology present in the Quebrada: (a) the urban industrial design found in houses, schools, hospitals, public transportation stations and services, hotels, shops and government buildings, which use reinforced concrete, fired brick, concrete block, plastered adobe, steel sheet, metal structures, Styrofoam, paints and industrial carpentry; and (b) the alternative, also present in different types of uses (public and private, state, NGOs, migrant, scientific projects) with different levels of development according to their origin and roots. These structures have increased in the last decade and are characterized by the search for an architecture and construction technology with local features, combined with urban industrial design and materials, that is more 'harmonious' to the environment and legacy of each place.

4.2 Pressures of urban industrial architectural and technological models

The non-native patterns, particularly those of urban industrial origin, generate pressure on the local communities. There are statutory and imaginary changes oriented towards consumption architecture, rather than to seek genuine expressions suitable for each place. The impact of urban industrial architecture in local popular strategies results in a conscious selection and use of materials and urban elements in architecture, looking for greater social status and local prestige, to live in houses like those of the cities, and of wealthy families (summer villas, residences). This also results in the devaluation of earthen architecture as a material of poor quality and durability, being considered the cause of regional poverty. The changes are also engendered by some privately funded architecture, business-funded architecture, and tenant or tourist dweller, who intentionally implement other models of architecture and other technologies, regardless of their impact on identity.

4.3 Changes in popular housing architecture

Changes were observed when comparing the popular earthen housing in rural areas with the housing typologies found in urban and semi-urban sectors:

- The existence of defined physical spatial limits (three or four limits of the plot, narrow dimensions of the plot) that determine the design and organization of the housing; and the presence of a street façade, which endows it with other formal connotations, and requires different statutory reactions.
- Regarding the natural environment, the orientation of the settlement is changed according to its location on the site. This causes changes in the insulation of the housing and patios, which in turn generates changes in the use of spaces, forms and people's activities. The grids, though irregular and distorted at the edges of each settlement, do not impede creating planned situations that compose spaces, forms and techniques: division walls, frontage, linear forms, and incorporated toilets, no construction of domestic equipment, space and use limits, and different privacy and community spaces. In turn, the organization of the spaces in local rural housing has also begun to incorporate changes, such as the idea of "being" (as a space for actual use, but also as an image of its owners); the incorporation of bathrooms and kitchens inside the building; and the idea of the image projected to the street, associated with the existence of the city skyline, along with better treatment and materials of greater social prestige.

4.4 Technological Changes

The construction technology in the Quebrada conveys the capacity of popular experimentation, evident in the combination of local materials and techniques with industrial materials and techniques. The causes are probably related to statutory aims, but also utilitarian ones (such as less maintenance). As in other areas of the region, autochthonous constructions finely built have a superior construction quality and durability than those hybrids, combining traditional and urban industrial technologies. For example, the use of lintels, sills, horizontal and vertical reinforced concrete reinforcements without continuity or bond to the resistant structure of the building. However, other situations are observed evidencing an adequate use of combined techniques, such as soil-cement with a selection of local earth, reinforced edges, and outer surface treatment to improve the adhesion of plasters, drains and pipes, prepared with local building elements.

4.5. Recommendations

According to the results obtained through research, recommendations were suggested aiming at implementing actions to enhance and preserve earthen architecture in Humahuaca Quebrada, considering the management of this area as a World Heritage Site by:

- Documenting and analyzing autochthonous architectures and building techniques, as well as their variants and innovations, for future use as a design database.
- Re-evaluating and disseminating the formalized historical and architectural, tangible and intangible heritage, and document and assess the popular domestic heritage.
- Informing and educating on the issue of earthquakes and regulations, recommendations, and current national and international codes for the design of new buildings and the improvement of existing ones.
- Promoting the use of multi-disciplinary and inter-institutional management models, and the contribution of communities and their organizational structures in the management plans and future planning of Quebrada.
- Disseminating interventions and the work of non-governmental organizations, universities and scientific projects developed in the Quebrada, engaging their skilled human resources in order to establish collaborative networks.
- Consideration of private, entrepreneurial and commercial initiatives, but also from local dwellers, which are respectful of the natural and cultural environment of the Quebrada.
- Incorporating environmental impact assessments (EIAs) in current and future regulations, in order to avoid negative impacts arising from the extraction of earth.
- Promoting the progress of recovery and use of popular systems of building practice and knowledge, which involve the use of natural resources and the environment.
- Developing appropriate regulations and specifications to address inadequate or out-of-scale real estate pressures.

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RECOVERY OF THE TARIMI MANSIONS FROM THE FLOOD OF 2008, TARIM, YEMEN

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Theme 4: Conservation and Development of Human Settlements and Cultural Landscapes
Keywords: Tarim, Yemen, floods, natural disasters, disaster response

Abstract

Tarim in Wadi Hadhramaut, Yemen is one of the three main cities in the valley, along with Seyoun, the regional capital, and Shibam, a World Heritage Site. Well known for its iconic 50-m tall mud-brick al-Muhdhar minaret, Tarim is also significant for its three important historic cemeteries, manuscript library, and its collection of eclectic mansions dating from the 1870s through the 1930s.

On 23-24 October 2008, heavy rains resulted in devastating flash floods that destroyed over 5,000 mud-brick structures in the Hadhramaut Valley. Although only the eastern extremity of Tarim was affected, the mansions, many of which were already in poor condition due to abandonment, suffered greatly from the prolonged downpours. Since their expropriation in the early 1970s by the then-Marxist government of the former People's Democratic Republic of Yemen, until their return to their rightful owners following the civil war that united north and south, these buildings lacked cyclical maintenance, became "white elephants," and underwent demolition by neglect. The Tarimi Mansions Preservation Project's documentation-training program worked from 2000-08 to record the significant abandoned mansions, as well as prepared two feasibility studies for their adaptive reuse.

Because of the flood, the Prince Claus Fund for Culture and Development and Yemen's Social Fund for Development provided emergency funding in 2009-2012 to conserve the exteriors of ten of the mansions, thereby mothballing them until adaptive-reuse functions can be agreed upon with stakeholders. In addition, Tarim was also selected to be the 2010 Islamic Cultural Capital, and simultaneously with our work, the Ministry of Culture restored additional mansion exteriors, so that a total of 17 were preserved. Using the impetus from these events, a Tentative List dossier is also being prepared based on Tarim's role in the spread of Islam throughout the Indian Ocean.

1. INTRODUCTION

Located in Wadi Hadhramaut of the former People's Democratic Republic of Yemen, Tarim, along with Seyoun, the regional capital, and Shibam, a World Heritage Site, is one of the three main cities in the valley. The area has been referred to as the valley of the mud-brick architecture (Damluji, 1992), and is well known for it tower houses, which in the case of Shibam, reach up to 12 stories in height.

Tarim, however, is full of massive mud-brick mansions, typically no taller than five stories. A city of over 100,000, Tarim is sited in the eastern end of the valley and is regarded as the spiritual capital of Wadi Hadhramaut. Its 50-meter tall mud-brick minaret, al-Muhdhar, is considered a monument of national importance and is depicted on the 500-Yemeni-ryal bill. Other important mosques can be found throughout the city, including the 1,000-year-old Ba Allawi mosque, as well as various institutions of religious learning, particularly in Shafa'i jurisprudence. Three historic cemeteries are full of saints and the source of devout pilgrimages. Parts of the city's fortification walls are still extant, as are forts and a customhouse. Tarim's al-Ahgaf Manuscript Library holds a wealth of significant hand-illuminated texts.

Tarim is also known for its ensemble of mansions dating from the 1870s through the 1930s. These villas reflect the ambitions of a Tarimi merchant class that made their fortunes in Southeast Asia and imported colonial styles from there, but are executed in the local construction technology of mud brick and lime-plaster finishes, and planned following the local typology in terms of spatial organization (Conlon and Jerome, 2011, pp. 56-57). Remarkably, at least 15 mansions in Tarim and two in Seyoun are attributable to the gentleman architect, Alawi Abu Bakr al-Kaf, one of only four historic architects whose names have been identified in Yemen.

1.1 Tarimi Mansions Preservation Project (TMPP)

Initial field seasons were executed in 1997 (Jerome, Chiari and Borelli, 1999) and 1999 (Borelli, 2001, p. 13 and 2007, p. 123; Lazio, 2000, pp. 6-7) with funding from the American Institute for Yemeni Studies (AIYS) and the American Institute of Architects. A preliminary feasibility study was conducted in the fall of 2000 (Jerome et al., 2003, p. 320) with the support of the Samuel H. Kress Foundation, a NYC-based NGO. This led to the establishment of the Tarimi Mansions Preservation Project (TMPP), which the author directed from 2002-2012 under the auspices of AIYS and Columbia University's Graduate School of Architecture, Planning and Preservation (GSAPP), with collaboration from Columbia University's Visual Media Center (1). The project was precipitated by listing the abandoned Tarimi mansions on the World Monuments Fund's (WMF) Watch List from 2000-2004. Twelve of the mansions were expropriated during the former Marxist government in the early 1970s and reused mainly as housing for the poor. The buildings languished from lack of cyclical maintenance, and by the time they were returned to their proper owners two decades later at the end of the civil war that saw the unification of the north and south, these mansions were in extremely poor condition (Jerome, Conlon, al-Radi and Crevello, 2003, pp. 319-320).

An initial assessment found four of the buildings beyond repair. Two of these have subsequently been demolished. The surviving abandoned buildings were in the process of demolition by neglect. Recognizing the significance of the abandoned mansions, the Yemeni Society for History and Heritage Protection (YSHHP), a local NGO, negotiated a long-term lease on al-'Ishshah palace, which has operated as a house museum and cultural center since 1997 with Muhammad al-Junied as its director (Conlon, Jerome and al-Radi 2003, p. 14).

The Tarimi Mansions Preservation Project, a documentation-training program, brought graduate students in historic preservation to work alongside colleagues from Yemen's General Organization of Antiquities and Museums (GOAM) and, during two of the seasons, undergraduate architecture students from the University of the Hadhramaut. Scaled AutoCAD drawings and photographic documentation were produced for seven of the significant abandoned villas (Conlon and Jerome, 2011, p. 58). Funding for these efforts came from Yemen's Social Fund for Development (SFD), a quasi-non-governmental organization, as well as the Samuel H. Kress Foundation, AIYS, and GSAPP. Additional grants from the US State Department's Ambassador's Fund for Cultural Preservation and SFD were used to reconstruct collapsed areas of al-'Ishshah palace (Conlon et al., 2003, p. 18), for which TMPP and its collaborators were awarded a Certificate of Outstanding Accomplishment by WMF in 2003. The Department of Cultural Heritage of UNESCO's Unit of Arab Countries also commissioned an updated feasibility study, completed in January of 2004. All of this work provided a means of raising the local, national and international community's awareness for the significance of these structures and Tarim as a whole.

Fig.1 The Hamtut after restoration of the exterior (credits: Pamela Jerome, 2010)

2. FLASH FLOOD OF 2008

From 23-24 October 2008, violent rains caused flash floods throughout the Hadhramaut province. Although the Hadhramaut region receives monsoon rains in the fall, greater intensity typically happens along the coast. However, flash floods are not unknown in Wadi Hadhramaut, and there is a traditional system of water management that takes advantage of periodic rainfall. What was unusual was that the deluge occurred throughout the wadi and its tributary valleys, causing several flash floods. 50 cm of rain fell in a 40-hour period in an area that normally receives a total of 7.5 cm annually. As a result, 3,000 to 5,000 buildings in the region were destroyed along with a human cost of approximately 200 lives.

In addition, the World Heritage Site of the Walled City of Shibam, which sits on a tell at a natural bottleneck in the wadi, was nearly lost due to the arrival of two floods within a few hours of each other. Fortunately, the floodwaters mostly damaged the perimeter wall. However, it acts as a retaining wall and the tallest buildings in the city are located at the edge of this wall; therefore, subsidence in the perimeter wall and its fill put these buildings at risk.

3. POST-FLOOD REMEDIATION

SFD retained the author to review damage resulting from the flood. From December 2008 through January 2009, the author assessed damage in the coastal city of Mukalla, and inland in Wadi Hadhramaut, Wadi Do'an and Wadi Sa. The author also prepared an assessment of the condition of the perimeter defensive wall of Shibam, which doubles as a retaining wall, at the request of UNESCO's World Heritage Centre (WHC). Reviewing damage throughout the wadis, some interesting patterns emerged from the evaluation that provided a deeper understanding of the effects of the commercialization of mud-brick construction practices (Jerome, 2010, pp. 54-55).

Fig.2 Al-Riyadh following restoration of the exterior (credits: Pamela Jerome, 2010)
Fig.3 Work in progress on the north elevation of the main building of al-'Ishshah Palace (credits: Mohammad al-Junied, 2011)

Although the plight of the Tarimi mansions was in the spotlight for over a decade, including research, publications, and presentations at local and international venues, the results were still disappointing in terms of physical repairs. With the exception of the reconstruction of the four collapsed areas of al-'Ishshah, and minor repairs to two other mansions, Hamtut and Dar al-Salam, very little had been accomplished in terms of physical interventions. Problems related to securing funds for their stabilization stemmed from issues of multiple private ownership for each villa, wherein numerous inheritors maintained rights, and the resulting lack of ability to negotiate reuse options for the structures. However, at an even more fundamental level, there is no national law in Yemen that provides for protection of private property as cultural heritage. These management hurdles were discussed in various meetings with local stakeholders, government officials, GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit – now GIZ) colleagues working in the area on the Shibam Urban Development Project, and UNESCO.

Despite these obstacles, along with the designation of Tarim as Islamic Cultural Capital 2010, the flood finally provided the impetus for the stabilization of the mansions. The work performed thus far has succeeded in restoring the exteriors of many mansions, greatly enhancing the aesthetics of the city's historic core, as well as mothballing the abandoned villas until management solutions can be agreed upon and implemented.

3.1 Prince Claus Fund-Sponsored interventions

Soon after the flood, the Prince Claus Fund for Culture and Development approached the author to provide a proposal for the repair of significant cultural properties affected by the flood. A successful proposal was submitted seeking US $35,000 to stabilize five of the abandoned al-Kaf family mansions, including Hamtut, al-'Ishshah, al-Riyadh, al-Fijr and Qasr Abd al-Rahman Bin Sheikh al-Kaf. Although the buildings had not been affected by flooding per se, the precarious condition of their roofs and foundations had been greatly worsened by the two-day rainstorm.

PCF divided the project into three contracts: a pilot project (Hamtut), second contract (al-'Ishshah and al-Riyadh), and third contract (al-Fijr and Qasr Abd al-Rahman Bin Sheikh al-Kaf). Work on the Hamtut, involving structural repairs to foundations, replacement of rotted beams and lime-plaster waterproofing of roofs (2), was completed between January and March 2010. Repairs to al-Riyadh were similar in nature, and were accomplished from October 2010 through January 2011. For al-'Ishshah, a large complex of structures constructed over a minimum of four phases, maintenance involved the conservation of the rear elevations of the structures along the north side, including the north façade of the main palace, east gate, Dar Dawil, kitchen wing, and pigeonnaire/well structure, as the south, east and west façades of the main palace had already been restored with funding from the Ministry of Culture. The work commenced in February 2011 and was completed in June of the same year. The repairs to al-Fijr and Qasr Abd al-Rahman Bin Sheikh al Kaf are scheduled to commence in September 2011. The latter suffered partial collapse of its main façade only two weeks after TMPP completed recording the building. Temporary shoring was installed in February 2007 following a GTZ-sponsored training workshop. The intent in this case is to use PCF money rebuild the corner, thus reinstating its monumental Neo-Classical façade.

Supervision of the work was accomplished by Muhammad al-Junied, responsible for accounting and distribution of the funds, and engineer Abduallah al-Qadr performing construction administration with architect Yaqub Sa'id Musa'id as his assistant (The latter is a product of TMPP training) Master masons Saleh Ahmed Burayek and Ali Obed Mue-eddil are the contractors. The author also periodically reviews the work, although the current political situation has made travel to Yemen difficult over the past year for Westerners.

3.2 Social Fund For Development-Sponsored interventions

A prerequisite for PCF's grant was the provision of matching funds. The Social Fund for Development stepped in to meet this requirement. A proposal was prepared for SFD to support the repairs to five more mansions, including al-Muntazah, Salmanah, Ba Heta, Ba Hawash, and al-Hawar. With the exception of Ba Hawash, an al-Juneid family mansion, these buildings are also products of the prolific construction activities of the al-Kaf family. In addition, some of these mansions are occupied, either fully or partially. However, they are significant in terms of the 19th-century history of Tarim and are visually important to the overall context of the historic core of the city. Using the same team, work was been completed on al-Muntazah, Salmanah, Ba Hawash and al-Hawar.

Fig.4 Dar Dawil, the oldest building in al-'Ishshah complex, during restoration (credits: Mohammad al-Junied, 2011)
Fig.5 Qasr Abd al-Rahman Bin Sheikh al-Kaf in its current state with the collapsed southwest corner stabilized by a GTZ workshop in February 2007 (credits: Pamela Jerome, 2007)

3.3 Tarim As Islamic Cultural Capital 2010

In addition to grants from PCF and SFD, the Hadhramaut Flood Reconstruction funds provided US $650,000 to perform repairs to the façades of eleven mansions, including Hamtut, Dar al-Salam, al-Riyadh, al-Munaysurah, al-'Ishshah, al-Fijr, Bait Ahmed Bin Abdallah Bin Aidarus Bil Faqih, Qasr al-Quba, al-Haddad, Attawahi, and al-Ranad. These endeavors were led by local architect, Mohammed Hamid al-Kaf, and his manager, Abdullah Mohammed al-Metafi. Their project was complimentary to the work implemented as a result of PCF and SFD joint funding, and dealt primarily with exterior restorations as part of the aesthetic enhancement of the city for the yearlong event.

PCF also provided funding for structural repairs to al-Muhdhar mosque, as well as for the rehabilitation of the commercial building façades surrounding the old souq at the center of the city, the perimeter walls of the three historic cemeteries, and the area of the camel races, which follow the traditional three-day pilgrimage to Qabr Hud, a site commemorating the pre-Islamic prophet, Hud to the east of the city.

Other work for the Islamic Cultural Capital event involved the demolition of al-Shatry, one of the mansions identified in both feasibility studies; however, the building was in very poor condition, and the resulting public square provided a much needed rehabilitation of the flood bed and a direct visual axial link to al-Muhdhar mosque. In addition, a small park was installed at the adjacent roundabout.

3.4 Tarim Proposed For Yemen's Tentative List

After meeting with Yemen's Minister of Culture, Dr. Mohammed Abu Bakr al-Muhflehi, in addition to the elderly statesman who is the chief advisor to Yemen's president on cultural affairs, Dr. Abd al-Karim al-Eryani, and the head of the cultural unit at SFD, Abdullah al-Dailami, it was agreed that the impetus from Tarim's selection as 2010 Islamic Cultural Capital should be used to propose the city for Yemen's Tentative List (TL). This concept was also reviewed with personnel from the World Heritage Centre in Paris, who agreed that there is potential.

There is, however, the lingering question of whether or not the World Heritage Committee would be willing to list another historic city in Yemen, given the current number of violations in both Sana'a and Zabid. However, unlike Zabid, there appears to be a real recognition and desire on the part of the Tarimis to valorize their city.

Whereas Zabid was listed as a center for Islamic learning, Tarim's Outstanding Universal Value (OUV) lies in its exportation of Islamic learning throughout the Indian Ocean region. Its ensemble of eclectic mansions, historic graveyards, manuscript library and historic mosques are the physical manifestations that represent a remarkable degree of integrity and authenticity. Tarim holds great reverence for Islamic visitors, particularly those from Southeast Asia. They flock to Tarim for religious studies or to seek out their ancestral graves, and many still hold strong ties to local families despite the distance of this diasporic population (Ho, 2006; Boxberger, 2002).

Two experts, Cristina Iamandi of Paris, France, and Sana'ani restoration architect, Abduallah Hadrami, accompanied the author to the site in March 2010 to perform the initial assessment for WH site potential. The former has been commissioned by SFD to prepare the Tentative List nomination dossier. The latter works as a local independent consultant for SFD.

Concrete structures pose less than a 5% incursion of inappropriate construction to the built environment of the city. Although some of the new buildings can be lime-washed to die-out into the background, those with cantilevered balconies are particularly inappropriate. Predictably, the majority of the concrete structures are found along the city's entrance roads and tend to be commercial in nature.

Proposed legislation for the protection of historic cities was under review by Yemen's Prime Minister, and was heading for debate in parliament in April 2010. The outcome has yet to be finalized, and given the current political strife, it is difficult to imagine that cultural heritage preservation will be given priority. Once the political situation is settled, however, a presidential decree should be issued with soft regulations: an end to permissions for cantilevered concrete façades, a closer review of proposed concrete construction for aesthetic compatibility, and an end to demolition of mud-brick structures. These steps are required to halt the city's loss of integrity and maintain status quo for Tarim's TL Nomination.

4. CONCLUSION

After more than a decade of building community awareness and capacity-raising amongst NGOs, Tarim finds itself on the cusp of a renaissance. Discussions with local stakeholders and the Minister of Culture have concluded that there are many potential adaptive-reuse strategies for the abandoned mansions, including a much-needed larger home for the manuscript library (Qasr Abd al-Rahman Bin Sheikh al-Kaf), a computer-learning center and contemporary lending library (Dar Bin Sahel), an al-

Kaf family museum (Dar Muhdhar), and a traditional crafts center (al-Fijr). Al-Mudarrabah and Bir Yimani, two country estates considered beyond repair, have Neo-Classical garden follies in ruinous condition, but if stabilized, they would make excellent backdrops for traditional cultural events, such as poetry readings and musical performances. Al-Riyadh, Dar al-Salam and Hamtut are in close enough proximity to be operated under a single management as boutique hotels catering to Southeast Asian visitors.

However, the question still remains on how to resolve ownership issues, and this can perhaps be done through BOT (build, operate, transfer) agreements, wherein the government and/or private enterprises could take out long-term leases on abandoned properties, restoring and converting them to public use for a period of 30 years and then returning them in good condition to the owners. This would satisfy the complaint of the latter that they have never been compensated for the poor condition in which the buildings were handed over to them, following the end of their expropriation. At the same time, it would give the government the excuse to expend money repairing privately-owned buildings, as well as solve the need for housing public cultural institutions in the revitalized city of Tarim.

Notes

(1) This paper is written in the memory of two deceased colleagues who worked with me over the years in Yemen: James Conlon (1972-2009), director of Columbia University's Visual Media Center, and Selma al-Radi (1939-2010), Research Fellow at New York University's Institute of Fine Arts.
(2) It is interesting to note the use of lime plaster as waterproofing for roofs, parapets and ground-floor façades in the Wadi Hadhramaut. Depending on rains, this treatment can provide 10-20 years of water-repellent surfaces (Jerome, 2000, p. 145 and 2006, p. 148).

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EARTHEN ARCHITECTURE: HELPING THE VICTIMS OF THE 2007 FLOOD IN BANDIAGARA, MALI

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Theme 4: Conservation and Development of Human Settlements and Cultural Landscapes
Keywords: Climatic change, flood, improved traditional techniques, development

Abstract

On 4 July 2007, the river crossing the city of Bandiagara overflowed due to unusually heavy rains. Within few minutes, 194 families (nearly 1,500 people), witnessed the devastation of all or part of their homes and means of subsistence. At that time, the Cultural Mission of Bandiagara and CRAterre were collaborating in the framework of the project "Renforcement des capacités locales pour une meilleure contribution du secteur de la construction au développement durable du pays dogon" (Reinforcement of local capacities for a better contribution of the construction sector to the sustainable development of Dogon country) financed by the European Union; they called upon institutions to enable them to include, as part of their activities, a contribution to the reconstruction of basic housing structures. The German organization "Misereor" and the Abbé Pierre Foundation, based in France, responded positively by funding the reconstruction of 20 houses for sheltering the most affected families.

The project was carried out in collaboration with the local Catholic Parish (Caritas), the municipality, the Flood Victims' Association, district chiefs, and the prefecture. A Committee was established to carefully select the 20 recipient families, which would commit to collecting materials from their affected properties and participate in the construction-training activities implemented. This reconstruction project benefited from the results of an inventory of the building cultures in Dogon country that included the study of land plots, building typologies and construction techniques. On the basis of these principles, 20 basic houses were designed and built, each with a different plan, defined by the types of materials recovered, the priorities identified by the families and the possibilities for future extensions. The reconstruction process was an opportunity to demonstrate and train workers to master innovative flood-proof building techniques and combine them with traditional practices.

1. INTRODUCTION

Due to perceptible climatic change in the Sahel over the past decade, localized torrential rains have generated a sudden and brutal rise of waters never before seen on the Dogon Plateau (Garnier, Moles, Caimi, Gandreau, and Hofmann, 2011). On 4 July 2007, high waves burst the Yamé riverbed, a tributary of the River Níger, that passes through Bandiagara. In the town of Bandiagara, many families living along the Yamé River lost almost everything (homes, food stocks, materials, etc). In light of the seriousness of this catastrophe, volunteers brought emergency aid to ease the suffering of the victims. Within this framework, the Cultural Mission of Bandiagara and CRAterre launched the idea of a reconstruction program for the most affected families, which would complement efforts by the municipality to provide the affected families with land to build on (Cissé, Joffroy, Garnier, Chamodot, Cloquet and Fecher, 2010). After a pilot study (Léon house) that helped define the technical and financial references, a project proposal was developed and submitted to Misereor through the Catholic parish, and then to the Abbé Pierre Foundation (Cissé, Dembele, Cornet, and Joffroy, 2011). The project became a reality when funds were obtained for the construction of houses for 20 families affected by the floods, which – together with the pilot study family – brought to 21 the number of beneficiary families.

The complementary activity for training workers on the building sites was financed by the European Union within the framework of the project "Reinforcement of local capacities for a better contribution of the construction sector to the sustainable development of Dogon Country", which had been running since 2007. On the ground, the project brought together the skills of the Catholic parish through Caritas/APH, the Cultural Mission of Bandiagara, CRAterre and the architectural firm Audex. In order to follow-up the implementation of the project, Misereor

Fig.1 The house built for the Adama Dramé family – AP4 (credits: CRAterre, Joffroy Thierry, 2010)

also engaged two technicians from the Bafoussam Professional Centre in Cameroon, which enabled a South-South exchange.

2. APPROACH AND STRATEGY FOR PROJECT IMPLEMENTATION

The underlying idea of the project was to use the reconstruction effort to demonstrate that the use of local materials, especially earth, can be compatible with resistance to adverse weather, and that this type of sustainable construction could be affordable and accessible to more people. In fact, with a budget of 3,000 euros per family, it is indeed possible to achieve quality construction and to have enough space to re-settle families in decent conditions. The costs of construction to such a standard would also ensure favourable conditions for the extension of future homes, as well as duplication of these methods by the masons trained in improved construction techniques.

The project was also able to show how such reconstruction projects could be carried out in a sympathetic manner, while adapting to:

• The priority needs of the families in the construction program;
• The specificities of the land and the distinct constraints of common ownership;
• The real possibilities that each beneficiary had something to contribute.

This contribution would allow to propose of certain additions to each family's construction plan (extra rooms, fencing, covered balconies, etc). Each family could choose from among:

• Participation through volunteer labor; in this case, a work-day is estimated at the same price as a laborer or mason hired for the project, and the overall is taken into account;
• Contribution of materials (reuse of recovered materials, production and supply of earthen bricks, contributions in sand, stone or other local resources, etc.);
• Financial contribution.

In this way, each family receives an identical 'base' financial package, but can have a variety of proposed construction plans, adapted to each layout, instead of replicating any single model.

Concerning the strategy for the dissemination of knowledge, it was envisaged that the project would have three main phases; at each stage, masons would be trained to independently take charge of a site at the next phase.

• Phase 1: Pilot sites for two families. These site projects would support training, i.e. Be a 'training project'. Each of the two site projects would be executed by a team of three trainee masons, each of whom would become trainers on the next site project, with the support of technicians hired for the project.
• Phase 2: The idea was that the head masons of six projects would be those who were trained in Phase 1; a newly recruited mason would have to help them in their work and thus benefit from their experience to learn and in turn become the head mason in the last phase.
• Phase 3: This last phase of the project involved the last 12 families, and at this stage a dozen masons who, theoretically, were autonomous enough to lead the process.

This phase also allowed to put in place a training strategy that resulted in 12 masons and 24 laborers (each mason being accompanied on the site by two laborers).

3. SELECTION OF BENEFICIARIES

Since the available funds would not be able to assist all of the victims, the organizations in charge of the implementation of the project established 12 criteria that would enable the most vulnerable families to access the resources of the reconstruction-assistance project. A call for applications was launched on 28 September 2009 through posters at relevant buildings and services, such as the Town Hall, the Prefecture, *Conseil de Cercle* (District chiefs), APH, etc., as well as through announcements on local radio stations. Finally, a meeting took place with the area chiefs and the Flood Victims' Association. An application dossier was developed to facilitate the evaluation of candidates based on the established criteria.

In order to select the beneficiaries from the 44 applicants, a selection committee was established, comprising technical-services representatives from Urbanism and Settlement, Decontamination and the Fight against Noise and Pollution, the Municipality of Bandiagara, Caritas/OPAH Bandiagara, the Flood Victims Association, the Cultural Mission of Bandiagara, and the architectural firm Audex.

The establishment of the final list of beneficiaries was made in the course of three meetings and site visits facilitated by the City Council. The results were announced through posters and on local radio, following which the 20 beneficiaries were invited to the Cultural Mission to be briefed in more detail on:

• The voting and selection process;
• The overall principles for the works, ie:
• A fixed financial package for each family and the possibility to enhance the construction plans depending on each family's own contribution;

Fig.2 Left: Analysis of urban fabric in Bandiagara and traditional organization of a house plot. Right: Description of the house building parts (credits: CRAterre, Mathilde Chamodot, Basile Cloquet, 2008)

• The possibility for each family to define the plan that best suits it according to their specific needs within a range of proposed features (bedrooms, living rooms, covered balconies, verandas, latrines, fencing, etc.);
• The availability of local materials (especially earth), etc.
• The division of the reconstruction program into several phases and the impending construction works at the first two projects/building sites.
• The meeting also had a question-and-answer session.

4. PERSONALIZED DESIGNS

This work was carried out on the basis of an inventory of building cultures in Dogon Country, previously carried out by the Cultural Mission, NGO Radev-Mali and CRAterre within the framework of the EC-funded project "Reinforcement of local capacities for a better contribution of the construction sector to the sustainable development of Dogon Country". This enabled us to focus on the bigger elements, at the level of contemporary local practices for land (plots) use, as well as on construction typologies, included in Bandiagara (Chamodot, and Cloquet, 2008; Cissé and Joffroy, 2006).

Using the results of this work, base models were conceived: one-bedroom, two or three rooms, balcony, covered veranda, bathroom unit, and kitchen. Aside from these models, numerous combinations could be offered. Concurrently, each model was cost-estimated, which also made it possible to make quick calculations on the price of planning proposals that would come out of the discussions with the beneficiary families. A table of costs was developed, allowing us to make variations based on different parameters: the amount of each component selected for the construction (e.g. one, two or three rooms, one kitchen or none, one bathroom unit), as well as the type of finishes (sealant, screed, etc.). Despite the amount of time it took to put this tool in place at the beginning of the project, it was indispensable for customizing the plans.

The specificities of each beneficiary family – and also of the environment and the urban framework within which the constructions will happen – have, since the formulation of the project, caused us to think about developing a participatory effort that would allow us to take into consideration:

• The priority needs of each family;
• Their capacity to contribute (financially or in kind);
• The necessity to protect against strong winds (and rain) from the east;
• The orientation, nature (rocky or not), slope and characteristics of common land ownership (water outlets, buildings on the edge of plots, etc.).

To this end, the representatives of the relevant technical organizations (Cultural Mission, CRAterre and the architectural firm Audex) organized a series of individual meetings and site visits with the beneficiaries so that they could express their needs and priorities, and also give their opinions on the proposed plans and the actual implementation strategy.

4.1 Description of the process for designing plots distribution

The implementation strategy was as follows:

• A first meeting made it possible to list the particular needs of each family, to identify the priorities, to take note of some technical or aesthetic preferences (rendering, types of windows), optional additions of other details (e.g. ventilation duct) and to be conscious of potential recommendations. It was also an opportunity to confirm the commitment that each family pledged in their application, so as to better assess the amount needed and the additional funding possibilities.
• Working time (without the family) was then set aside to develop the proposals to be submitted to the families, keeping

Fig.3 Work sessions with the beneficiaries (credits: CRAterre, Laure Cornet, 2009)

in mind their demonstrated needs and the financial package available to the family based on their own contribution.

- A second meeting took place, whereby each family was presented with the various proposals that fit within the given budget (at least two different choices, and sometimes as many as five, given the possible combinations). The decision was then made with the help of a prepared model, allowing the families to get a better idea of their construction project and how it would fit into their plot.
- The approval of one proposal was then made by the family, either on the same day, or after consultation with other family members.
- The family was invited one last time to the Cultural Mission to sign a contract.

Each "dossier family" was finally established with the following documentation:

- Application;
- Needs/recommendations and specific choices;
- Proposal of options;
- Approval/selection of one of the proposed options;
- Estimated budget according to the options selected by the family;
- Technical file (plans) – building permit;
- Model and photo;
- Contract between the family and the partners (and, eventually, receipt for the funds);
- Construction follow-up forms;
- Eventually, the family's budgetary participation, kept at the Cultural Mission of Bandiagara.

The dossier remains available for consultation at all times by the beneficiary family; particularly the model, to which everyone can easily refer.

5. DESCRIPTION OF THE MAJOR BUILDING PHASES

The works were initially planned in such a way as to have three phases, which would allow for the training of masons and transmission of expertise during the different building stages. The order of the construction was not left to chance, and a strategic choice was made. The first two site projects and plots were selected because of their proximity to the Cultural Mission of Bandiagara and their proximity to each other, to facilitate movement by the technicians between the projects and follow-up.

Another criterion was added to this: the first two families to benefit from the program were also among the most needy; as such, it was decided to prioritize widowed women with no resources. The second group (six projects) was established in the same way, with plots located in a restricted area and families in the most difficulty. The third phase, which in theory would require fewer follow-ups, involved the remaining 12 families.

It is important to note that the training strategy was not able to completely fulfill its objectives. The masons trained in the first and second phases of the works exhibited varying levels and apprenticeship ability. As such, at the end of the second phase, those masons who were sufficiently independent and competent were allocated site projects, whereas the others stayed in their role of assistant.

5.1 First phase

The procedure with the first two families was launched at the beginning of November 2009 and the two (2) site projects (on plots O/6 and R/1) were started soon thereafter, on 19 November. The training element was also primarily made possible through support of a technician from Audex and the Cameroonian foreman made available by Misereor. The technician from Audex, having worked closely with CRAterre since the end of 2007 within the framework of the EC-funded program, already participated in several projects of this nature (in terms of local material, especially earth), and was thus able to become a trainer at this stage.

Through some sessions on theory by the CRAterre expert at the beginning of the work, the masons and the supervisory staff were reminded of some basic principles. In fact, the work should have begun with the professionals who had already benefited from training sessions within the framework of the EC-funded program, and who were already skilled in improved earthen-construction techniques. It was important to count on competent masons, who were able to transmit their skills.

Fig.4 Construction of cupolas (credits: CRAterre, Laure Cornet, 2010)

5.2 Second phase

The second phase of six building projects was initiated on 22 December 2009. At this stage, six extra masons joined the main team, bringing the team to a total of 12 masons, each builder working with two laborers. Therefore, about 36 professionals were working simultaneously, which explains the speed of the works. Midway through the project, a session of technical review was carried out, so as to emphasize some details that were still not being observed and, perhaps, misunderstood. This short training, which was both theoretical and practical, was organized by leaning heavily on the technicians on site, so as to reaffirm their role as trainers of the builders, and as the ones who would ensure the proper execution of the work.

A supplementary training session was organized during this phase, in February 2010, for the construction of kitchens that were built without wood, and whose roofs were domed, made from unfired-earthen bricks (adobe). The transmission of skills having been accomplished, the local team carried out the next cupola projects independently.

5.3 Third phase

This last phase of execution was launched on 8 February 2010, simultaneously with the second round of works on the first eight contracts. The work plan was developed with the aim of finishing the construction and handing over the keys to the beneficiaries before the onset of the rainy season. In order to allow enough time for the houses to dry before plastering, the project advanced slowly. It was first of all preceded by the execution of the main work of the last houses, then the complete execution of the finishes (plasterwork, interiors and exteriors, floors, balconies, placing of doors and windows) of the first eight houses, and then for all of the remaining houses.

Unfortunately, at this stage, the pond from which the water was drawn ran dry. To overcome this obstacle, it was necessary to transport water from a source about 5 km from the town of Bandiagara. This was made possible thanks to the support of the Catholic Mission that provided a mobile tanker, with the pick-up truck of the Cultural Mission. This exemplified the importance of planning the projects well from the beginning, when faced with this type of climate. In this way the construction work, which used a lot of water, were carried out before embarking on the finishing touches. This was also what was done from the beginning of the project with the estimate of the number of bricks that would be required for all the building sites and the anticipated mass production of adobe just after the rainy season, so as to take advantage of the natural reserves of rainwater.

Fig.5 Construction of cupolas (credits: CRAterre, Laure Cornet, 2010)

6. CONCLUSION

Despite some difficulties during the implementation, and a slight delay in the anticipated delivery date, all the social partners of Bandiagara deemed the execution of this project as a success. The handing over of the keys occurred right at the beginning of the rainy season (early July 2010), which also provided shelter for the beneficiaries during that time.

On the whole, the follow-up and training program was fruitful. It is now clear that the strategy to have the builders become progressively more responsible should have been revised based of the different levels expertise they gained; we are nonetheless aware that an investment in training allowed us to strengthen and eventually multiply the skills for the execution of a building project by young builders.

Through the promotion of local materials and practices, the project created a lot of employment for builders, laborers, transporters, etc., which resulted in increased economic benefits for the population of Bandiagara. In addition, the construction of the buildings allowed the masons, laborers and brick builders to learn new techniques. The project thus introduced ideas and skills that are today being built upon to improve the availability of basic housing.

After the rainy season, most of the project homes were the subject of new works, executed by the families to expand their basic housing (addition of extra rooms), or to finish the funds provided (equipping the kitchen, boundary wall, etc.). The evolutionary aspect of the homes, through the integration of lintels in the masonry, allowed the placement of doors in the walls. As such, the beneficiaries could easily add rooms, economizing on wall space and overall space on plots that are often home to many families.

As flood victims, their first instinct would have been to build new houses out of concrete blocks and sheet metal – which would have been smaller. Based on the experience in the improvement of traditional homes (foundations, method of execution of the basement, capillary barriers, quality of bricks, etc.), the local technicians and the families are now convinced about the potential of high-quality earthen construction, suited to their own means.

It is worth noting that this acceptance was especially demonstrated by some people on projects outside this program, who adopted technical details or proposed construction typologies. The technicians have also had some initiatives and started to apply, when they deemed fit, certain construction principles learnt in the course of the reconstruction project. This was notably the case in the construction of the boarding facility for students at the Protestant parish.

In addition, the project was visited by representatives of Delegation of the European Union in Bamako, as well as the Governor of the Mopti region, and His Excellency Mohamed El Moctar, the Minister of Culture. This visit took place on 7 May 2010, with the political and administrative authorities of the District of Bandiagara. This was good publicity to show the authorities the possibilities offered by the effective use of local materials.

Fig.6 Adobes ready for the recovery (credits: CRAterre, Thierry Joffroy, 2011)

As a result of its success, the reconstruction program came to the attention of the national television station's programming editors. A news-reporting team was sent to Bandiagara by the directors of the station; this resulted in a 10-minute program broadcast in a widely-listened-to one-hour slot during the course of March 2011, and several more times in the same year.

With regard to the results and benefits, it can be stated that the project fulfilled the expectations of both the partners and the participants. For the beneficiaries, the flood of 2007 is now but a bad memory for them. Thanks to this humanitarian action, communities were able to be housed and, above all, to have a home of their own for their children and their parents.

This resettling was undertaken with a view to establishing a procedure for sustainable development, while strengthening the capacities of the building workers and technicians. It also provided a better understanding for the local and national authorities of the solutions offered by local materials (Manifesto, nd). For the local population, this project increased their resilience by decreasing dependence on foreign construction techniques and materials.

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THE MANAGEMENT PLANNING PROCESS, A CONSERVATION AND DEVELOPMENT TOOL FOR KSAR AIT BEN HADDOU, MOROCCO

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Theme 4: Conservation and Development of Human Settlements and Cultural Landscapes
Keywords: Participatory management planning, revitalization of abandoned sites, earthen World Heritage, conservation of architectural values

Abstract

The first management plan for Ait Ben Haddou was produced in 2006, 19 years after the inscription of the Ksar on the World Heritage List. Despite the high number of visitors attracted to this emblematic site, the Ksar had lost its soul and was quickly deteriorating; its function had become purely commercial, and served the business interests of tour operators and souvenir dealers from outside. The anarchic movement of visitors in the ruins reflected the poor management of this prestigious place, which generated no benefits for the local population.

The management plan was developed over a period of one year with the active participation of the population, all the government agencies active in the region, and the heritage technicians based in Ouarzazate. This paper describes the various steps of this participatory process that involved 67 people, and brought this World Heritage jewel back into the framework of municipal development strategy. All the activities integrated in the document were suggested by the stakeholders, who slowly formulated the plan through a series of workshops, with the support of CERKAS professionals and a CRAterre expert. The full transparency in the discussions and the wide dissemination of the plan in both French and Arabic languages led to the prompt implementation of many activities, and brought positive changes into the life of the local population (water supply, cleanliness and safety, and street paving, to name a few).

Five years after the preparation of the plan, we can assess its impact on private and public initiatives, and list all of the activities, which were made possible because of the better distribution of roles and responsibilities. The site has been revitalized thanks to the increased number of actors who, rather than fight for selfish interests, have a common vision for the place.

1. PRESENTATION OF THE SITE

Like many historic villages in southern Morocco, Ksar Ait Ben Haddou has lost its function as a dwelling place, and was abandoned in favor of a new village built on the other side of the Wadi (1), more comfortable, better served and closer to services. The Ksar has, however, kept its splendor and annually attracts hundreds of thousands of visitors fascinated by the natural beauty of this site perched on the mountain. The site was listed on the World Heritage List since 1987 (UNESCO-WHC, nd).

This status has not prevented the continuous deterioration of the structures and the gradual population decline. In 2006, only nine houses were occupied and two-thirds of the village had collapsed. Anarchic movement of visitors within the ruins and the proliferation of souvenir shops reflected the poor management of this prestigious property, which brought no benefits to the local population. The site presented extraordinary strengths that many other sites would dream of having to revitalize the

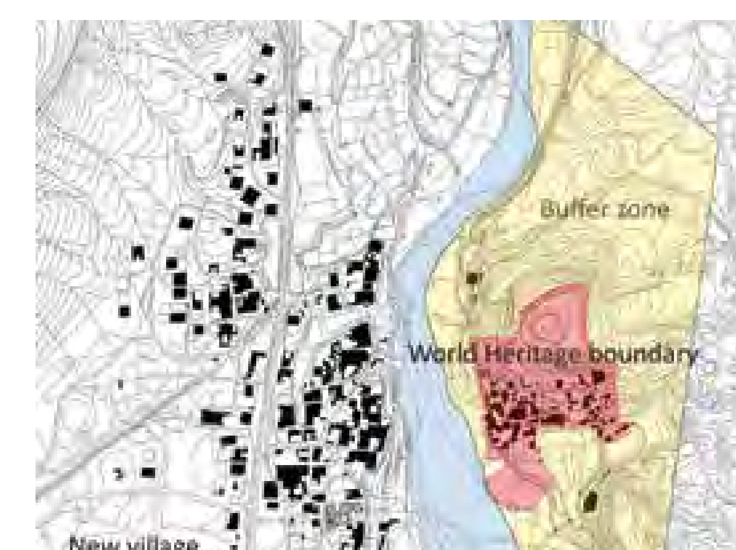

Fig.1 Site Map of the Ksar Ait Ben Haddou (credits: Sébastien Moriset, 2009)

Fig.2 Ait Ben Haddou, Morocco (credits: Sebastien Moriset, 2010)

community and achieve exemplary management:

- Easy access;
- High number of visitors attracted by the international reputation of the site;
- A young population available around the site;
- Extensive documentation produced by successive groups of international and Moroccan experts, scholars and students;
- A thriving film-industry activity (shooting of blockbusters such as Gladiator or Prince of Persia on site);
- Administrative and technical state services within a radius of 30 km.

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- Easy access;
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- A thriving film-industry activity (shooting of blockbusters such as Gladiator or Prince of Persia on site);
- Administrative and technical state services within a radius of 30 km.

2. THE NEED FOR A PARTICIPATORY MANAGEMENT PLAN

To ensure the conservation of the values for which the Ksar was enlisted in 1987, UNESCO called upon the State Party of Morocco to produce a site-management plan in 2002. The need was especially pressing because a large number of alarming reports about the continued deterioration and implementation of inappropriate projects at the site had been received since its inscription. Each expert sent to the site had made recommendations and proposals to safeguard the property, but none of the proposed ideas could be implemented, since they were not formulated with the active participation of the public and local stakeholders. Some recommendations even contributed to discourage the few local conservation initiatives, by suggesting that massive funding from outside would soon allow a complete restoration of the houses.

Within this context, the site suffered from a lack of transparency in its management, and its future was unclear. The visions were multiple and conflicting, and served the interests of their authors, not those of the community. There were almost as many views as stakeholders related to the site. In all the scenarios, the municipality itself did not include the Ksar in its development initiatives, as it was seen as a source of conflict rather than a mine of wealth to be exploited. It was thus necessary to initiate the formulation of a shared plan, involving all the parties linked to the site, either for cultural, sentimental or professional reasons.

3. THE PLANNING PROCESS

3.1 People involved and methodology

The formulation of the management plan mobilized 67 people representing three main groups of stakeholders:

- Public sector personnel responsible for the development of the municipality and/or conservation of the Ksar (Municipality staff, Ministries' representatives, various state Departments, Technical Services – in total, 23 institutions were represented);
- People with an interest in the site, represented by residents' associations, business owners, guides etc, amongst others;
- Heritage experts and external consultants.

Three workshops were needed to develop the structure of the management plan. They lasted a full day each and required several days of preparation. For the first workshop, for example, a comprehensive review of all the available literature on Ait Ben Haddou (over 30 reports and books) was conducted. It lasted three days and resulted in the drafting of a very detailed SWOT analysis, which was then reworked by the stakeholders.

The supervision of the process and the preparation of the final document were handled by the two authors of this article, who also facilitated the stakeholders meetings. The process unfolded throughout 2006 and the document was released at the end of the year in French. It was translated into Arabic and disseminated in 2007.

3.2 Editing and dissemination of group-work results

The documents produced during each workshop were edited and distributed to all stakeholders within a week in order to maintain their enthusiasm and develop a sense of responsibility. The realization that their words were recorded, and were gradually fed into a meaningful document motivated the participants who followed the exercise with passion up to the end.

A special effort was made to produce a short and clear document for easy use. The management plan was synthesized into 60 pages plus ten pages for appendices. These 60 pages contain 81 graphic illustrations including 50 photographs, 11 maps/plans and 12 tables and diagrams.

To clarify the roles of the key actors, six pages of the document are devoted to the responsibilities of each institution and each of the stakeholders' subgroups. This part was not achieved at the beginning of the year because the responsibilities were often confusing, even for the groups themselves.

3.3 Planning actions

The action plan contained in the document presents a set of precise activities, listed under four objectives:

1. Revitalization of the site
2. Preservation of the architectural values
3. Better distribution of the profits generated by the site
4. Improvement of the visitor experience

The stakeholders suggested these activities themselves, especially during the second and third workshops. Many more activities were actually suggested but only a few were kept. The activities rejected were those for which no party was willing to take responsibility, either because they were too complex or because they were totally unrealistic.

3.4 First results on the ground

The transparent process of preparing the management plan has generated confidence in the regional institutions, especially by the Ministries in Rabat. The widespread dissemination of the management plan in two versions, French and Arabic, has accelerated fundraising for the implementation of many actions between 2007 and 2009. These first projects were achieved thanks to the regular meeting of local Management Committee, who play an active role in implementing and monitoring daily activities:

- Installation of water points (financed by ONEP: National Potable Water Agency);
- Construction of a ticket office (funded by the Ministry of Culture);
- Maintenance and extension of the paved streets (funded by the Ministry of the Interior);
- Restoration of the fortifications and historic walls of the Ksar (funded by the Ministry of Culture). The preliminary studies and design of this project were conducted by CRAterre in collaboration with CERKAS and funded by the World Heritage Fund;
- Completion of the reception office, installation of dustbins and closing up some access routes (funded by the World Heritage Centre);
- Completion of the technical studies for the construction of the bridge and the installation of the sewage system;

		Workshops Program		Results
2006	1	*Morning* - Presentation of the process - Work on the vision	*Afternoon* - Work on the SWOT - Work on the objectives	- SWOT updated - Common vision drafted - Objectives defined
	2	*Morning* - Vision updated - Work on the action plan	*Afternoon* - Work on the action plan - Presentation of the group work results	- Action plan drafted
	3	*Morning* - Action plan finalized - Work on the responsibilities	*Afternoon* - Work on the financial arrangements	- Action plan finalized - Mechanism for the use of the financial benefits proposed
	4	On Friday, April 28, 2006, the action plan discussed at the local level was presented in Rabat to the members of the National Management Committee at the Ministry of Culture in the presence of the Director of the UNESCO Office in Rabat		- Approval of the action plan at the national level
2007 and after		Regular Management Committee meetings - Convened by the Governor of the Province of Ouarzazate		- Responsibilities and tasks clearly defined - Regular progress observed on the field

Table 1. The main steps of the management-planning process (credits: authors)

Fig.3 and Fig.4 One of the groups during workshop 1 and discussions during workshop 3 (credits: Sebastien Moriset, 2006)

• Installation of gabions (2) (funded by the High Commission for Water and Forests).

Beyond the visible positive impact on the site and on the atmosphere of the village, the ongoing work has triggered a determination to safeguard the outstanding universal values of the Ksar, to make them better understood and recognized by all. The success of the first actions also strengthened the role of the management plan, accepted as an efficient tool and essential reference document.

3.5 An ongoing process

The Management Committee, under the chairmanship of the Governor of the Province of Ouarzazate, continues to meet regularly to adjust and decide on activities to be undertaken within the framework of the management plan. At each meeting, CERKAS officials present a report on the state of conservation, project progress and problems observed. In the field, a monitoring committee, which includes the police, tours the site twice a month, to ensure that building regulations are not violated, thus controlling the evolution of the site.
Among the projects recently completed or in progress, it may be noted that:

• Funding for the sanitation project managed by the National Water Agency comes from the Belgian government;
• The Provincial Delegation of Health conducted the training of two young residents to ensure the provision of first aid at the site. The first-aid room has already been prepared inside the Ksar, with support from both the Ministry of Culture and the World Heritage Centre;
• The restoration of walls, floors and roofs within the Ksar was funded by the Ministry of Culture;
• The construction of the bridge, the symbolic connection of the Ksar and the new village, has marked a decisive step in the integration of the heritage site into the overall Municipal development policy.

3.6 Residents' role in the implementation of actions

In addition to the previously described actions, managed to a large extent by CERKAS, substantial results have been achieved by private owners who have regained confidence in

Fig.5 Tourists climbing (credits: Sebastien Moriset, 2004)

the site. The most remarkable one is the complete restoration of a private house inside the Ksar. This home, which was ruined, now includes guest rooms and a weaving workshop for women. Today, about 20 people are working there. In parallel, an association named Anarouz was created by the weavers of the Ksar. This private action initiated by women has proven the relevance to reinvest in the old village, and showed that it was even possible to create sustainable jobs.

To support the restoration and revitalization efforts by the population, CERKAS will establish a branch office in Ait Ben Haddou to provide technical advice. The technical expertise offered by CERKAS will be accompanied by material aid in the form of equipment loans. CERKAS has a large stock of equipment (scaffolds, rammed-earth formworks, adobe molds, scales, wheelbarrows, hoses, buckets, shovels, picks, sledge hammers, levels) purchased with funding from UNESCO to be lent to the population to facilitate repairs.

3.7 Establishment of a mechanism for collecting and redistributing income

Following the recommendations of the management plan and numerous management meetings, the idea of opening a special account for the conservation of the Ksar Ait Ben Haddou was established. This account should help improve the collection and redistribution of income from the site. This Municipal Council adopted this idea at a special meeting on October 29, 2008. The main income into the account will come from entry fees, and taxes paid by film producers and other tourism and commercial activities taking place in Ait Ben Haddou. This special account is entirely devoted to the conservation, rehabilitation of the Ksar, as well as to the creation of other income-generating activities proposed by the residents themselves in consultation with the local Management Committee.

Fig.6 New pathways bringing visitors to the top of the hill (credits: Sebastien Moriset, 2004)

3.8 Local, national and international dissemination of the management plan

The management plan, which exists in French and Arabic (Moriset, and Boussalh, 2007) was distributed to all local and national institutions involved in the preservation of the Ksar and members of the local Management Committee. It was also sent to the National Management Committee in Rabat and to the World Heritage Centre. At its meeting in 2009, the UNESCO World Heritage Committee noted the progress made regarding implementation of the management plan.

4. LESSONS LEARNT

Working in groups took a lot of organization and preparation, but has brought real benefits in terms of management:

• Stakeholders are now more aware of their roles and work together;
• The division of responsibilities between UNESCO, the Ministry in Rabat, regional institutions and local stakeholders is now clarified;
• Fewer resources are wasted because there is no duplication of efforts;
• Residents and users better respect the site and know they are actors and not victims of its development.

Five years after developing the management plan, real changes can be seen on site, and the goal of combining conservation and development is partly achieved. Women have created jobs in the Ksar and this is one of the remarkable results of this slow revitalization. The construction of the bridge in 2011 has opened the door to faster development, and it will be necessary to revise the plan and set new objectives for 2016. Defining a new action plan becomes a priority, especially as some owners have expressed their desire to create tourism-related activities in their properties. Several requests have been received by Cerkas and by the Ouarzazate-Zagora urban-planning office, and we must unite forces to produce a new management plan shared by all.

Notes

(1) A wadi is a dry ephemeral riverbed that only contains water during heavy rainfalls.
(2) Gabions are cages filled with rocks laid along the wadi banks for erosion control.

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NEW GOURNA, EGYPT: CONSERVATION AND COMMUNITY

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Theme 4: Conservation and Development of Human Settlements and Cultural Landscapes
Keywords: Human settlement, cultural landscape, urban conservation

Abstract

In 2009, UNESCO initiated a Safeguarding Project of Hassan Fathy's New Gourna Village. In 2010, after New Gourna was included on the World Monuments Watch, World Monuments Fund (WMF) joined forces with UNESCO to evaluate conditions. WMF's contribution included a community assessment to integrate social and economic concerns into decision-making about the future of the village.

The findings of the assessment underscore difficult challenges regarding the conservation of human settlements and the complex relationship between people and heritage. Hassan Fathy inspired a new generation of practitioners worldwide through his integration of earthen materials with modern architectural principles. His innovative mixed-use plan for New Gourna, incorporating schools and other public buildings, remains a powerful and well-preserved element of the village; however, nearly 40 percent of the original buildings have been lost and many have been significantly modified.

The loss and modification of these structures are attributable to a number of factors, including changing environmental conditions, technical issues, as well as evolving social dynamics. In short, Fathy's buildings, in their traditional form, do not effectively meet the needs of most inhabitants today. To ensure the sustainability of the community, as well as preserve the legacy of Fathy, this social reality must be reconciled with the goals of protecting this earthen architecture icon. The process of creating – and now conserving -- New Gourna is as important as the product itself.

Fathy championed the inclusion and empowerment of society's less fortunate through participation in design and building processes, a signature theme in his seminal publication, Architecture for the Poor. As planning for the village moves forward, particularly in light of political shifts, such engagement will be evermore critical. This paper addresses the tensions between heritage conservation and social needs, and examines how community participation can serve as a tool to forge common aims.

1. INTRODUCTION

At New Gourna, Hassan Fathy undertook an experiment to promote vernacular building traditions and integrated planning through participatory design and construction. Intended as a model public housing project and perhaps the codification of a national style, the mud-brick domed dwellings gained international attention and are today considered early experiments with appropriate technology and sustainable architectural systems. Fathy also insisted on the construction of schools, as well as a mosque, a khan, and a souk within the village. While many original Fathy buildings have been renovated or replaced, the New Gourna community thrives. The village remains a place strongly rooted in the social principles set forth in Fathy's mixed use plan, which centered on education, commerce, and religion.

This small, experimental village remains a focus of global interest. New Gourna was nominated to the World Monuments Watch in 2010, just as UNESCO spearheaded an initiative to safeguard the village. In collaboration with UNESCO and the Luxor Governorate, World Monuments Fund (WMF) undertook an assessment study in the fall of 2010 to understand the relationship between the people and place of New Gourna, which included a survey and interviews with more than a third of New Gourna's households (1) (Haney, Allen, Avrami, and Raynolds, 2011).

One of the most poignant lessons learned by Hassan Fathy in the experiment of New Gourna is that community participation is critical. To design or conserve a built environment requires understanding of its inhabitants – the ways in which they use and re-shape space, their quality of life, and their values. The residents of New Gourna are its primary stewards. The safeguarding and sustainability of the village hinge on effectively incorporating the concerns of the community into planning efforts. With this in mind, the aims of this assessment included the following:

- Analyze social and economic conditions;
- Identify factors of change within the community and environment;
- Study use of space and adaptation patterns;
- Examine the community's attachment to place and concerns for its future.

2. DIFFERENT STAKEHOLDERS, DIFFERENT VALUES

That New Gourna is a treasured place of great importance is not disputed by the various stakeholders associated with this architectural heritage and the Fathy tradition, from local residents to international scholars. However, there is less agreement with regard to the elements and values – tangible and intangible – that constitute its cultural significance. Therein lies a fundamental tension regarding how New Gourna should be preserved.

The conservation community has traditionally focused on original design and fabric. Scholarship in the field and shifting paradigms have engendered greater recognition of the evolution of the built environment over time. Yet New Gourna, as a planned community created during a distinct moment in history, seems to defy that notion.

As Fathy's greatest opus and most profound disappointment, the fact that the village and its design are an ever evolving construct is often lost, in reverence to the man and his legacy. As one looks upon the vestiges of this 65-year old experiment, with its graceful architecture and social idealism, it is difficult not to wish it whole again.

The reality, however, is that New Gourna has changed. As Fathy himself foresaw:

> … a village, after many generations have lived in it, comes not only to fit its inhabitants' routine of work and recreation, but grows to reflect the oddities of its community…The buildings take on the many-dimensioned shape of the society, as an old shoe takes the peculiar shape of one man's foot, or rather as some growing plant constantly adapts itself to its environment
>
> (Fathy, 1973, 51).

The village of New Gourna has indeed grown and adapted. Buildings have been modified, expanded, and replaced in response to evolving social, economic, and environmental factors. These same factors have spurred a common trend within the village to abandon the use of earthen materials in such alterations. This dynamic puts conservation interests, which champion Fathy's application of sustainable materials and vernacular forms, potentially at odds with those of local inhabitants.

3. FACTORS OF CHANGE

3.1 Environmental Factors

According to residents, a number of environmental factors have influenced the alteration and replacement of buildings within New Gourna, first and foremost of these is changes in groundwater conditions. Older residents who participated in New Gourna's construction maintain that the water table was approximately 3.5 meters below ground level 60 years ago and has now risen to approximately 40-50 cm below ground level. This may be attributed to a number of factors:

- Uncollected sewage is a significant problem that is potentially contributing to groundwater accumulation. Informal interviews conducted at the Egyptian Water and Waste Water Authority indicate that fresh water delivered through the West Bank piping network for domestic use amounts to around 400,000 m3 per month, while the collected sewage water is 40,000 m3per month—a shortfall of 90%.
- Local agricultural irrigation and run off, and recent regional irrigation projects and barrages (including the Aswan High Dam) are likely contributing factors to the rise of the water table.
- The increase in impervious surfaces within the village, including the paving of roads (near the mosque) and the use of concrete and fired brick in construction, have changed the patterns of groundwater percolation, surface evaporation, and run off.

These groundwater conditions increase the capillary rise of moisture and salt migration, contributing to the disaggregation of limestone within foundations and the de-cohesion of mud bricks. In walls, this results in significant basal erosion, destroying the outer wythes of earthen bricks. The lower courses show efflorescence, and the failure of the physicochemical matrix forms deepening concave features at the wall base. The degradation compromises structural integrity, thereby reducing the load-bearing capacity of foundations and lower story walls.

When repairs are made or buildings altered, residents tend to use cement-based materials, which are perceived to be more durable and to require less frequent maintenance than earthen materials, given the groundwater conditions.

3.2 Social factors

Complex social and economic factors likewise influence changes to the architecture, the most prevalent of these being growing households. Among surveyed households, more than half (52%) contain six to nine members; 27% contain from two to five members, and 12% contain more than nine members. Nearly all (90%) of those interviewed are married and most often live in households with an average of six members. The relatively large household size and the increasing number of households within New Gourna can be attributed to three main factors:

- Married sons are expected to raise their families close to or in their parents' home. This allows commodities and tasks to be shared and provides support for aging parents. As it is not possible to expand the footprint of buildings or to acquire adjacent land, many married sons live in the same dwelling as their parents, often on floors above.
- Some men take two or more wives, and custom requires them to provide housing for all wives equally. In several cases, Fathy homes have been split in half to accommodate two households; depending on available space this can mean two

Fig.1 New Gourna Resident showing effects of rising damp (credits: World Monuments Fund/Community Consortium, 2010)

kitchens and two bathrooms.

- In New Gourna, daughters remain in their parents' home until marriage. The costs associated with marriage in Egypt have climbed dramatically in recent decades and young people are consequently staying home longer and marrying older.

In short, New Gourna, as a thriving traditional community, must house a growing population. At the time construction was halted on New Gourna, the completed structures were intended to house 77 households. Extended families have expanded, and those same building plots now house the equivalent of 174 households. To accommodate these evolving needs, original buildings have been subdivided, enlarged, and in some cases replaced.

4. CHANGING FABRIC, ENDURING VALUES

4.1 Alterations to the architecture and construction materials

Many original structures have not survived in New Gourna. Among the remaining Fathy buildings of New Gourna, interior spaces have been refashioned to accommodate multiple households in dwellings intended for a single family's use, or have been altered and expanded with added extra floors. The following are typical alterations:

- Fathy's exterior open porches have been transformed into rooms, often small reception areas.
- Open loggias have been roofed and many domes demolished to accommodate more rooms on the second floor. Many residents feel unsafe under Fathy's domes, and find them impractical encroachments on usable space.
- Most archways, doorways, and window openings have been modified; retrofitted door and window components tend to be rectangular and smaller than the original opening. The voids are filled, substituted, or partially covered with cardboard or sheets of wood.
- Nearly all front rooms constitute the living or most public room (Fathy's intended use) and often double as sleeping quarters. These rooms are now generally entered from the street through a rectangular door frame. In many cases, Fathy's original arched entrances can been seen from the inside and as masonry traces on façades.
- Original open staircases have either been enclosed and/or have had balustrades added to accommodate changes in upper-floor usage and to ensure safety for the elderly and children.
- Almost every Fathy household has a cooking area and toilets. Many residents devote a room to stabling animals. When the house is divided to create a household for a married son or second wife, the second floor or second half of the house may lack these facilities.

These design alterations and the use of modern materials are largely perceived by the world beyond New Gourna, especially by those in the heritage conservation and earthen-architecture fields, as disregard for Fathy's original design. However, while Fathy's tangible legacy at New Gourna – the buildings and the materials – may be significantly altered, the intangible values that he promoted through both his plan and his collaborative-design process thrive.

4.2 Preservation of the plan and community vision

While the number of households in New Gourna has more than doubled and the architecture has changed, Fathy's plan has endured, both in design and vision. The mixed-use plan was extremely innovative for the time and place. While the mid-20th century is marked by a trend toward rational planning paradigms that segregated uses within urban environments, Fathy fully recognized the importance of providing for a concentrated diversity of spaces and services. Although he is recognized within the field of architecture – and especially earthen architecture – for his graceful design of buildings and sustainable materials, his plan was equally seminal with regard to land use and community development.

Today, altered houses and replacement residential structures generally do not extend beyond the original footprints. The public spaces that Fathy included in his plan for New Gourna have been adapted but generally remained, some to meet the evolving needs and demands of the community and some in response to change in the Qurna district. Many public structures have been retained, stabilized, and restored, while others have been reclaimed and adaptively reused.

A testimony to Fathy's enduring legacy, the mosque in New Gourna remains an intact and iconic centerpiece. Still today, New Gourna contains no other place for collective spiritual thought, and the landmark continues to form the moral fiber of community identity. It is also now home to a regional office of Awkaf property management. The public square in front of the mosque, now paved, remains as a public gathering space for residents, as does the khan.

Fathy's "village hall" has been replaced with a concrete structure, but it continues to serve a variety of community

Fig.2 New Gourna residents gathered in the khan (credits: World Monuments Fund/Community Consortium, 2010)

events, including weddings and funerals. Whenever possible, community members contribute small sums to maintain and clean the facility, as it continues to be an important piece of the social and physical fabric of New Gourna. A community member noted that if families prefer to hold celebrations at home or in the public space, the community hall lends its wooden benches at no cost.

Fathy insisted on the construction of schools as part of the integrated plan for New Gourna. The original plan specified that two schools, one for boys and one for girls, were to be constructed. Although the boys' school no longer exists in its original form and the girls' school was never built, New Gourna remains a place strongly tied to and proud of its history of accessible education. Today, a number of operating, mixed-gender schools are located in the immediate vicinity and are well attended by local children.

Envisioned as a place bustling with local merchants, Fathy's souk was, by 1961, an underused space. However, the former souk now houses the Upper Egypt Flour Mills storage area and distribution point; the company conveniently services New Gourna bakers and is the sole enterprise in the former souk. Understandably, commercial businesses have instead concentrated along al-Temsalyn Street, a major thoroughfare that now runs along the south perimeter of the village.

The continued use of interstitial space, a component of Fathy's overall vision for New Gourna, is an important component of the public landscape. Contemporary streetscapes containing sleeping benches (*mastabas*), makeshift stables, and creative plantings all reflect Fathy's original vision. Outlying agricultural lands have been continually used by residents of New Gourna for grazing, planting, and harvesting.

New Gourna continues to uphold the vision first employed by Hassan Fathy because unifying elements, mosque and mastabas alike, endure and change. The social principles of access to education, commerce, religion, and community, probably the most important set forth in Fathy's plan, are still manifest in the New Gourna of today.

The end result is a preserved plan and vision of New Gourna through adaptation, as well as densification. Such increases in density are the most sustainable way to manage urban growth and prevent sprawl around cities. Thus, in its evolution, New Gourna has ironically championed Fathy's principles of sustainability writ large. It has maintained a cultural tradition of close-knit families that maximize socio-economic efficiency through shared and adapted households. It has nurtured the value of education by providing easy access to schools and other social services. And, quite astonishingly, it has accommodated a growing population while minimizing the consumption of open space and land, thereby preserving the important agricultural resources that help support the community.

However, this phenomenon of densification is in potential conflict with heritage conservation, which tends to emphasize the traditional form and fabric of the cultural landscape. A primary challenge of any safeguarding efforts at New Gourna will be to resolve these tensions through conservation approaches that meet the full range of stakeholder interests.

5. A PARTICIPATORY PROCESS

This small experimental village is grappling with challenges similar to those of many larger, historic urban landscapes and settlements. Concerns regarding sustainable land use preclude expansion into open space surrounding towns and cities, and compel the need for increased density to accommodate growing urban populations. That densification can promote environmental, and often social and economic sustainability, but it can likewise erode historic fabric. In a place like New Gourna, what are the options for maintaining the village as a vibrant urban environment and also honoring the Fathy legacy? How can preservation work to the benefit of the local community, as well as the many other stakeholders that cherish this architectural icon?

The decisions residents have taken to remain in, manage, and maintain New Gourna derive from a host of factors. However, the modification of this landscape should not be readily dismissed as a lack of respect for Fathy's legacy. On the contrary, New Gourna holds significant meaning for its residents, with 78% wanting to remain in the village, and a large percentage wanting to remain in Fathy dwellings. This sense of grounding is accompanied by the realization of the significance of Fathy's work. Over half of interviewed residents believe that Hassan Fathy and the model he created at New Gourna are of great import. This notion includes the recognition of Fathy's building style as good, though not appropriate to current environmental conditions or extended family lifestyles.

One of Fathy's greatest contributions to architectural scholarship and practice was his profound understanding of the inextricable link between people and places. Intimate and safe *hawaari* (residential enclaves/alleyways), extended families spanning several generations, and visual and physical connection


Fig.3 and fig.4 Grazing animals in the New Gourna fields A shaded New Gourna Streetscape (credits: World Monuments Fund/ Community Consortium, 2010)

to greater Luxor have given rise to a community with a strong sense of and attachment to their environment. This attachment to place is codified by residents who do care about building fabric and frequently extend limited family resources to make repairs and renovations.

As the primary stewards of New Gourna, residents are critical stakeholders in the conservation process. Living and working in the historic landscape, they are the linchpin to preserving the core values of New Gourna, which extend far beyond design and fabric. That the village remains a vibrant, closely knit community is testament to the endurance of Fathy's ideals. He gave dimension to notions of urban intimacy, access to education, and community engagement, all of which were codified in his innovative, mixed-use plan. These elements remain as cornerstones of New Gourna's physical and social foundation, and likewise can serve as tools for forging common ground amongst the varied interests engaged in planning for its future.

The institutions involved in safeguarding the village must balance these sometimes conflicting values regarding the significance and conservation of New Gourna, but they have a tremendous resource and precedent in the community. The Fathy legacy is as much about participatory design as it is about the forms resulting from it. Capitalizing on this history by engaging the community in cooperative planning would tap a critical resource. It would enable a sharing of knowledge and inform a more robust program of revitalization, one that serves community needs, as well as heritage interests.

A fundamental first step in safeguarding New Gourna and engaging its residents is the establishment of a structured vehicle for community participation. Open, public meetings involving government officials and others engaged in conservation efforts will be a critical element, providing a regular forum for gathering and sharing information. Such communication will dispel the rumors that prompt anxiety and mistrust on the part of local residents, whose ties to Old Gourna stir up a history fraught with displacement and relocation. Ultimately, a structured vehicle for participatory planning will build mutual respect and trust amongst the various stakeholders and entities involved in the project.

6. CONCLUSION

As noted above, in the eyes of some conservation professionals, the New Gourna community has destroyed Fathy's masterpiece through modifications and new construction. However, this assessment found a great deal of respect for the history and heritage of New Gourna among residents. Given the evolving social dynamics and the problems caused by changing environmental conditions, their actions are borne out of necessity. They are taken with the best of intentions, and with limited financial and information resources. Their stewardship of New Gourna should not be judged by the loss of original fabric, but rather through their perpetuation of Fathy's principles of community empowerment and sustainability.

While many individual Fathy buildings have been replaced and renovated, the findings of this assessment support the idea that the cultural landscape of New Gourna today is very much a product of Hassan Fathy. In this respect, the value of this place and of Fathy's legacy is not simply that of mud brick and plaster. It is not even that of domed dwellings and open loggias. However, it is that of the place-based social fabric that serves to knit together this community. The unifying, somewhat intangible, elements of this plan concern education, religion, and economy all of which remain intact in New Gourna.

Thus, conservation of the built environment of New Gourna should be a community-driven process that integrates issues of environmental, economic, and social sustainability – from improved housing to agricultural land use to tourism management – into a balanced set of actions. Effectively integrating heritage protection into a broader program of infrastructure and service improvements, education, and development will forge a strong foundation for sustainable preservation of Fathy's legacy and improved quality of life within the village.

Notes

(1) A downloadable PDF of the assessment report can be found at: http://www.wmf.org/dig-deeper/publication/new-gourna-village-conservation-and-community. An associated film can also be found at: http://www.wmf.org/video/hassan-fathys-new-gourna-past-present-future.

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CULTURAL LANDSCAPE OF THE DRÂA VALLEY, MOROCCO

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Theme 4: Conservation and Development of Human Settlements and Cultural Landscapes
Keywords: Earthen Architecture, Drâa Valley, Moroccan Cultural Heritage.

Abstract

The six Drâa Valley oases are a system of several rural villages called ksur, characterized by a profound balance between agronomic, economic, social, architectural, ecological, and cultural dimensions. The Drâa valley oases are an exemplar of secular sustainable living systems and contain also a diversity of ethnic groups that defines the rich socio-cultural diversity of the area. Sophisticated irrigation systems, ruled by traditional local resource-management institutions to ensure a fair water distribution, integrated with significant earthen architecture, constitute a complex and important, both material and immaterial, cultural heritage.

Local building technologies use raw earth as the main material; earth, due to its easy availability and its low cost, constitutes a precious resource in the building of construction elements, from the structural to the decorative. The predominantly earthen-building techniques, used simultaneously and symbiotically in the different architectural elements, are rammed-earth and adobe.

In the Drâa Valley the cultural heritage represents an undeniable value and an excellent and competitive resource for quality, distribution, levels of preservation and permanence in today's cultural and socio-economic structures – thus, it is a decisive element in the process of local development.

Effective projects toward local development and cultural heritage conservation and innovation, in conjunction with the objective to improve living conditions of local populations, should therefore be founded on these general actions:

- Identification and systemic understanding of local, traditional and sustainable knowledge by all actors and especially by local populations;
- Integration of cultural heritage with the processes of local development, in particular adapting the traditional houses into new cultural and living needs, to end the general abandonment of housing and the loss of this important heritage;
- Construction of government and management systems in which the local actors know how to have dialogue and organize the real course of development, in an autonomous way, improving the specificities of identity that characterize the place.

1. INTRODUCTION

Situated in the southeast of Morocco and located in a relatively isolated and distant position in relation to the principal city centers of the country, the Drâa Valley stands out for its rich historical and cultural heritage. The six oases of the Drâa Valley are a relevant and unique environmental and social system developed by man in a constraining and harsh environment. They display a complex, diversified and intense relationship between man and nature, which has been developed over millennia. Sophisticated irrigation systems, managed by traditional local governance institutions, not only ensure a fair water distribution, but also constitute a crucial element of the oasis agricultural and social systems (Badia, Cusidó, Luria, and Noy, 1998).

These ancient socioeconomic systems based on the date palm, experimented through more than 2,000 years, produce an urban network of ksur (villages) and an important architectural heritage, strongly integrated with palm trees, base of the pre-desert oasis ecosystem. The earthen architectures and the palm trees are strictly related to the harsh, dry and hot climate, offering shade and lowering the ambient temperature, making it possible to live in the pre-Sahara landscape in a sustainable and low-energy manner, creating a surprising place of recreation (Mecca and Biondi, 2005; Mecca, Tonietti, and Rovero, 2007).

Traditional water resource management systems, transhumance practices, traditional earthen-architectural design of human habitats and social cohesion among local people and tribes are relevant examples of local knowledge, of sustainable and low-energy strategies for human settlements in desert regions. Since 2,000, The Drâa Valley Oases has belonged to the UNESCO Man and Biosphere Reserve, called "*Réserve de biosphere des oasis du sud Marocain*". The Museum Project

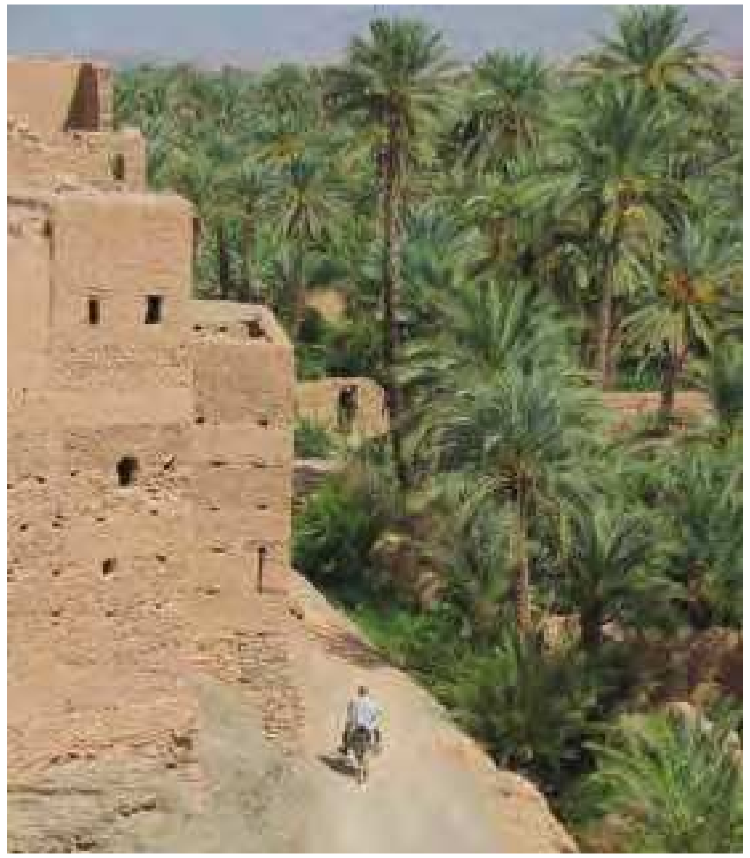

Fig.1 Tamnougault Ksar (credits: Eliana Baglioni, 2009)

would serve particularly in the Zagora area to promote the conservation and enhancement of the rich and invaluable cultural heritage created by Drâa Valley communities.

The future of the communities living in the Drâa Valley is not only related to conservation of biodiversity, but mostly to conservation and innovation of indigenous knowledge and cultural aspects related to social systems, which produced and improved biodiversity. The development of projects (and tourism can play a part) that are able to create effective value-added actions generate income for all sectors of the Drâa Valley society. This is possible based on a holistic approach, able to conserve biodiversity, as a result of cultural practices, and based on a complete understanding by stakeholder groups of its socioeconomic values.

2. DRÂA VALLEY RESOURCES

2.1 Natural and cultural biodiversity

The Drâa Valley is a long oasis that goes south from Ouarzazate city into the Sahara Desert. The valley is the middle part of the Drâa River, which is the largest in Morocco. The river begins on the Saharan side of the High Atlas Mountains, creating a wide valley at the base of the Anti Atlas, entering the Sahara Desert, and finally flowing into the Atlantic Ocean.

The Drâa is characterized by an irregular water flow – from which it derives its name Oued Drâa, so it is only during periods of prolonged heavy rainstorms that the water reaches the Atlantic; this happens only occasionally; therefore, the southern and western channel leading to the sea seldom sees water.

The Drâa Valley features a rich forest of palm trees, inserted in a very arid and rocky landscape, and fertile earth; this area was chosen, already in antiquity, for human settlements and supported ancient agricultural communities. From the 9th to 15th century, the Drâa Valley was one of the most important caravan routes between Europe and Timbuktu. The goods transported were ivory, gold and slaves. The last caravan of slaves is said to have crossed the Sahara in the 1950s.

The biodiversity of the Drâa Valley oases is characterized not only by a rich range of wild and cultivated plant and animal species, but also by a millenarian civilization that preserves its knowledge in concordance with current sustainable development norms. Traditional management systems of local resources are directly correlated to social and cultural structures that are based on solidarity in the elaboration of common infrastructures, such as those for mobilizing water resources. Oasis-production systems have allowed, therefore, to local populations to live in such an extremely fragile natural environment.

2.2 Human biodiversity of the Drâa Valley oases

The Berber population, native to all northern Africa, was present in the Drâa valley already in the Neolithic period (6000-2000 BCE), as established by petroglyphs in the Atlas Mountains and in the Jbel Bani Mountain, which border the Drâa Valley to the east. The petroglyphs represent hunting and herding scenes, activities present also today.

Arabization began in 1150 CE with the arrival of some Maâquil tribes, Tunisian Bedouins, but the Berber language persists today, in speech only, and is the mother tongue for most of the population, particularly in southern Morocco. The actual society is composite and embodies different social groups, born in the past century but still very distinct and hierarchical both from the social and the urban organization point of view (Taoufik Zainabi, 2004).

The Chorfa, and the Mrabitine are the religious families that, diffusing the Koranic laws, have many land properties and have the role of conflict mediator in the village. The Imazighen (in Arabic) o Hrar (in Berber), descending from the nomadic Berber tribe that protected the village, are engaged in breeding and commerce. The Haratine (in Arabic), Ahardan (in Berber), also called Draoua, are composed both of a native sedentary population of the valley and the Sudanese slaves imported during the caravan commerce. These classes are at the service of the others, as servants in homes or laborers in the fields. The presence of Arabs is dated from the 6th century CE, after the Arab conquests. Finally, there persist some Jewish communities, some of the most ancient inhabitants of the territory, living peacefully but separately from Muslims.

These populations contributed to the development of the history and culture of the region, and gave rise to the production of this cultural heritage, distinguished by a mixture of languages and religions.

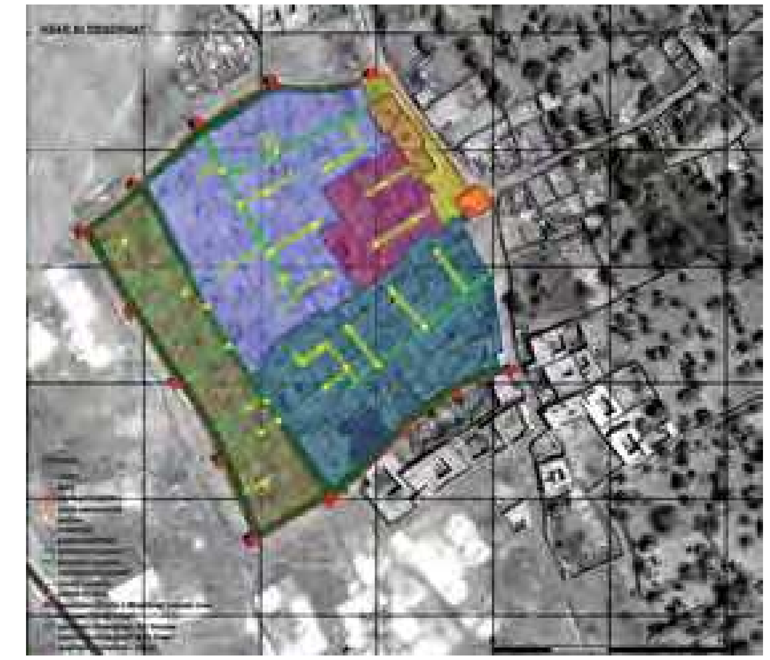

Fig.2 The Tissergat Ksar case study (2) (credits: Eliana Baglioni, 2009)

Fig.3 Kasbah Dâr El Hiba in the Tissergat Ksar (credits: Eliana Baglioni, 2009)

2.3 Local knowledge systems of land and water-resource management

The agricultural system is based on the palm tree that needs little water for its growth and sustenance but, on the contrary, creates shade and humidity beneath, generating a micro-climate and permitting three production levels: the date palms at the highest level, fruit arboriculture at the middle, and annual/pluri-annual crops, with a wide variety of vegetables, cereals and forages, medicinal and aromatic plants. Management practices and agricultural techniques reflect the remarkable skills of local populations at using biodiversity in a sustainable way so as to ensure the continued economic productivity of these ecosystems (Chetto, 2003; Zirari, 2003).

Due to low river water levels, the population also became increasingly sophisticated and efficient with systems of water sourcing: the seguia, the tabia, and the khettara (Baglioni, 2009, pp. 6-7). The most common irrigation system in the valley is the seguia that consists of branched channels conveying the river water to the fields by small dams built with stones, mud and branches. Because the fields to be irrigated have a higher altitude than the river, the seguia must begin very much upstream and be built with a diagonal path (in relation to the river axis), to allow gravitational water flow. These channels extend from 1 to 10 km and need considerable maintenance; the water distribution is controlled and regulated by the ammazal, which open and rebuild the small dams to distribute the water according to the nouba.

Another system, used in the most peripheral territory of the valley, is the tabia, an interception and collection basin of runoff water coming from the neighboring mountain slopes. Tabia are made of earth and stone and have an average size of 100 m by 30 m.

The third system, used extensively throughout the Arab world, is the khettara. This is a complex system that permits the transporting of groundwater to the village by gravity. This system is composed of several elements: a mother well upstream, which captures the groundwater, and a horizontal underground tunnel, which carries the water to a collection basin. From these basins, the branched channels for field irrigation leave. The path of the khettara features numerous wells, necessary for the construction and inspection of the underground tunnel. This system is very susceptible to the changes of groundwater level, and is therefore in continuous evolution.

Water use in the Drâa Valley is social and communal, and water rights are proportional to individual, family, or village participation in the construction and maintenance of the water-sourcing systems, as indicate by the nouba.

Human interactions in the oases ecosystems were enabled to provide ecological and socioeconomic services to meet the needs of the local populations. The Drâa Valley oases are, therefore, havens of agricultural biodiversity: during centuries of experimentations, autochthonous and cultivated plants have been carefully selected from natural or artificial ecosystems for life in this challenging environment.

3. ARCHITECTURAL AND BUILDING KNOWLEDGE HERITAGE

3.1 Urban Morphology and Building Techniques of Drâa Valley Settlements

The Drâa Valley region has one of the greatest earthen-architectural heritage in the country and in the world. Along the valley, in fact, exist over 300 Berber villages, ksur, constructed entirely with raw earth. These rural and fortified villages are characteristic of the Drâa and Dadès valleys, and date from the 15th-century period when the sedentary Berber population found it necessary to enclose villages with high walls and defensive towers, caused by continuous attacks from nomadic Berber tribes.

The ksur (sing. ksar) have a very dense urban fabric, with houses built one against the other in mutual protection from the heat. In addition, the first floor is often constructed on a bridge over the road, thus creating a grid of cool, dark tunnels below which protect inhabitants from heat and sand storms (Baglioni, 2009, pp. 22-34). It is interesting to see how this type of aggregation simulates underground architecture, enjoying the advantage of thermal insulation and, at the same time, solving the major problem of ventilation (Bourgeois, 1988, p. 48).

The ksur are usually on the edge of palm forests, in order to avoid taking up agricultural land, which is the main source of livelihood; the palm forests, in fact, are crossed by labyrinthine paths between the different properties, limited by rammed-earth walls. The village has a very strict urban division into public and private spaces, and for different social classes.

In addition to ksur, Kasbah are spread across the valley, big fortified houses belonging to Berber families who protected the villages and adjacent territories, or, later, belonging to the representatives of Pasha Glaoui, who exercised administrative control until Moroccan independence.

Both in the kasbah and the ksur, the housing type used is constant and recognizable as a patio house. This type, with its specific and various models, has spread throughout the Arab world and the Mediterranean, and is identified with the center of home and family life.

In a Drâa Valley building, the patio is not just a vertical hole in the building, but defined by a perimeter gallery present at all floors, which creates a trading plan between the central vacuum and the private rooms; the patio size and shape are determined partly by local building techniques and climate and partly by local traditional culture. The importance of this space in housing composition is also expressed in the architectural details and decorations are very rich compared to other walls where there are no specific details (Baglioni, 2009, pp. 38-43 and 51-55).

The heritage represented by these urban settlements constitutes evidence of the existence of technical knowledge, competence and skills accumulated during thousands of years of practical and local experience. In the traditional building technique of the Drâa Valley, the earthen material used plays a major role: it is utilized for walls, floors, roofs, mortar and plaster. Earth is used for its versatility in many various situations, for its easy availability and low cost, but it also proves an effective response to the warm, dry climate of the place. The masonry techniques utilized are rammed-earth, called alleuh, and adobe, called toub, used separately in different parts of the building (Baglioni, Mecca, Rovero, and Tonietti, 2010).

Besides earth, palm wood is used for horizontal

Fig.4 Rammed-earth masonry construction in the Drâa Valley (credits: Saverio Mecca, 2007)

structures, and canes are used for floors and roofs. It was also observed the limited use of stonework, mainly for the construction of foundations.

3.2 Climatic Interaction and Energy Efficiency in Drâa Valley Architecture

The ksar is a paradigm of the climatic adaptation of architecture. Drâa Valley buildings follow some basic principles (Baglioni, 2009, pp. 48-49):

- Building technology: raw earth as construction material, besides being abundantly available in these places, is able to achieve high levels of thermal mass, especially if associated with considerable wall thicknesses;
- External walls: due to the very dense urban construction, there are very few surfaces exposed to the sun (practically limited to the roof terrace), limiting heat exchange;
- External windows: the houses have very small openings on the outside, in order to protect from heat and dust, but also due to the culture of privacy;
- Patio: it plays the double function of light shaft, limiting the direct exposure of the ground floor, and ventilation, which like a chimney pulls the warm air up and contributes to the cooling of the rooms;
- Use of space: nomadic culture is practiced even inside

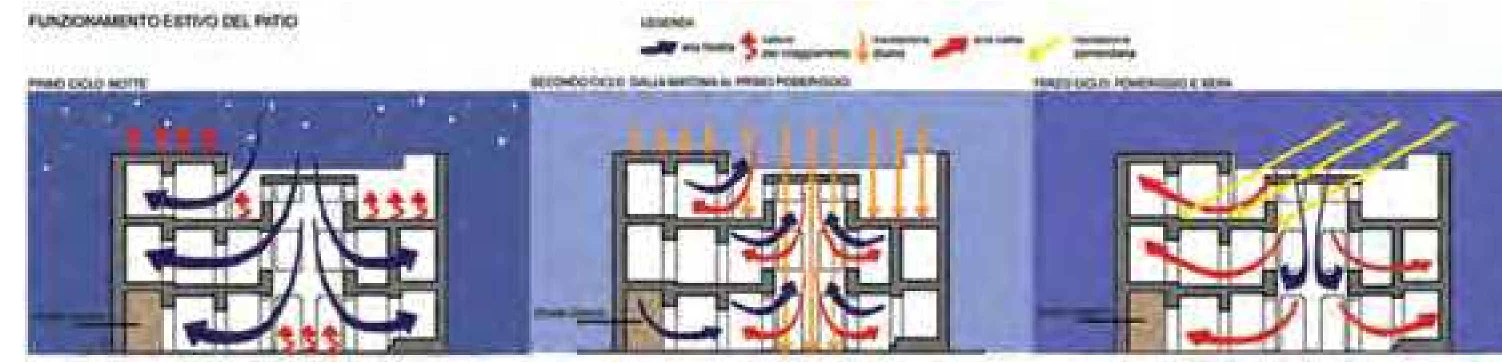

Fig.5 Summer bioclimatic operating of Drâa Valley patios (credits: Eliana Baglioni, 2009)

the house, so that the housing spaces have a low definition of use for different living parts, according to outside temperatures. This practice involves sleeping on the terrace in the summer and living on the lower floors of the house during winter.

3.3 Weaknesses and critical points

The cultural heritage and the highly sustainable living systems of the Drâa Valley oases are exposed to many threats under the effects of different aggressive environmental factors that can be either biological, physical or human: Bayoud palm disease, locust invasions, water and soil salinity, soil erosion and degradation, periods of drought and diverse forms of desertification, loss of traditional knowledge, poverty, seasonal and definitive migration, modern urban extension and related activities, the use of the most recent building technologies, and architectural and urban low-energy consumption schemes. All of these factors affect the delicate sustainability equilibrium of the oases.

4. CONCLUSION

If it is assumed that cultural heritage as the strategic factor of socioeconomic development, development plans have to be oriented to empower local resources and productive systems (agriculture, urban and architectural construction, craftsmanship, and tourism activities), according to three general actions:

- Identification and systemic understanding of local and traditional knowledge and site environment by local populations;
- Integration of management and improvement processes for cultural-heritage valorization with development processes integrating the local communities;
- Implementation of government and management systems in which the local actors know how to organize the real course of development, in a controlled but autonomous way, to improve the specificities of identity that characterize the region.

Based on these principles, it can be enumerated the fundamental parameters for the planning and control of the effectiveness and sustainability of maintenance and improvement projects in the relevant 'cultural landscape' of the Drâa Valley: environmental-systemic knowledge of site, local and traditional knowledge and living heritage, governance, sharing, and partnership.

4.1 Environmental-systemic knowledge of the site

This can be obtain only through the elaboration of multi-disciplinary researches, according to a systematic approach on natural, social, juridical and human environment, and on the needs and expectations of people living in the Drâa Valley. Not only is it essential to know the site and its environment, for an understanding of its dynamic, to underline strong points and criticisms or weaknesses, to discuss and to establish priority and objectives before any decision or project of improvement, but the quality of the local population's systemic knowledge of the site's environment can also constitute a basic condition in planning and management of development processes.

4.2 Local and traditional knowledge and living heritage

The cultural heritage of this region is not only material, but also immaterial traditional knowledge and it needs an integrated approach (social, cultural, economic) based on the accurate management of local resources, and the recovery and the correct recognition of production traditions (architecture, agriculture, resources, etc). Only an exemplary process is able to oppose environmental and urban degradation: improvement and maintenance must be united in a continuous process of revitalizing local identity, its heritage, its scientific and technical knowledge, and its individualities.

4.3 Governance

The choices made in regards to a site have to be shared with the local communities that must assume the responsibility of planning and management, becoming themselves protagonists of such a development, and assuring continuity and sustainability over time. The ability to govern the process needs a recognized and legitimate local political and technical organization to animate, plan, accompany, appraise, and communicate the future territorial dynamics: this means the growth of local technical competences to help local autonomy versus central authority, and transparent processes of development in the relationship among institutions, and between rulers and those governed.

4.4 Participation

This determines the involvement of local populations in the elaboration of politics, and the recovery of community power towards active expression. Participation in the sharing of knowledge, choices and actions, implies a form of balance among the different subjects, a redistribution of power compared to an initial configuration in which there are 'strong' and 'weak' interests, and suggests the necessity of complementary processes: the top-down approach in which a strong actor, the public sector, typically represents the local community, or the bottom-up approach in which the same community promotes the involvement and development of the territory with which it is identified.

4.5 Partnership

The construction of a network and channels of communication for explicit and tacit knowledge is necessary to facilitate the identification of common cultural, political and economic interests. An improved strategy for cultural landscapes as an economic resource is founded on systemic environmental knowledge of site, local and traditional knowledge and living heritage, governance, participation, and partnership and demands a key role of research:

- To sustain training strategies, adapted to different Drâa Valley communities;
- To sustain the building capacity of technical operators of communities;
- To facilitate the communication among rulers and those governed;
- To supply scientific knowledge in the sector of integrated appropriate technologies with local and tacit knowledge;
- To contribute to the experimentation of strategies and technologies in accordance with local communities.

Notes

(1) INN-LINK-S: Research Center on Innovation and Local and Indigenous Knowledge Systems.
(2) Caption of the Fig. 2. In red color, the defensive walls and tower. In orange color, the only original door access. The orange arrows indicated the door opened in the '70 of the 20th century. In dark green color, the main streets along the defensive walls. In light green color, the streets and the alleys (derb) for access to the houses, with shafts of light indicated with yellow dots. In pink color, the Chorfa and Mrabitine district. In blue color, the Imazighen districts, descendants of two different tribes, and the Kasbah (at the bottom). In grey color, the Harratine district, probably added in a second time.

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EARTHEN ARCHITECTURE IN PUNA DE ATACAMA, ARGENTINA: LOCAL KNOWLEDGE AND PRACTICES

Jorge Tomasi

Theme 5: Local and Regional Knowledge, Intangible Heritage and Social Impact
Keywords: Puna de Atacama, local knowledge, construction rituals

Abstract

Earthen building techniques form a corpus of relevant technical and social knowledge that has not always been nor is duly recognized. A significant issue about these techniques is that they assume, in Latin America, a remarkable diversity in both names and specific procedures. This great variability, which often acts as an identifying brand differentiating between different societies, arises from the recognition of needs and possibilities, as well as the particular historical trajectories of these societies. Diversity of local knowledge is then established as a value of earthen building, which must be recognized and sustained.

In this paper, the characteristics of earthen building techniques used in the area of Susques, in Puna de Atacama, province of Jujuy (Argentina) will be analyzed. These techniques will be understood and described within an integrated construction system that ranges from stone and earthen foundation, the use of adobe, and even roofing, made of earth and guaya (straw). The particularities of each of these techniques, as well as their interrelation, will be discussed. The transformations that have occurred to procedures and materials in recent years will be considered as well. The starting point will be the understanding of the act of building, which is not only embedded for technical reasons, but fundamentally is a social fact that interlocks with other dimensions of people's life within a society. Also in this regard, the sociability that comes into play in the construction practice of Susques is considered. The material presented in the text comes from continuous ethnographic fieldwork in Susques since 2003.

1. INTRODUCTION

In recent decades, and especially since 1970, researchers from different backgrounds became interested in the vast field of earthen construction. While historical stigmas have not yet ceased, the different techniques that have been part of the knowledge corpus of many societies in different places and times began to be incorporated into academic agendas. The same has occurred throughout Latin America, where the dense and varied traditions in the use of raw earthen materials that characterizes our countries, has been recorded. In fact, certain collective efforts were explicitly used to account for the variability in Latin America with respect the earthen building, and thus promoting, in turn, the dialogue between researchers from different countries (e.g. Viñuales, 1994).

The Andean highlands have particularly benefitted from analysis, both by the diversity of the techniques involved, and by the amount of time that has been devoted to recording earthen architecture usage and important symbolic connotations. In Argentina, from the first decades of the 20th century, and especially since 1970, important workings allowed visualizing earthen building techniques from historic (Asencio, et al., 1974), geographic (Ardissone, 1937) or from a more technological standpoint (IIV, 1972), focusing specifically on an area known as Puna. From different fields of study, in recent decades, various researchers have addressed this area's architecture, making significant contributions (Rotondaro, 1988; 1991; Delfino, 2001; Göbel, 2002; Pujal, Marinsalda, Nicolini, and Demargassi, 2002; Ramos, Nicolini, Demargassi, and Marinsalda, 2004). This paper will focus on the Susques area (Jujuy province, Argentina) with the objective of recognizing the local reasons for using earth as a building material.

It is interesting to note that, as in many other places, earthen architecture in Puna was historically reviled and minimized, associating it with poverty, backwardness, lack of hygiene or structural instability. From authorities, there were even raised specific policies to eradicate it. In this context, the Puno local communities held onto their traditions and construction practices, long before architects, engineers and other professionals looked into these issues. In fact, the use of earth has had a remarkable persistence and vitality in these places, further demonstrating its ability to transform itself into their techniques while solving new problems.

As suggested, to understand this type of earthen architecture requires the recognition that it is inseparable from a set of social practices. Technical knowledge is embedded in a web of meanings, in such a way that it is socially defined (Dietler and Herbich, 1998). In this sense, talking about earth construction involves not only technical knowledge, regarding the capabilities of materials to meet structural requirements or environmental constraints, but also a universe of social relations and symbolic universes.

Therefore, this paper will focus precisely on the practical and constructive expressions based on the use of earth in Susques, and understanding them as part of a social world. Thus, initially the constructive aspects will be characterized, not as isolated decisions, but as part of a system (Guerrero Baca, 2007). Afterwards, some brief comments on the social links established around the act of building will be addressed. The material that emerged from the fieldwork with an ethnographic approach has been collected in Susques since 2004, within a broader research on the pastoral spatiality that led to a doctoral thesis (Tomasi, 2011). Also, the research was recently published in a volume on construction techniques in Puna (Tomasi and Rivet, 2011).

2. APPROACHING *SUSQUES*

When referring to *Susques*, it is important to consider the town and the surrounding rural area where households and grazing territories, are also considered. While today it is part of the province of Jujuy, the incorporation of this region of the Puna de Atacama into Argentina's territory occurred only in 1900. Before that, it was part of Bolivia. Later, it become part of Chile. At the time of annexation, it was part of what was once the territory of the Andes (*Territorio de Los Andes*), which was dissolved in 1943 when Susques was finally incorporated into Jujuy (Benedetti, 2005). Currently, the village has about 1,500 inhabitants having had a significant population growth in the 1970s, but especially during 1990, which was directly related to the opening of Paso de Jama, linking Argentina and Chile, from which Susques is about 150 km.

Located at an altitude of 3,675 m above sea level, Susques is within Puna, which in environmental terms is a high semi-desert, between 3,500 and 4,200 m, with little rainfall, which is concentrated between November through March, and a considerable daily temperature range. These environmental parameters provide adequate conditions for extensive grazing of herds of llamas, goats and sheep. This activity remains essential for economic reasons, but especially in social and cultural dimensions. Pastoralism structures are part of everyday life, and define key-moments of the annual ritual calendar - also fundamental for social cohesion. There are about 100 domestic units that hold grazing lands. As in other pastoral societies, the management and use of herds is organized around households, which is also important for the purposes

Fig.1 Location of Susques in the province of Jujuy, Argentina (credits: Jorge Tomasi, 2011)

of construction practices. In Susques, the households are also considered to belong to a certain territory of pastures, known as 'grazing lands' (*pastoreo*). Each household has different settlements, among which the herd grazes throughout the year. Synthetically, every household has a main house, known as residence (*domicilio*), and an average of five to six line cabins or outposts (*estancias*) distributed at strategic points within their grazing lands.

3. THE LOGIC OF A BUILDING SYSTEM

When analyzing constructive logic, the first thing to note is the remarkable extent of construction techniques based on the use of raw earthen material at all stages in the building of a house. According to the National Population Census of 2001 in the village, 96% of the 199 households surveyed incorporated adobe as the main building material of the walls, with or without plaster. In the case of roofs, this proportion is lower (25%) lower, due to the use of corrugated metal roofing sheets in recent years. Nonetheless, considering that the sampling was collected from only 83 different settlements, as well as both the field and the people (and disregarding the criterion of main building material used by the Census), 100% have at least one enclosure built of adobe and 85% have some roofing based on the use of earthen techniques. The sample size does not allow extrapolation of the results, but the data itself is significant.

A central issue is that this is not a constructive scheme that at some stage includes a technique based on the use of earth, but rather a complete system that incorporates different techniques that are all based on the use of this material. This extensive use ranges from mortars, stone foundations and the production of adobes for the walls, up to the terminations of the earthen roof or "*guayado*" (straw thatch). These techniques, in general, have a remarkable length of use as stated in various descriptions of the late 19th and early 20th centuries (e.g. Boman, 1991 [1908]), and even earlier. This does not mean,

Fig.2 One *puesto* built with *pirca seca* (credits: Jorge Tomasi)
Fig.3 A case of a circular kitchen in a rural house, with a false vault in stone (credits: Jorge Tomasi)

however, that these are static practices; instead, there have been substantial changes in the continuum of know-how.

It is common to build a stone-plinth foundation with up to 1 m in height and 30 to 40 cm in width made with earthen mortar. These plinths aim to improve not only settlement, but also protect the adobe wall from the possible rising damp, and the backsplash and runoff of rainwater (Schilman and Reisner, 2011). *Estancias* and other specific types of constructions, such as *fuegueros* (open spaces for cooking) or farmyards, and even today it is common to find walls built that are built in *pirca seca*, a type of crude wall construction of dry-laid unshaped stones without using mortar.

Although the use of stone today, in general terms, is limited to the foundations, the oldest buildings show that it was usual that all the walls were raised using this material. Stone construction was involved even in the execution of false vault ceilings. The descriptions from the early 20th century are consistent with these observations. In fact, Eduardo Holmberg, who toured Puna in 1900, referring to the characteristics of the houses, noted that *"the walls are always of stone, some also being observed of adobe, the roofs use Puna pasture, and are supported by crossbeams or tie-rods of cardón"* (a giant cactus species) (1988, p. 74-75). Throughout the 20th century, it is possible to notice a change, mostly from the mid-20th century on, in the role of stone as a building material. This is noticed by a continuous growth in the use of adobe up to today. In some cases, it becomes the exclusive material used when building a house. On the one hand, the construction of adobe walls is faster and more accessible to less skilled builders. On the other hand, the increased availability of vehicles to carry the adobes to country houses has allowed overcoming the problem of the lack of sufficient water to produce the adobes in many places.

While it is true that it is now possible to recognize in Susques certain people dedicated to the production of adobes for sale, the most common practice is that each household, with the collaboration of other people, produce their own adobes. Usually, more adobes are produced than what is required for use in the immediate future. The study found that the measurement of older adobe blocks shows some variability, whereas current adobe measurements have homogenized at 40 x 30 x 12 cm.

The blocks are used in two different ways, either as a running (stretcher) bond (*muro soga*) or in a header bond (*muro doble*) (Barada et al., 2011). In the first instance, the blocks are used on the short side, while the second, uses the longer part, thus obtaining a wider wall. Since the incorporation of processed wood, providing greater strength, and the use of zinc sheet metal, significantly lighter than traditional roofs, there has been a tendency to use muro soga, which also allows for greater material savings. Another important change is that the oldest buildings have battered walls. In this way, the horizontal thrust of the *tijeras* in gabled roofs was counteracted. This practice has been completely abandoned, and it is common to see the cracks in the walls as a result of structural efforts. The mortar used for bonding of both the stone walls and adobe walls, varies in a ratio ranging from 1:2 (clay to sand) to 1:3, depending on the preferences of the builder and the varying purity of the clay used.

Roofing is either the historically common gabled type or single-pitch roof, which has a greater presence today. In the case of gabled roofs, trusses (*tijeras*) are assembled, consisting of rafters that create the slope of the roof and are crossed with a horizontal piece known as tie-beam (*torillo*) (Corrales Barboza et al., 2011). Although nowadays, wire is often used, the various parts were traditionally joined with tientos, a kind of rope that is cut from leather, preferably from llamas, allowing further adjustment as it shrinks when dry. These trusses (*tijeras*) are placed every 60 cm and are crossed by perpendicular wood pieces, known as purlins (*costaneras*).

On the trusses and on the purlins is placed a layer composed of teasels, reeds, branches or bunches of woven straw, which must provide a firm surface for the roofing material. The roof can be built using one of two techniques: earthen roof (*torteado*) or straw thatch (*guayado*). The first is based on the application across the roof of one or two earthen layers mixed with straw, between 5 and 10 cm depth (Rotondaro, 1988). Guayado consists of the successive placing of rows of bundles of straw (Daich and Palacios, 2011). Unlike what happens in other sectors of the Andes, where the straw on the roof is attached to the ceiling using ropes, in guayado, straw bundles are partially soaked in mud, which once placed, causes the layers to stick together.

3.1 New materials

As in many other places (Göbel, 2002), in Susques, the use of certain materials, such as corrugated metal roofing sheets, fired brick or reinforced concrete has expanded significantly over the past 20 years. The use of certain formal materials (Delfino, 2001) has been actively fostered by certain public, academic and private initiatives, virtually making these synonymous with progress and social advancement. At the same time, as already stated, some technical and constructive knowledge has been looked down upon historically from these fields, while associating them with backwardness or lack of strenght and cleanness. While reviewing the real use of these formal techniques within the study area, it should be

Fig.4 Domestic church (*oratorio*) with the *guayado* technique (credits: Jorge Tomasi)

noted that in 48% of the houses, reinforced concrete has been integrated either for the entire structure of the building or at least the lintels; in 62%, there is a partial use of cement mortars generally for joining the foundation stones, as well as cement-based plaster in some rooms or concrete flooring; and finally, 76% of the houses have at least one enclosure roofed with corrugated metal roofing sheets.

A possible interpretation is to consider these formal materials, such as corrugated metal roofing sheet or concrete, in sharp contrast to those considered 'traditional'. In practical terms, the situation is more complex and should be considered more than a mere imposition of new materials, acceptance, and resistance or negotiated appropriation from the settlers. The use of corrugated metal sheets for roofs is interesting in terms of this issue. In many cases, its use is locally associated with certain 'improvements', such as quick erection or less maintenance, even if it means less thermal and acoustic insulation. The percentages shown have demonstrated the coexistence of different techniques. Many families that have incorporated corrugated metal sheet for some roofs of their houses, such as kitchens, prefer to continue using the earthen roof or guaya for others. Without losing sight of the processes of imposition of a certain constructive logic, it could be said that both the corrugated metal sheet and other materials have been incorporated into the repertoire of technical options that a builder has at his disposal.

4. THE SOCIABILITY OF TECHNIQUES

Constructive logic is embedded in a complex social and symbolic world. On the one hand, it must be considered the dense mesh of relationships that come into play around the construction of a house. On the other hand, these construction practices constitute a space in which from childhood, people incorporate important aspects of their life in society.

A first fact to note is that there is some organization of labor by gender. While women are generally those engaged in the daily care of the animals, men, on the other hand, among other activities are responsible for all tasks related to construction: building new houses and corrals, or maintaining the existing ones. This does not mean there are no mutual collaborations; and, indeed, women frequently participate in some specific construction tasks.

In any case, within the tasks daily or periodically performed by families, there are some that involve pressure related to available resources and, in some cases, exceed the possibilities of work of the closest family. Often these tasks are linked to annual ceremonies in connection with the animals; others have been historically associated with journeys to the valleys. And in what this research concerns, construction activities are one of those moments. Building involves the mobilization of a significant amount of resources, both material and human. Building materials (such as water, earth, stone, wood, leather or straw) are not always available in the domestic territory, or those that are, are not considered ideal. In the current context, characterized by fewer people who remain in the field and are in most cases, elderly or young children, the presence of more hands for work becomes indispensable.

Consequently, when building new corrals, repairing a room or even producing adobes, a series of social relationships, in which kinship plays an important role, are at stake, but it is not the only link available. In this context, multiple relationships of cooperation and reciprocity are established. When building a house, a number of important social ties are required. These will affect the possibility of having a certain number of people join the work, certain materials procured that are not owned, or some means for transporting them.

For the purposes of a thorough understanding of the significance of everyday construction practices, another aspect must be considered. As is common in other places, houses in Susques are in a continuous transformation process. This occurs in a context in which constructive knowledge is not only in the hands of a few specialists, but is remarkably extended to the whole population. Throughout life, a person in Susques undoubtedly makes multiple changes, some substantial, to the family home. It is very common in most homes that families produce adobes throughout the year; they are then stacked in a corner of the yard and are ready to be used. Construction practices are not sporadic, but rather an everyday practice. People then socialize in ordinary ways, of which building is a part.

The result is that building is not only a daily task, but also a body of extremely widespread knowledge within the population. Most of the people cannot only explain any of the techniques used, but could also and, in fact do, build their own house. From early on, children learn the different techniques, either participating in the work at home to the best of their ability and knowledge, or playing different games that usually involve building their own miniature houses. When a child recognizes this knowledge, he is not only learning to build something that will be necessary in his adulthood, but he is also incorporating the relationships that exist in their domestic group while being part of it, which is a certain way of constituting spaces and understanding the world.

5. CONCLUSION

Throughout this paper, it was intended to outline some characteristics of earthen building, as has been observed from the fieldwork in Susques. In this sense, the aim has not been to define the characteristics of the building systems and different techniques, but rather to summarize different dimensions of these practices, such as methods of technical resolution, the processes of socialization when building, and collaborative networks established. The superposition and the network of these different dimensions expose the complex universe that is present in any constructive practice.

Following the path taken by many researchers, case studies become important to recognize assumed local forms of building with earth in our countries, as well as to establish overviews. The study of these peculiarities helps to highlight on the one hand, the extent and present condition of these techniques, and on the other, the current wealth of their diversity. In many cases, significant differences in construction methods between neighboring towns and even between different domestic groups are found, while the singularity in the execution of a technique can act as a brand identity.

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PLANTS USED AS CONSTRUCTION COMPONENTS OF VERNACULAR EARTHEN ARCHITECTURE IN LA RIOJA PROVINCE, ARGENTINA

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Theme 5: Local and Regional Knowledge, Intangible Heritage and Social Impact
Keywords: Plant materials, rural housing, constructive technology

Building materials of plant origin are widely used in vernacular earthen architecture. Their significance is such that they can be found in a variety of applications, from auxiliary building components up to primary structural elements. The present paper identifies a variety of plant species, whose materials have been used in rural households in the province of La Rioja, Argentina. The study area is confined to the region of the province's valleys, located within the botanical geographic region of Monte. The material collected from houses was later identified in the laboratory, which was compared with known samples. Further information provided by the villagers was also taken into account. The aims of the study were to draw up a list of plant species used, and to establish which of their parts and what qualities are exploited for the purposes that they were employed. Plant material was identified in: a) adobe and lattice filler material, b) ceilings, c) structures of lattice walls, d) woodwork, e) roofing systems and f) supporting structures in general. Plant materials tend to be present with more variety and quantity in the roofs. The use of plants responds to three types of specific functions, as primary or secondary structural elements, surface finishing, and stabilizer. The results confirm that plant species have significant involvement in the shaping of earthen architecture in rural areas of this region in the province.

1. INTRODUCTION

As building materials, plant species, are employed in a very diverse way in vernacular earthen architecture. Their versatility is such that a wide range of situations occurred: integrating auxiliary building components, used as stabilizers, or forming main structural elements. In the latter, they are considered a constructive technology that various authors refer to as *lattice* or 'mixed technique"'(Flores, 1994; Maldonado and Vela, 1999; Minke, 2008). In these situations, the earth is generally incorporated as a secondary or auxiliary component in the form of filler.

Other fields of study, such as the Economic Botany and Ethno-botany, have also developed studies, where the use of plants is analyzed in areas of the building (Luoga, Witkowski and Balkwill, 2000). In particular in Argentina, Keller (2008) has performed interesting work with a detailed description of the lattice technique used by Guarani communities of Argentina's Misiones province, with a list of plant species used in the construction of their homes and temples. In the case of temples, an array of cultural guidelines restrict the use of construction materials to only natural resources, exclusively available in the immediate environment.

In a more difficult situation, due in part to the lack of evidence and the difficulty of conservation, archeologists are also interested in the use of plant species in the construction (Sánchez García, 1999; Ryan, 2011). Moreover, from works dealing with domestic architecture and restoration of the built heritage, some authors (Viñuales, 1981; Sosa, 2003) have provided descriptions of earthen construction techniques from the northwest of Argentina, showing the different ways in which plant materials were used in vernacular buildings. Viñuales (1981) only refers to the common names of the plant species used, without going into greater detail (1). Sosa (2003) is more thorough about addressing the different building systems, the names of the plant species commonly used, and the characteristics of these plant components employed. In these descriptions it is possible to infer, for example, the amount of plant materials involved in the construction of earthen roofs (Viñuales, 1981 p. 11; Sosa, 2003, pp. 84-85). Armellini, Cóppola, Iglesias Molli, and Rosso (1970) conducted a more detailed description for the Antinaco Valley, Los Colorados in the province of La Rioja, taking into consideration different types of earthen-built dwellings, mentioning the plant species traditionally used, and the function with which they are employed.

Until the mid-20th century, earth was the material predominantly used in much of the Argentinean vernacular architecture in the province of La Rioja, both urban and rural. There is a significant usage of adobe masonry with single-pitched or completely flat earthen roofs. The materials of vegetal origin were used in a complementary manner in earthen construction. The abundance with which these exist in historic buildings confirms this. Numerous researchers have addressed the study of riojana vernacular architecture from various approaches (De Aparicio, 1937; Cáceres Freyre, 1946; Viñuales, 1981; Rolón and Rotondaro, 2010). However, in recent decades, this building tradition that used natural materials with little transformation experienced major changes, due to the increased communication with regional-service centers and the availability of new industrial building materials.

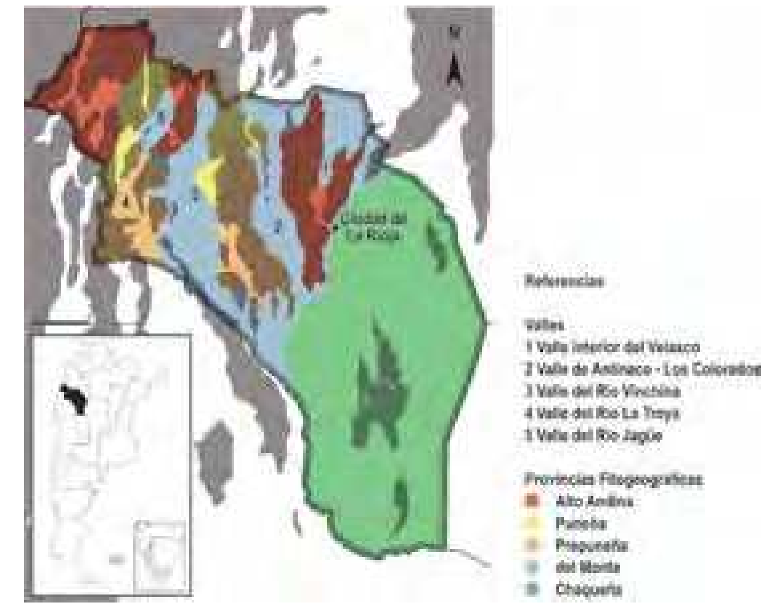


Fig.1 La Rioja Province in Argentina - area under study (source: Cabrera, 1976 (credits: Guillermo Rolón)

2. AREA AND PURPOSE OF THE STUDY

2.1 Description of the area under study

The area under study is confined to the valleys of the province, in the north and northwest sector of its territory. Specifically, it comprises the three main valleys of the region concerned, and two secondary valleys inside the Velasco, including the Valley of Antinaco, Valle-Los Colorados, Río Vinchina Valley, and the valleys of the rivers La Troya and Jagüé. These valleys are botanically within the geographic province of Monte (Cabrera, 1976), except for Río La Troya Valley, which also extends to the Prepubeña Province. In both areas, shrubby jarillas (Larrea sp.) and algarrobo (Prosopis sp.) are the dominant vegetation types. The climate is subtropical, arid, warm-temperate with an average annual temperature of 15ºC. Precipitation ranges from 80 to 200 mm per year. Almost all of the rainfall occurs in the summer, between the months of December and February, in the form of torrential rains or downpours. This rainfall causes the course of rivers and streams to be of a temporary nature.

2.2 Aim of the study

The overall aim of the study was to establish a list of plant species of a constructive nature that are economically valuable to the rural population of the province of La Rioja. Thus, the study pursued a dual purpose: first, to draw up a list of plant species that have traditionally been used in the construction of rural housing in the region of the aforementioned valleys, and, secondly, to establish which parts and what qualities of the same plant species are exploited for the purposes for which they were employed.

3. MATERIALS AND METHODS

The collection of vegetal material was performed during several field surveys between 2009 and 2010, by taking representative samples in these five valleys (2). Primarily, a visual inspection in rural households that were in a state of abandonment was performed; in order to select what material to collect that had been used as a building component.

In addition, samples were also taken of the most common plant species of the natural vegetation detected while scanning adjacent areas of the sites of interest to be used as controls, in order to compare these materials with those from construction sites. The locations identified by locals where they sourced provisions were particularly taken into account. The resulting Herbarium specimens were compiled, taking care to preserve vegetative and reproductive structures, which could be potentially informative with respect to taxonomic identities. They were later identified on the basis of a literature survey of regional floras and monographs (Tortorelli, 1956; De la Peña and Pensiero, 2004) and by comparison with other previously identified herbal materials deposited in institutional herbaria.

The identification of the plant species used was accomplished two different ways depending on the nature of the collected material: either by the wood or other vegetative elements (branches, stems, leaves, etc.). Samples taken from a given location were used to determine species of wood. In addition, wood was cut into cubes of 2 cm, except where the dimensions of the material prevented it. The cubes were boiled daily for five hours over 10 days in water with detergent. Each cube was prepared so as to achieve transverse, radial longitudinal and tangential longitudinal cuts of 5 μm thickness with a sliding microtome. These were mounted on slides with a gelatin-glycerin mixture. They were then observed under an optical microscope and conclusively identified based on comparisons with known materials and bibliographic descriptions.

For the remaining materials, special care was taken to include the reproductive structures of the respective branches collected (flowers, fruits, seeds), as the vegetative elements are highly variable within plant species groups, and

Muestra	Nombre cientifico	Nombre vulgar	Valle	Relev.
Vigas y soleras	Prosopis sp.	Algarrobo	Río la Troya	ZAP2
	Prosopis sp.	Algarrobo	Bermejo	CON1
	Populus sp.	Álamo	Bermejo	CON1
	Salix sp. o Populus sp.	Sauce o álamo	Bermejo	CON2
	Salix sp. o Populus sp.	Sauce o álamo	Velasco	ANL1
	Zuccagnia puntacta	Lata, Pus-pus o Jarilla macho	Río la Troya	ZAP2
	Populus sp.	Álamo	Río la Troya	ZAP2
	Geoffroea decorticans	Chañar	Río la Troya	ZAP2
Cubierta (cielorraso)	Arundo donax	Caña de Castilla	Bermejo	CON1
	Arundo donax	Caña de Castilla	Antinaco	BCA1
	Arundo donax	Caña de Castilla	Antinaco	PIT1
	Arundo donax	Caña de Castilla	Antinaco	ANT1
Cubierta (enramada)	Arundo donax Prosopis aff. argentina	Caña de Castilla Algarrobilla	Bermejo	CON3
	Atriplex aff. suberecta		Antinaco	BCA1
	Chenopodium cordobense	Quinoa corbesa	Antinaco	BCA1
	Cortaderia sp. Prosopis aff. argentina	Cortadera ¿Algarrobilla?	Jagüe	JAG1
	aff. Poaceae ('Gramineae)	¿Gramínea?	Antinaco	BCA1
	Larrea cuneifolia	Jarilla	Velasco	ANL1
	Larrea divaricata	Jarilla	Antinaco	CON1
	Physalis viscosa	Camambú	Antinaco	BCA1
	Solanum elaeagnifolium		Antinaco	BCA1
	Symphyotrichum squamatus		Antinaco	BCA1
	Triticum aestivum	Trigo	Antinaco	BCA2
	Xanthium spinosum var. spinosum Eragrostis aff. mexicana		Antinaco	BCA1
	Zuccagnia puntacta	Lata, Pus-pus o Jarilla macho	Antinaco	BCA2
	Zuccagnia puntacta	Lata, Pus-pus o Jarilla macho	Antinaco	BCA1
Cubierta (enramada fina)	¿Cyperaceae?		Antinaco	ANT1
	Jarava ichu	Ichu, Paja ichu, Paja brava o Aibe	Velasco	ALT1
Cubierta (enramada gruesa)	Cercidium australe	Brea	Bermejo	VIC1
	Cercidium australe	Brea	Antinaco	PIT1
	Larrea divaricata	Jarilla	Antinaco	PIT1
	Prosopis aff. argentina	¿Algarrobilla?	Bermejo	CON3
	Prosopis aff. flexuosa	Algarrobo	Antinaco	ANT1
	Tessaria aff. dodoneifolia	Chiica	Antinaco	PIT1
Cubierta (en torta)	Triticum aestivum	Trigo	Jagüe	JAG1
Cubierta (pelicula de contención)	Arundo donax	Caña de Castilla	Antinaco	PIT1
	Poaceae (=Gramineae) (aff. Sporobolus rigens)		Bermejo	VIC1
	Triticum aestivum	Trigo	Bermejo	CON1
Aberturas	Prosopis sp.	Algarrobo	Bermejo	CON3
	Prosopis sp.	Algarrobo	Velasco	ANT1
	Prosopis sp.	Algarrobo	Bermejo	CON1
Horcón	Prosopis sp.	Algarrobo	Bermejo	CON2
	Salix sp. o Populus sp.	Sauce o álamo	Bermejo	CON2
Muro	Arundo donax	Caña de Castilla	Bermejo	CON1
	Tessaria aff. dodoneifolia	Pájaro bobo, Chilca o suncho negro	Bermejo	CON3

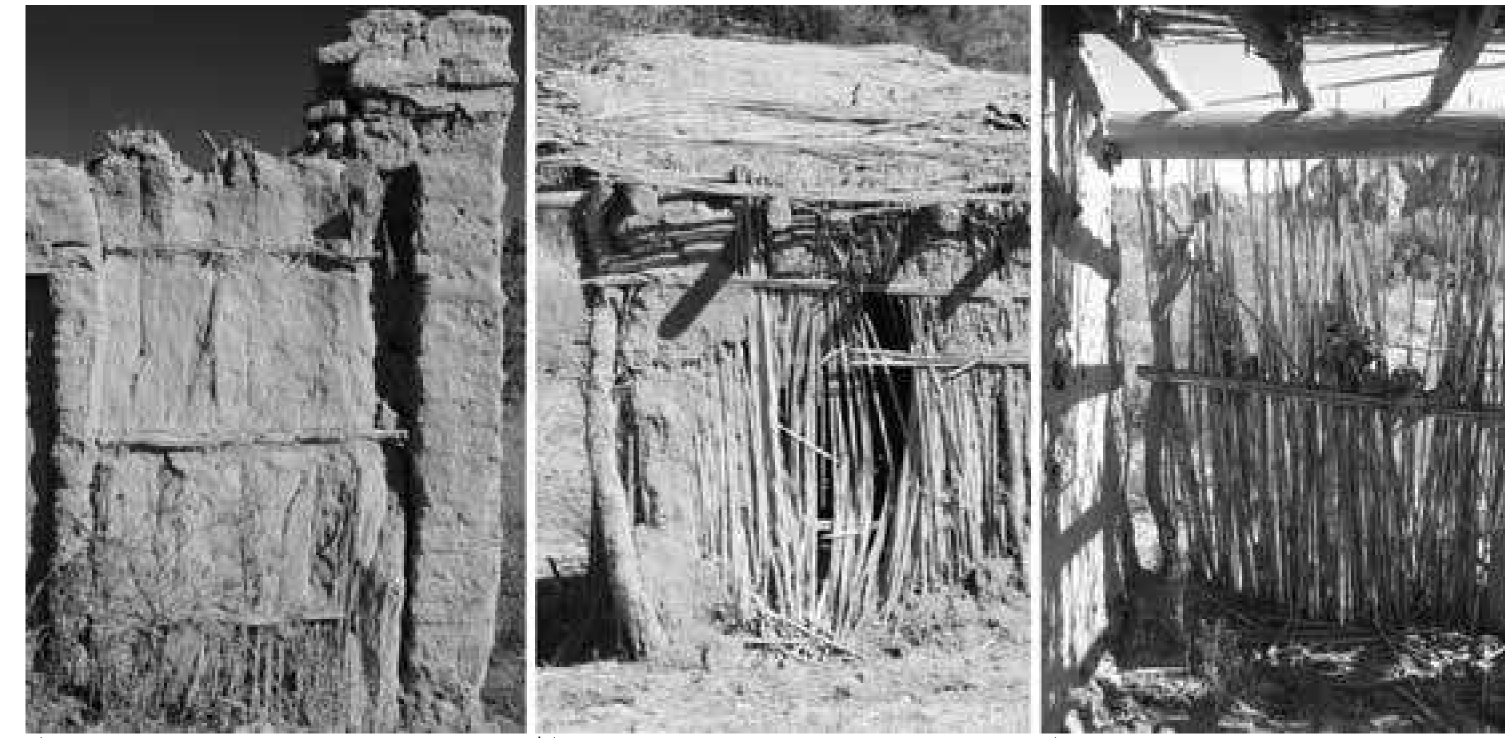
Table 1. Taxonomic original table with reference to plant species used in construction elements (credits: Sonia Rosenfeld, Pablo Picca and Guillermo Rolón, 2011)

taxonomically uninformative. In many cases, the finding of such structures permitted identification at the species level of some components. Other materials, however, have only been identified within more inclusive taxonomic levels (genus, family) or could not even be identified. The identification of these materials was primarily accomplished by using technical literature, together with, comparing them to the organized reference collection.

In order to establish which parts and what qualities of vegetal material were being used, the construction system for houses was analyzed from the graphic and photographic perspective, which was accomplished in the field. At first, it was performed at the level of components and construction elements, in order to determine types of solutions. At a later stage, the various building systems and their different variations were determined, so as to decide how the components and elements were connected between themselves. Thus, a broader picture on the distribution of vegetal material in construction was provided.

4. RESULTS

In this study, 34 rural houses, mostly in a state of abandonment, were surveyed. Earth constituted, to a greater or lesser extent, as one of the building materials. In all situations, the vegetal material collected was part of a construction system, where earth



a) b) c)

Fig.2 *Quincha* walls with Castile cane and carob lattice (credits: Guillermo Rolón, 2011)

was the main component. To systematize the study, the origin of the vegetal material was indicated by the constructive element where it was integrated: roofing, linear structural elements (beams, wooden slats, etc.), woodwork (doors and windows), walls or plasters.

A total of 95 samples of vegetal material were collected. Building components samples corresponded to: 49 samples of the materials of different layers of roofing, 13 of structural elements, three of woodwork, and two of wall materials. The leftover materials collected corresponded to 28 samples of plant species from sourcing sites indicated by locals. So far, a total of 60 samples have been identified, of which 43 correspond to samples taken from construction elements (Table 1).

The analysis of the housing components and structural elements found the presence of vegetal material in all case studies, and virtually in all parts of construction with the exception of foundations and plinths, with different levels of development of the materials used. The observed wood was mainly used in *horcones* (wooden vertical beams), roofing structures (beams and slabs), and woodwork. Other types of plant species material (branches, reeds, leaves, grasses, etc.) were identified in walls, roof coverings, plasters and mortars. In the walls, the vegetal material was found serving two different functions: first, forming the lattice structure of *quincha* walls (wattle and daub), and secondly, as a stabilizer incorporated as herbal fibers in the raw earthen material. In the case of *quinchas*, the columns or main *horcones* that make up the framework are usually logs or large branches of algarrobo (Prosopis sp.) with little or no transformation, though with variable dimensions (diameters ranging from 8 to 25 cm). *Caña de castilla* (Arundo donax) (giant reed or cane) was typically used for the skeleton of the vegetable framework. In all observed cases, the fabric of *quinchas* was resolved through skeletal frameworks filled in with vertical reed, largely due to the dimensional regularity of the reeds used (3). Thus far, five timber species were identified amongst the structural elements (wooden columns, beams and slabs). These included Prosopis sp. (algarrobo, mesquite), Populus sp. (cottonwood), Salix sp. (willow), Geoffroea decorticans (Chilean palo verde) and Zuccagnia (Jarilla, creosote bush). In terms of woodwork, the collected samples corresponded in all cases to algarrobo (Prosopis sp.).

Among the constructive elements discussed, roofing was the most complex element, in terms of diversity of the observed plant species material (4). Twelve kinds of reinforced roofing, grouped into two main patterns, were identified: lightweight covering and heavy covering. The types and subtypes were then established taking into account the number and function of the different layers that make up the roof, differentiating nine types of layers. Plant species material was observed in eight of them:

a) *Torta:* This consists of a layer of rustic earth of varying thickness. It is always the top layer, and it is intended for the evacuation of rainwater, thermal insulation and solar protection. The vegetal material present in this layer is crop-waste material; preferably fine fibers (e.g., wheat or alfalfa chaff).

b) *Enramada:* This consists of a layer of branches of shrubs, or plant parts without any transformation. Generally, the materials selected are as flat as possible are selected to facilitate their placement and the shaping of the layer itself. It combines the functions of containment of the earthen roof (*Torta*), as well

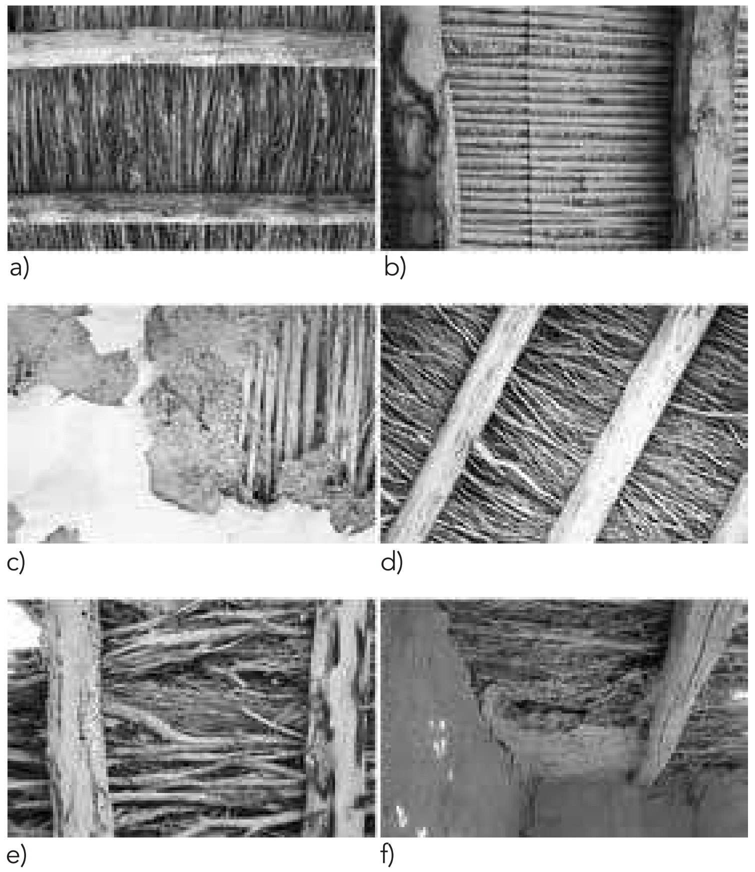


Fig.3 Some plant types identified in soffits below roofs. In photographs C and F, an abundance of plant materials of different species can be seen, as well as the use of earthen mortars with fibers (credits: Guillermo Rolón, 2011)

as the structure of the entire roof, which is why it is always composed of thick and resistant branches (undifferentiated arbor was identified as Z. punctata, Larrea divaricata and/or L. cuneifolia). These branches are generally located at the bottom of the layer. In some cases, they also become the support for the finishing coat. The diversity of plants used for this layer was quite high with great variety even within a single case study (note the variety of plants identified for BCA1 in Table 1).

c) *Enramada fina*: This is a thin layer (less than 2 cm) of slim branches and/or leaves (e.g. Cortaderia sp. leaves). It was observed fulfilling the function of containment of the Torta. It always appears associated with an enramada gruesa; otherwise, it was regarded as containment.

d) *Enramada gruesa:* This is a layer of medium-sized branches of bushes were used based on regularity of size and shape. They are used solely for the structural containment of the enramada fina and the Torta layer. At least five different species were observed that were used for this type of layer (Table 1). Several more species identified in the enramada can be considered as fulfilling the same function (e.g. L. cuneifolia and Z. punctata).

e) *Cañizo* (Wattle): This is a layer formed by reeds of a specific variety of cane (only A. donax was observed), arranged in parallel without interstitial spaces. Its function can be structural, for containment of the Torta, for the soffit of a ceiling, or for substrate to apply a finish to a ceiling.

f) *Capa de Acabado* (Finish Coat): Consisting of an earthen-plaster material and fine vegetal fibers (similar to the torta), it is applied to the ceiling or to the timbers when it is a reinforced ceiling.

g) *Película de contención* (Containment Film): This consists of a continuous and thin material. When composed of plant materials, it is always observed with leaves, preferably those having ribbon-like sheets or parallel ribs.

h) *Sujeción:* This is an open layer, consisting of a transverse linear element to the cañizo for holding them. The most frequently used vegetal material is Castilla cane (A. donax).

5. CONCLUSION

Due to the abundance and diversity of vegetal materials observed in roofs, the focus of the study centered primarily on this construction element. Viñuales (1981) describes two types of roof coverings used in the province of La Rioja, differentiating them according to the characteristics of the layers of vegetal material that comprise them: characterized by the presence of a thick layer of Pus-pus branches (Z. punctata), which locals call *enramada*. While the presence of the Pus-pus is confirmed in many case studies, it is not the only vegetal material observed in these layers that perform this function. It is also necessary to redefine the arbor, not only by its morphology, but also by its function. In addition, different degrees of complexity in constructing the arbor were observed, depending on the number of layers, and the layout and function of each one. The thin arbor is a layer of thin branches containing the earth layer. The thick arbor underneath provides a structural function for the entire roof, and is prepared with thicker branches. It should be clarified that this basic pattern of arbor-layer arrangement was also observed in more complex construction, presenting other perfectly distinguishable layers.

Given the complexity of the roofing layers, it was possible to establish 12 types that take into account morphology, arrangement and function. Of these types, five of them lack the light earthen roof covering, and have the simplest configuration of this constructive element. Whereas, tree boughs used in a roof are more complex, because they involve selection and procurement of materials at earlier stages.

By focusing the work on the diversity of plant species used in the earthen architecture of the region studied, it was possible to confirm that their use was more diverse than expected, even if the botanical geographic area of the study has a reduced plant-species variety. Clearly, builders acquired a very precise knowledge of the physical characteristics and economic value of various plants growing in the region, and how to use these to their advantage in the construction of houses.

Notes

(1) "*We saw that there is a system called quincha or estanteo that is supported by a previous framework; as the case of champas, whose framework is constituted by the very same roots of grasses cropped from the soil. In the case of adobes, the rammed earth and the plaster in general, the fibers are chopped. The most common use in our country is straw, which is incorporated with different lengths for each type of application, and which will be of one or another grass from those the place offers [...] To the vizcachera, ichu, brava, are added the remains of linen, corn, cotton, rice and cereals in general, apart from bark, shavings and sawdust*" (Viñuales, 1981, pp. 27)
(2) The number of samples per valley includes seven from Valle interior del Velasco, 43 from Valle Antinaco – Los Colorados, 28 from Valle del Río Vinchina, seven from Valle del Río Jagüe, and 18 from Valle del Río La Troya.
(3) The nomenclature of the components from mixed construction techniques was based on Hays and Matuk, 2003, pp. 140-197.
(4) Other complementary aspects of this construction element are described and analyzed in the paper "Constructive techniques of the earthen vernacular housing in the valleys region of La Rioja, Argentina" presented at Terra 2012.

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GUARDIANS OF THE EARTH: CULTURAL DIMENSIONS OF EARTHEN ARCHITECTURE IN LADAKH, INDIA

Tara Sharma

Theme 5: Local and Regional Knowledge, Intangible Heritage and Social Impact
Keywords: Mountain, architecture, belief, natural calamities

Abstract

In the arid mountainous region of Ladakh (northern India), people have developed a unique relation with the austere environment in which they live. This is reflected in a range of belief patterns and traditions that influence their habitats. Each Buddhist village has its own mountain deity (lha), which protects the village from evil and misfortune often seen in natural calamities, including drought and floods. The layout of every village is marked by symbols of protection, as are the houses within the village. Rituals and beliefs associated with the construction of traditional earthen- and stone-masonry houses reflect this constant need for maintaining a balance with nature.

The selection of sites for construction of houses and, even more so, for monasteries and temples is governed by special consultations with astrologers, most notable being the monks from Tagthog monastery in southwestern Ladakh. From the first digging of the foundations and the placating of the earth lords, to the laying of the roof and the final blessing of the house, everything is marked by rituals. To this belief was added the deep knowledge of the traditional village mason and carpenter who knew exactly what kinds of mud, stone and timber were to be used for what purpose.

Today as these beliefs gradually erode and modern construction materials replace traditional material, the impact is being felt on settlement patterns and the architecture across the region. The flashfloods of 2010, one of the worst in living memory, highlighted the loss of some of this traditional wisdom as newer construction fell prey to the wrath of nature. This paper will highlight some of the indigenous practices and beliefs associated with the earthen architecture of the region, the gradual decline of this traditional knowledge base and its resulting impact on Ladakh today.

1. INTRODUCTION

In geographically remote and climatically harsh regions of the world, many communities have developed a unique relationship with their landscape which is manifested in all forms of culture. This is particularly true for Ladakh where its indigenous architecture and the associated belief and knowledge systems have for centuries dictated how, where and when a building should be built. It is these knowledge systems stemming from centuries of experience that permitted a relatively sustainable lifestyle.

These belief and knowledge systems functioned as informal planning and building guidelines. The gradual erosion of these knowledge systems and their replacement with unsustainable development frameworks, are proving detrimental to the fragile earthen architectural landscape of Ladakh.

1.1 Geography and climate

The arid cold desert region of Ladakh in northern India is one of the world's highest inhabited places, which is flanked by two of the world's highest mountain ranges, the Karakoram and the Himalayas. The area is essentially a cold arid desert where temperatures plummet in winter to -40°C and can rise in summer to over 30°C. The region is denied access to the monsoon-laden winds that sweep across much of north India by the Great Himalayas. So the main source of water remains the glaciers and heavy winter snowfall that feed the network of springs and streams. Many of these streams eventually join the major rivers that traverse the region. Foremost among them is the River Indus, which begins its journey near Mount Kailash in Tibet and enters Ladakh at Demchok, about 155 miles (250km) southeast of Leh. According to one legend, the river emerges from a large opening in the shape of a lion's mouth and the mighty Indus is, therefore, given the name of Sengge Khabab (Lion's River). The Indus continues flowing through the central Ladakh heartland, before entering Pakistan. It was along this river and its tributaries – the Zanskar, Shayok, Nubra and Suru Rivers – that human settlements first arose (NIRLAC, 2008, Vol. 2, i).

1.2 Historical introduction

The valleys have been home to humans since at least the Bronze and Iron Ages (2500-300 BCE). The mountain passes created a network of routes that linked Ladakh to the larger region of Tibet and Sinkiang in the east and Central Asia in the west. Apart from trade, the routes also served as corridors of exchange for building and decorative arts, religions and cultural practices. One of the most significant movements of Buddhist novices and teachers travelling from the great Buddhist universities of Kashmir and Bengal in India to Tibet resulted in the introduction of Buddhism to Ladakh and Tibet. In Ladakh as in neighboring Tibet, Buddhism was accepted here in waves, successfully amalgamating the local animistic and nature-loving deities, many of whom became protectors of the new faith. Thus sacred mountains depicting the protectors, village-mountain deities and underworld deities became part of the landscape helping people maintain a balance with nature. The architecture of Ladakh arises in this setting – one element in a complex web of relationships.

2. SETTLEMENT PATTERNS – THE SACRED AND CULTURAL CONTEXT

2.1 The heavenly, earthly and underworld realms

The Tibetan Buddhist landscape is divided into several realms – the realm of the gods (*lha*), the realm of human beings and the realm of the underworld deities (*lu*). Each realm has its place in the balance of nature and a disruption of this balance can lead to catastrophes and misfortune.

Each Buddhist village in Ladakh has its own protector deity (*lha yul*) who often reside up in the mountains. An earthen altar (*lha to*) for the deity is built by the village community usually in the purified setting of the mountain overlooking the settlement. Almost every village has its own story of how the village deity came to reside there, often at the time of the first settlement. Every year, the lhato is renewed with much ritual including the replacement of offerings of bundles of juniper (*shug pa*) branches, known for its purification properties, at the time of Losar (Ladakhi New Year) when the mountain deity's protection is sought. In some villages, the lha is manifested through an oracle every year, as in the case of the village of Shey.

The oracle can make prophecies for the coming year, as well as give strict guidance for any transgressions. Interestingly, in the case of Shey, the oracle manifesting the spirit of the deity, Dorje Chenmo, has in recent years been speaking out increasingly on the need to preserve ancient earthen chorten (Buddhist stupa) and temples. The oracle's proclamation has a deeper impact than any government policy. Angering the oracle can prove disastrous and if the guidance is not followed the oracle may refuse to appear the following year – causing further calamity.

The next realm is that of humans. This realm is also exposed to malevolent forces in the forms of tsan – a type of demon who can inhabit a person and cause disease and misfortune to befall a house or locality. To protect the house against the tsan, protective markings in red color are painted on the exterior walls of houses.


Fig.1 A traditional Buddhist house with marks of protection – a rigsum gonbo built over the entrance and red markings on the walls to protect the house from the tsan (credits: Tara Sharma, 2011)

The third realm is that of the underworld serpent deities known as lu. The world itself is believed to rest on a mythical serpent on whose coiled body the earth rests. The lu are very powerful, controlling the supply of water and the balance of the earth. Disturbing them could result in catastrophes usually occurring in the form of natural disasters, such as floods, earthquakes, drought or epidemics. Specific cubical-shaped earthen structures known as lu bang (residence of the lu) were erected in the pastures (in fact, near most water sources) to placate the lu.

The lu find mention in many folklores. In a legend of the 9th century, it is said that the Buddhist sage, Nyima Gungpa, was meditating in the Ladakh region, which at the time was covered by a network of lakes. These lakes were ruled by the lu who resided deep below. Impressed with the sage's meditation, the lu offered him a place to meditate in the middle of the lake. The saint blessed the lake and its water gradually began to recede, enabling human beings to settle here. He offered votive offerings to the lu and prophesied the founding of a great monastery. The ritual offerings of barley were tossed into the lakebed, which sprouted in the shape of a swastika (*Yung-drung*). This site later became the site of the Lamayuru monastery.

2.2 The traditional village setting

In the past, settlements were usually located along the mountain slopes, often clustered together, and surrounded by protective fortified walls, with village fields located in the midlands, lower down the slope. The ruins of hilltop fortifications are found throughout Ladakh. Comparisons with still-occupied settlements suggest that these ruins were sometimes villages clustered around the castle of a local ruler, and sometimes an independent settlement built for self-defense. As defense became less imperative in more settled times, villages began to disperse into their fields, and the rulers' palaces were built in more accessible locations (Harrison, 2005, pp. 20-33). In many older villages these settlement patterns can still be seen. Most

Fig.2 Monastery at Chemday with monks residences built along the slope of the hill and village fields beyond. The village today extends on the flat plains at the foot of the hill (credits: Tara Sharma, 2013)

monastic settlements still display this setting. In Ladakhi folk literature, an ideal village is portrayed as having its head (upper regions) touching the snowy mountains, which form the source of water for the streams and springs that irrigate the land, a central broad midland with fields surrounded by verdant hill slopes on the side ending in a thin tail which forms the outlet for surplus water and floods. In a popular folk song, Lha Yul na Mi Yul (between the Land of Gods and the Land of People), this setting is appreciated by the villagers of Shakar who praise their king for this beautiful land (Khan, 1997, p. 197).

The boundaries of the village are often marked by symbols of protection. In a typical Buddhist village, the entrance and exit to the village is marked by rows of long mane walls and chorten. These are circumambulated by the villagers as acts of merit, which garner protection for the lives of all sentient beings. Chorten are also built as acts of merit following a natural disaster. In the village of Lingshed, the Lung Ze Mane ("mane in the middle of the fields") chorten was built to protect the fields from drought and insect attacks. In 2011, a number of chorten are being built across Ladakh following guidance by H.H. The Dalai Lama to build them at specific locations across last year's flood-affected villages for the benefit of all sentient beings. Consultations with senior Rimpoche (abbots) are constantly taken by the village community to understand what needs to be done to protect the village from disasters. More specific structures, the rigsum gonbo are built particularly to address natural calamities. Interestingly, a mapping of these structures gives some indication on sites of previous flooding, landslides/rock slides. In a study carried out last year (INTACH, 2010, pp. 41-42), it was discovered that the flood paths followed older routes, and evidence of earlier flooding were highlighted by the presence of rigsum gonbo at vulnerable points.

2.3 Changing settlement patterns

Over the past century or so, settlement patterns have changed. Initially the move was made lower down the mountain slopes. Over the past 50 years or so, the move is towards the village streams or on the barren boulder-strewn flood plains – a dangerous pattern that was highlighted in the floods of 2010. In the case of Leh town, the gradual expansion of the town to the suburbs has resulted in rampant development along flood-prone tracts. Choglamsar, the worst affected settlement in the 2010 flash floods, is a recent settlement where much

of the construction was built over subterranean networks that channeled water outflows from catchment areas up in the mountains towards the river Indus. With a scarcity of space for expansion, reconstruction of flood-affected homes and commercial complexes continue even today in these very areas.

However, in other instances, particularly in the villages, it is the breakdown of traditional knowledge and belief systems that has resulted in increased construction on pasturelands and along the banks of streams. This is one of the major causes of damage in recent flooding. When natural calamities occur, it is ascribed by a senior monk, to a disturbance of this natural order where human beings have not fulfilled their role in maintaining the balance.

3. EARTHEN ARCHITECTURAL TRADITIONS AND PRACTICES

3.1 Selecting the site – sacred and cultural considerations

Within the village, there were belief systems that governed where houses could be constructed. The selection of a site for construction was determined after lengthy consultations with learned *lama* (monk) and *onpo* (astrologers) - monks from Tagthog Monastery being some of the most well-versed in the field of astrology. The traditional almanac is consulted to determine an auspicious time for digging. This contains information on the subterranean spirit lords of the soil (*Sa-bDag*) who move their position according to the cycle of the years, months, days and hours and infringing on their geomantic space can incur their wrath. The Wheel of Sadak Tochey was used in the astrology of geomancy for laying the foundations of monasteries, stupas, palaces, houses etc.

The wheel depicts the earth lord with the upper body of a human and the lower body of a reptile. After precise calculations of an auspicious time of year and selection of the site, the initial ritual digging is located under the left armpit of the earth lord (Men-Tsee-Khang, 2012). Blessings are taken from the gods and permission from the earth lords before beginning any construction through ritual purification of the land (sab chog) and recitation of Nang Gyad to place the underworld deities.

The site was usually never selected too close to major water sources (such as the pastures where village springs emerge or the major village streams) where the lu are believed to reside.

The house would not be built at the foot of a mountain that projects out onto a ridge nor in front of a mountain that has a second mountain hidden behind it (*rhi wo phag te* – a mountain that cannot be seen), as the second mountain could be malevolent and cause harm to the inhabitants. Interestingly, this belief translates into more a pragmatic rationale of not building along the route of water catchment areas that can flood in times of heavy precipitation.

3.2 Architecture and layout

The Ladakhi house has evolved over centuries and portrays a remarkable evolution of building knowledge and craft skills combined with an intrinsic knowledge of the landscape in which it flourished. Built primarily out of earth (adobe and rammed earth), stone and the scarce timber, the houses testify to the knowledge of the ancient building craftsmen. The layout of houses was dictated both by socio-cultural needs and, more importantly, climatic considerations.

Houses are generally double or sometimes three-stories high. In the more remote villages, they could be just a single story. The architecture is very robust – massive walls at the ground-floor level, which narrow upwards towards the roof. In some of the oldest single-story houses, the central living room cum kitchen, known as the chantsa, was surrounded by the various animal pens. The chantsa served as a living room cum kitchen, where the traditional clay stove burned through the day warming the room. Families usually slept in this room as well. A single opening in the roof permitted the smoke to escape. In some of the oldest houses, this room has no window opening at all. The chantsa was surrounded by a passage or srol around which the other rooms were arranged. There were animal pens around the *chantsa* – *tangra* for cows and sheep and the *stara* for horses. The heat generated by the animals helped retain warmth in the mud walls of the chantsa. In summer, the animals were kept in an open pen outside the house known as the *yarlas*.

Near the chantsa was the *changkhang*, where the traditional fermented-barley beer was stored in large jars. The *dzod* was used for storing grain, while the bang stored vegetables. In a corner of the house on the ground floor was the *shilkhang* or cold room where dairy products, such as milk, curd and butter were stored. Water channels were cut at the corner of the room and covered with stones to keep the room cool (NIRLAC, 2008, Vol. 1, p. xiv).

In the more affluent houses, the ground floor was used to stable animals and store fodder for the winter months, the first floor used as winter habitation, while the second floor was used for summer habitation.

Openings are kept to a minimal at the lower level – usually narrow slit-like openings for ventilation. Before the advent of glass, the windows of the upper levels although larger than the openings of the ground floor remains relatively small. Grand wood-carved rabsaal (projecting timber-framed balconies sometimes with intricately carved lattice screens) were seen in the more affluent houses.

The layout of houses has altered dramatically over the past 50 years. Houses are built on low plinths of stone masonry with larger window openings at the ground-floor level itself. Concrete frames are now erected within which mud-brick walls are built often of a single-brick thickness. Walls are no longer tapered but are of uniform width from base to roof. The roofs, considered to be the most vulnerable part of the house, is now increasingly being laid in concrete with metal or PVC pipes providing drainage. The advent of glass permits wider window openings

Fig.3 A lubang built over a boulder near the village pond, Chemday (credits: Tara Sharma, 2012)

and the introduction of a glazed room, usually at a south-facing corner of the house, is today seen in almost all houses. The recent floods highlighted the danger of some of these changes, as large boulders crashed through the fragile walls and window openings causing serious damage to the affected houses.

3.3 Traditional materials and techniques

The architecture of the region highlights the judicious use of scarce resources – walls are generally built of sun-dried mud bricks based on foundations of stone masonry. The ground floor is built in stone masonry, while the upper levels are constructed in adobe. Timber ring beams encircle the masonry ensuring seismic stability. Timber posts and lintels provide the structural framework for the building. In the past, only local timber would be used, which was primarily poplar (*yarpa*) and, in rare cases, juniper (*shugpa*) – the latter being used largely in temples. Today, timber is brought in from neighboring Kashmir, and with relatively easy availability is used more lavishly now.

Window frames, lintels and doorframes were all created out of timber. To begin with, these were sparsely embellished, but gradually became more elaborate with the *shing tsak* (carved timber lintels) becoming a major architectural feature in later architecture.

The roof was laid out in layers – layers of *taalu* (twigs usually of willow), over which were laid layers of *yagzes* or *umbu* (local hardy shrubs), followed by different compositions of mud carefully pounded and laid in courses. Drainage outlets were generally made of timber sections.

The walls were traditionally tapered, narrowing upwards as they reached the roof. An elderly mason, Meme Sonam Palgyes (Chemday), responsible for the periodic repair and new construction at Chemday monastery, demonstrates the knowledge of the traditional builders. Stone was quarried from specific sites near the monastery and carefully dressed. He points out to the quality of the masonry in older construction where each course is carefully laid and bonded and the slope of the tapering wall measured according to the number of stories. Corners were specially bonded to ensure structural stability.

Varieties of mud (*tsa*) were known to the traditional masons and an understanding of the properties of each type informed what kind of mud was used for what purpose. Local clay/mud pits and stone quarries were sourced for raw materials depending on the financial capacity of the homeowner. Each village traditionally had its own network of sources for procuring raw materials needed for earthen construction. Today, with the advent of modern materials, the knowledge of traditional materials and their sources is gradually being lost.

One such example can be seen in the production of commercial mud bricks. Specific soils were used for the production of mud bricks that were known for their strength. To the soil were added small pebbles or chopped straw to bind the mud together. The soil was usually watered a day before production and then mixed with chopped straw and aggregate as needed. The mixture poured into the moulds (traditionally wooden moulds now replaced by metal frames) was pounded repeatedly with a stout willow branch, especially at the corners to ensure it is well compacted with sharp edges. The mould was then lifted and the brick left to cure for up to a week depending on the weather. The knowledge of the production process is now getting lost. Today, the mud pits are contracted out to migrant labor unfamiliar with the local technique. Mud is poured into the moulds without any additions of straw or aggregates and lightly pressed by hand to form an even top surface. This results in air pockets inside the brick and especially uneven edges.

Stone masonry is another declining local skill today. Meme Palgyes of Chemday highlights the poor quality of construction seen today. He points out newer construction where rough infills of stone are used to fill in the now narrower bases and where there is very little bonding of the masonry. The poor quality of contemporary earthen and stone construction was highlighted in last year's floods.

3.4 Traditional calendar of repair, renewal and maintenance

The deterioration or decay of earthen architecture is attributed to the action of natural elements – earth, water, fire and wind. To address this, earthen houses traditionally followed a calendar of maintenance. Periodic maintenance of the houses is manifested in the traditional Tibetan calendar (*Lo to*), religiously followed by most Buddhists, which highlights dates every year when houses should be repaired (usually in early summer after the building has undergone the winter's snowfalls). This usually meant adding additional layers of mud or *markalag* (a type of clay) over weak spots in the roof and correcting the slope. Drainage outlets were also regularly cleaned. Other structures, such as the village chorten, *mane* and rigsum gonbo are annually renewed on the Zhipe Chonga (15th day of the fourth month of Tibetan calendar).

Fig.4 Contemporary production of mud bricks in the village of Shey (credits: Tara Sharma, 2011)

Unfortunately, with declining knowledge and skills and replacement of traditional materials by incompatible materials, these maintenance cycles are not regularly followed. The floods of 2010 revealed that damage to earthen architecture was linked to poor maintenance and repair cycles. Ironically, it was seen as a general failure of earthen architecture, although earthen architecture in the region dates back over a thousand years and has stood the test of time.

4. IMPACT OF CLIMATE CHANGE

The increased frequency of floods in the region is seen in the larger context of global climate change. Usually, the area experiences heavy snowfall in the winter, particularly in January and February, with less snowfall till the end of April. There are aberrations to these trends, though, and over the past several years, it has been noted that there are years when there is relatively less snowfall in winter followed by heavy unseasonal snowfall in May and June The onset of summer in such instances leads to a rapid melting of the glaciers causing water to gush down the village streams. A single spell of unduly heavy rain can prove catastrophic in such cases, flooding the already heavily saturated banks. Seasons of unprecedented heavy snowfall over a few weeks of winter in 2013 saw a huge loss of the valuable pashmina goats reared by the nomads of Changthang.

Meteorological records, vouched for by village elders, however, reveal that floods and earthquakes have occurred in the past (in 1921, 1933, 2006) and are not unknown to Ladakh. While natural disasters are not new to Ladakh, what is unprecedented is the scale of devastation, which has been exacerbated by the increased frequency of such disasters. The scale of damage can be linked to the declining belief in traditional knowledge systems and associated changes in settlement patterns, architecture and declining traditional building-craft skills. Integrating this traditional knowledge, evolved from a profound understanding of the landscape, into contemporary regional and local development plans could help perhaps reduce the scale of damage in future disasters.

Notes

(1) A structure comprised of three stupas (chorten) on a common platform. The chorten are usually painted in the traditional colors of red/orange, blue and white, denoting the three Bodhisattvas, Manjushri (Wisdom), Avalokitesvara (Compassion) and Vajrapani (Strength) who protect the three classes of beings – gods, humans, serpents or demi-gods.

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MOORCHEH KHORT HISTORICAL FORTRESS: THE ENTRY GATE OF IRAN'S ANCIENT CAPITAL

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Theme 5: Local and Regional Knowledge, Intangible Heritage and Social Impacts
Keywords: Fortress, Civilization, Physical Protection

Abstract

Moorcheh Khort historical fortress is a much valued but lesser known historical site located on the Iranian Central Plateau. This article attempts to develop a model by utilizing an archeological and architectural research methodology framework with spatial analysis to study the interaction among existing spaces with consideration given to the outcomes of social changes, which have occurred throughout the various historical periods in Iran with a focus on local significance. Moorcheh Khort is used as the model in this study due to its historical significance as one of the largest clay construction complexes on the Iranian Central Plateau and its possession of unique architectural features characterized by the material used in its construction.

1. INTRODUCTION

Research programs on the Iranian Central Plateau and on Moorcheh Khort have been conducted in a coordinated fashion since 2008 under the supervision of Sherkat Ehyaeh Bafteh Tarikhi Ghale'h Moorcheh Khort (Renovation Company for Moorcheh Khort Historical Fortress). Academic and scientific centers, including Shahid Beheshti and Tehran University, are contributing members to the research programs. The Moorcheh Khort site remains unknown to most of the architectural and renovation community because of dispersed and limited documentation. Due to the unique architecture, documented historical background, and strategic location, the establishment of short- and long-term interdisciplinary and intra-disciplinary research programs on the subject is required to deal with the numerous unanswered questions and vast issues involved. These research programs receive government support and are in compliance with all international charters as is perquisite for its registration as a World Heritage site. Moorcheh Khort can be considered an example of a manmade fortress with different applications fashioned after the cultural setting in Iran during that period (Sotoodeh, 2001).

1.1 Regional geography

Moorcheh Khort village is located 45 km north of Isfahan on the way to Tehran. This village with a population of 1,761 is located 1,760 meters above sea level at a coordinate of 6' 36° North Latitude and 29' 51° East Latitude, and is sited on an open plain surrounded by highland areas to the north and northeast. The most important factor in the settlement of humans at Moorcheh Khort has been the existence and availability of water resources in the area. A sufficient water supply for the community provided by aqueducts and wells has made abundant agricultural and plantation output possible for hundreds of years to the residents of the community and surrounding area. The history of Moorcheh Khort goes back to 980 AD (4th-century lunar hegri). The original settlement was formed along a route made for commercial caravans. The residents made their living by providing services to the commercial caravans and passengers. Service provision expanded when Moorcheh Khort village was established (Azari Damirchi, 1974). The interments of Imam Zadeh Ali and Imam Zadeh Qasem (Imam Reza's brother, 8th Imam of the Shia Moslems) resulted in an increase in the population due to immigration into the area.

1.2 Nomenclature

The origin of the name of Moorcheh Khort is not clear. The late Professor Mehryar (professor of Persian literature, 1918-2010) wrote the following: "This name is commonly used in two ways. Some call it Moorcheh Khort and others call it Moorcheh Khar". Moorcheh Khort is made of two words: Moorcheh and Khort. Professor Mehryar pointed out that the Arian civilization used the word "Moor" meaning "ant" in naming places and villages because the Zoroastrians believed that exterminating ants was a holy act.

Fig.1 Floor plans of the historic site of Moorcheh Khort (credits: Renovation Company for Moorcheh Khort Historical Fortress, 2008)

1.3 History of conflicts

The important point in the history of Moorcheh Khort is the battle between Nader Shah Afshar and Ashraf of Afghanistan in this area resulting in the conflict making the name of this part of Isfahan well known in Iranian history. This battle, which started in the early hours of the 11th of November 1729, was the final victory of Nader Shah, which resulted in the conquering of Isfahan and the prevention of the Afghans from making advancements to take over Iran. It concluded with the destruction of the Ashraf artillery. Nader Shah freed the Ottoman prisoners held by the occupiers. Laurence Lockhart (English historian, 1890-1976) mentioned Moorcheh Khort as a decisive battle with evidence viewable in the northeastern section of the fortress.

1.4 Early architecture characteristics

Moorcheh Khort is located on a plain of the same name with strategic, security, economic and locational significance throughout history. Numerous micro-spaces were gradually formed in Moorcheh Khort based upon different applications and activities defined for the area. Preliminary studies and historical documentation show that this fortress was originally built in the form of a non-equal four-sided shape as a defensive point. The presence of guards and fighters in the fortress mandated building certain forms to meet the requirements for the early defense of this part of Isfahan against any foreign invasion. Low covered passageways accompanied by a complicated layout were intended to make this fortress unconquerable against possible onslaughts. This fortress with its four main caravansaries (Madar Shah, Chapar Khaneh, Chal, and Maimeh) became a trading and storage point for goods received from nearby or faraway lands after Isfahan became the capital during the Safavid era. Moorcheh Khort was also known as Shahr-e Karbas, so named for the cotton plantations in the surrounding area made possible because of the productive land and abundant water supply.

Moorcheh Khort gained economic importance in addition to its defensive capabilities after its surrounding walls were extended to include the main spaces. The formation of a bazaar during this period, with its many stores, textile workshops, and warehouses attracted new traders and residents. The forms of covered spaces are indicative of the extended economic activities in this period. Changes in living conditions made the available space in the fortress unable to meet the requirements of the increasing population resulting in residents gradually moving out into the surrounding areas or to other cities and communities for better convenience and availability of services. Moorcheh Khort was eventually abandoned after the area experienced many periods of drought and once Isfahan lost its place as the capital toward the end of the Safavid era.

For a period, Moorcheh Khort became the central activity point for brigands looting commercial caravans passing through this area. It became important once again after the Qajar gathered strength and gained control of the country. The area was once again populated by people moving from nearby or faraway lands. The shortage of living space inside the fortress resulted in the need to accommodate an increasing population and the addition of new public spaces, such as a Grand Mosque, an expansion of the bazaar, and bathhouses.

1.5 Physical structure

The new private residential areas in conjunction with passages, covered passageways, and public spaces have created an integrated and complicated ensemble, which is difficult to segregate. The high concentration of buildings inside the fortress can be attributed to the high value of the surrounding land. The complicated vertical and horizontal integration of the adjoining structures in this fortress has created numerous physical layers and different proprietary systems. Architectural and historians have referred to Moorcheh Khort as "Iran's thousand-inner architecture" (Noorbakhsh, 1995; Falamaki, 2007b). Family relationships created a social system, which governed the formation of a complicated system for occupying residential spaces within the fortress (Zoka, 1995). Every single private living space and every covered or open space inside



Fig.2, Fig.3 and Fig.4 Historical structures in Moorcheh Khort, Iran (credits: M. R. Manouchehri, 2008)

the fortress had a proprietary and period title. Each room had separate property documents issued based on social status and family relationships (i.e. father, son, brother, and so on).

2. MORPHOLOGY

2.1 Type of spaces

The complexity and concentration of physical spaces resulted from an increased population and defensive requirements that created architecture on which it is difficult to differentiate private spaces from public ones. This makes it necessary to study the inner spaces based on their applications and identify existing spaces as residential, religious, public and private services, or production and commercial unites.

A) Residential Spaces including:

- Single-family unit including one room plus the required conveniences;
- Multi-level, multi-family unit consisting of several rooms and the required conveniences;
- Multi-family unit with a courtyard consisting of several rooms on multiple levels built around a courtyard plus the required conveniences;
- Large residential unit with shared conveniences consisting of several rooms on multiple levels built around a courtyard in penthouse format or over passages plus the required conveniences.

B) Production-Commercial Spaces including:

- Production and commercial spaces built along the bazaar area or scattered throughout the fortress in a more or less systematic way;
- Production and commercial spaces built along high-traffic inner passages in the form of shop-residence or store-workshop combinations.

C) Religious Spaces including Hosainieh, Grand Mosque, and holy shrines. The religious spaces are scattered around a central focal point and along the main pathway. They have orderly plots with irregular boundaries.

D) Service Spaces include male and female bathhouses built around the central point of fortress. These bathhouses are built underground and their roofs serve as passages connecting religious spaces to the bazaar area. Their plans are similar to traditional bathhouses in Iran.

2.2 Spatial characteristics

Residential units within Moorcheh Khort have special characteristics. They are constructed on multiple levels with courtyards as their focal points. The courtyards are usually built on one side of the living quarters. Residential units have private conveniences, which are connected to a central sewage system with water wells being built in one corner of the courtyard under staircases. The size of the well would depend upon the total area of residential unit.

Staircases are considered one of the main characteristics of the residential units in Moorcheh Khort fortress. They attract the attention of visitors from an aesthetic point of view. Each residential unit has a separate cooking space equipped with hearth and oven. The position of each element of a residential unit relative to the positions of the rooms on different levels forms a contiguous space.

2.3 General concepts approach

Influencing factors on the formation, development, and expansion of Moorcheh Khort historical fortress were the following:

A) Cultural Factors:

The traditional Iranian architectural characteristics present at Moorcheh Khort are also prevalent in other structures throughout the Iranian Central Plateau. High walls surround residential units, with all rooms opening out onto a central courtyard.

B) Local Conditions:

Residential fortresses around Iran are created conforming to the local conditions and are representative of the local architecture. The availability of construction material depended on the natural and geographical conditions of the area. A limited water supply forced settlements to form around springs and streams. Community living was required because living and cultivation in higher lands and plains are only possible as group activities.

C) Security-Strategic Factors:

The formation of fortresses in mountainous and plains areas, as well as along the main and side commercial routes and near major cities was due to the high importance given to the security concerns of communities. Welfrom Klays in his studies on the formation of fortresses along the main roads and caravan routes concluded that perhaps Moorcheh Khort was one of these fortresses originally built for security concerns. He wrote that the fortresses built on caravan routes were for protection of caravans and their merchandise. These fortresses had military and defensive applications and were built close to caravansaries (Klays, 2001).

D) Economic Factors:

The formation of these types of residential fortresses had roots in the land-ownership system prevalent in Iran. The feudal system (the system of landlord and peasants) was common in the area throughout history and was enforced by the local rulers, as well as other people of power. This system required a central location near agricultural land to facilitate its management and protection. This requirement led to the type of land ownership and the special architecture prevalent during this period. The result of centralized feudalism was the creation of a strong relationship between settlements including cities and villages. The development and expansion of cities and villages increased the number of access roads and commercial routes to facilitate the exchange of goods and services between communities. The location of settlements along commercial routes may not have been the only reason for formation of communities. However, it can be considered as the main reason for their survival, development and prosperity.

E) Social Factors:

This type of architecture may be attributed to the specific tribal social system of patriarchy, which promoted community living and that has been prevalent in the area throughout history. This may be considered as another factor in the formation of fortresses. Fathers and elderly men have high positions in such a system and are the leaders and possessors of the rest of the tribe. Members of such a community are dependent upon and perform under a power center. This relationship resulted in related and intertwined residential units.

The special economic requirements of the family required continuous and rapid contact with paternal properties. In such a setting, a family residence consisted of a large house, a large stable, a main barn, and many multi-level residential units built above them.

Family settings required a closed living arrangement to prevent intrusions from non-family members. All these requirements are the formative elements of residential structures in a residential fortress. The effects of various factors on the formation, development, and prosperity of a residential fortress and the roles those factors played during different time periods are sometimes vividly evident and sometimes not so obvious. The cultural, social, and economic structures that have prevailed throughout the existence of Moorcheh Khort fortress plus other influencing local conditions have formed the available physical-space arrangements inside the complex turning it into a city structure. This structure includes residential units; a central area consisting of a fortress, bazaar, and Grand Mosque; and city-service spaces, such as male and female public bathhouses, public drinking fountains, and other such places. The fortress also had prayer quarters, shrines, and Hosseiniehs providing religious services.

All spaces within Moorcheh Khort historical fortress were built relative to each other and connected by passages, covered passages, and gates. The structural relationship and connectivity evident within the fortress resulted in turning it into a real city or township structure. Such structure required accommodation for a defensive force, means for feeding the population through cultivation on the surrounding lands, and possibility for future expansion. The fortress was also required to facilitate working spaces at different levels for tradesmen, craftsmen, and merchants. Different construction materials were used in building fortresses in the desert and lowland areas depending on the local conditions and characteristics. Studies and observations reveal that most of the fortresses were built by using clay materials. They were seldom built with brick and stucco. Fortifications in fortresses were generally made of stratified or thick clay walls.

2.4 Studied elements

Variations of building structures and the ways different elements were built next to each other in a fortress stemmed from the complicated social structure prevalent in the community, plus the various applications defined for the fortress including military, security; commercial, economic, cultural, etc. The building elements behind the construction of a fortress along with a review of historical drawings and historical events will define the ways to define a study on the subject and provide a theoretical framework. A study of the physical structure, a review of all hidden and evident historical dimensions, sociological studies of different periods, the recreation of unique mores, and a study of cultures and micro-cultures surrounding the complex will assist in uncovering the facts about the fortress architecture.

A complete study on the subject will require a multi-disciplinary knowledge base, which includes:

- Identification of physical forms including dimensions and number of levels, and their relationships to adjoining units.

Fig.5 General view from above the historic fortress (credits: M.R. Manouchehri, 2008)

- Identification of structures including spatial arrangements in architectural units and their relationships to the land (structural and load-bearing elements).
- Identification and recording of the relationship between surface and volume based on the main applications and recognition of changes that may have taken place.
- Identification of family and tribal sociological relationships.
- Identification of social and cultural strata.
- Identification of micro-cultures existing in the surrounding environment.

3. BUILDING SYSTEMS

3.1 Forms

Historic architecture found on the Iranian Central Plateau reflects a traditional tendency of Iranian people to adapt to their local environment. Local architects formed structures conforming to the requirements of the local climate. They effectively used local construction materials to block the influence of hot and dry weather in summer and extreme cold during winter.

Covered passageways built inside the city structure pleasantly connected neighboring units and were representative of the interaction among various city elements. High walls and supporting doors provided privacy for families.

3.2 Construction materials

Many factors have influenced architecture on the Iranian Central Plateau. Residential complexes in hot and dry climates were built using local construction materials, such as clay, stone, etc. The physical forms of the surrounding environment and the selection of a land influenced the building of architecture.

Earth and stone, with their strengths and weaknesses, were the most available construction materials in any place in Iran. Local architects and builders cleverly and effectively used local materials to build structures and create spaces. Good examples are earthen structures built in desert areas by using locally available soil.

Local architects used a technique for building large residential fortresses wherein they excavated earth from a large area and used that earth for building the structure. A good example of this technique was the digging of trenches around the site and using the earth for building fortifications and walls. Indeed, digging trenches were prerequisite for building a fortress.

The availability of water resources has long been an influencing factor on settlements in desert areas. Settlements were formed and caravansaries were constructed where water resources could be found. With the special geographical position of the Iranian Central Plateau and the situation of major routes (such as the Silk Road) connecting faraway civilizations and different countries, sometimes it became necessary to create communities where water was scarce.

Dry weather and limited precipitation prompted the creation of irrigation systems for agriculture and other cultivation. These irrigation systems extracted water from deep underground reservoirs and brought it up to surface level with water flow based on land incline and earth-gravity pull. Irrigation consisted of a network of irregular water channels taking on geometric shapes dictated by their location within agricultural land and cultivation areas situated around these systems.

Fig.6 Historical structures in Moorcheh Khort, Iran (credits: M.R. Manouchehri, 2008)

Fig.7 Historical structures in Moorcheh Khort, Iran (credits: M.R. Manouchehri, 2008)

3.3 Construction methods

Large fluctuations in temperature between days and nights in different seasons and limited availability of heating materials, such as wood, prompted construction using local materials with high thermal properties. Clay is one construction material with a high thermal property found in abundance and at a very low cost in most of Iran. Its usage goes as far back as the construction of ancient site of Persepolis near Shiraz.

3.4 Physical structure

3.4.1 Main Structure

Walls: Moorcheh Khort, with an area of 33,000 square meters, has a protective wall with a thickness of 2 meters and a height of 6 meters. The inside of this wall is made of stone surrounded with stratified clay materials.

Towers: The fortress has eight sentry towers, which were important in providing security to the residents.

Entrances: The fortress has two main entrances with one being on the southeast side and the other on the northwest. They are positioned in two orthogonal directions connected by the main inner pathway. Each entrance is built inside a tower. The entrance doors are wooden structures of 25-cm thickness with reinforcement provided by thick metal sheets nailed to the wood. The entrance on the southwest opens into a huge vestibule, while the other entrance opens directly into the main pathway.

Emam Zadeh Ali: The burial site of Imam Zadeh Ali is located next to the main entrance on the southwest side and features a conical dome of turquoise and azure tiling. It has a courtyard with a portico that is surrounded by the monument, as well as service rooms, which were also used as a burial site.

Bathhouses: Bathhouses were located at the centre of the fortress along the main pathway. The eastern bathhouse was for males and the western one was for females. They were built two meters underground with a stone foundation, brick walls and lime ornamentations. Each bathhouse had a portal, a twisting entrance corridor, a changing room, a connecting entrance, a hot room, a pool, a hearth, and a main well for the water supply. Light and ventilation were provided by ceiling vents and skylights. Catwalks underneath the stone floor provided a means for the distribution of heat from the hearth throughout the bathhouse.

Grand Mosque: The Grand Mosque was built on the main pathway. It has two porticos, one portal, one central courtyard, one summer-prayer area, and one winter-prayer area with stone columns. Clay is the main construction material used in the Grand Mosque. The interior and exterior of the Grand Mosque are decorated with bricks, tiles, and stucco works.

Bazaar: Bazaar is a Persian word. Its Pahlavi root is Bahachar, meaning a place for prices. From a historical point of view, a bazaar was a place where sellers and buyers met to exchange goods and services. Bazaars were originally formed during the Sasanian era in cities where commerce was the main activity, and were considered the socio-economic element of a community. The main bazaar was usually formed next to a city's main entrance and would normally expand inward along the main access ways as trading increased. Their formation, development, and organization were dependent on increases in trading volume by which their dynamism influenced the interaction and coordination of the various elements.

The major elements of a bazaar were a main pathway, side paths, corridors, crosses, squares, and shops. Most bazaars in Iran formed in a linear format with the shops on the busiest line creating the main part of the bazaar. The main bazaar in Moorcheh Khort was located on the main pathway between two entrances. These shops provided the daily staples required by residents and played an important role in fortress commerce.

Prayer Quarters: Prayer quarters were located next to bathhouses and fashioned after the religious beliefs of the residents. These were an important element in the fortress structure.

Main Pathway: The main pathway in Moorcheh Khort extended from the southwest to the northeast connecting the two main entrances. Side pathways branched out from the main pathway based on the positions of neighboring residential units, their relationships, and possibility of intrusion from other units.

Covered Passageways: Covered passageways were considered important in Iranian architecture from ancient times and were arranged in such a way as to provide continuous shade from the sun and heat during summer days. They also helped to provide protection from seasonal winds. Many covered passageways ended at residential units and were helpful in building a sense of solidarity and neighborliness among residents, as well as providing extra security. This type of passageway is referred to as a locked passageway.

Roofs, as well as rooms, were built over these passageways and were formed based on the positions of adjoining units, their relationships, and possibility of intrusion with considerations given to environmental conditions and the effective use of space.

4. CONCLUSION

Based on the first article of the Venice Charter (ICOMOS, 1964), a historical site not only includes single buildings but also urban or rural community complexes that represent a certain civilization, a recognized advancement, or a historical event. Historic classification can include major works of arts, as well as ordinary ones, which have gained cultural significance by passage of time. Rehabilitation works on historical sites create a working relationship between the historical site and workers (Falamaki, 2007a). Rehabilitation works are an undertaking that requires knowledge more than ingenuity; patience more than productivity; conscience more than enthusiasm; and pride more than financial gains.

Research on historical sites requires multidisciplinary studies involving the identification of construction materials and the interrelationship of structures. Protective rehabilitation programs based on guidelines provided by international charters require intra-project decision-making. Project supervisors can obtain funding for rehabilitation projects based on priorities. A detailed program was drawn up outlining the protective needs for Moorcheh Khort historical fortress. Meanwhile, a short project was conducted to provide emergency protection to the ceilings, walls, pathways, public, and main buildings of the fortress with limited damage or to halt deterioration.

4.1 Importance of dissemination

If it is accepted that architecture is the consequence of changes in society and its major and minor events, as well as many of the experiences gained by past generations throughout the centuries that have been forgotten by the newer generations, then by conforming to the principle of returning to traditions, it should be undertaken the task of introducing Moorcheh Khort historical fortress to the next generation. This should be done by using the results of the studies performed and classifications of historically documented findings, while a rehabilitation program of its physical structure is in progress.

Knowledge about past generations and recognition of their achievements can contribute to scientific advancement of the current generation. Therefore, arranging local and national programs for students and teaching workshops at the college level for students, and post-graduate level for experts, and governmental professionals can help introducing the public to Moorcheh Khort historical fortress.

Additional dissemination programs included the publication of a pictorial book on Moorcheh Khort fortress, which served as an entry point to the historic capital of Iran in 2009. In addition, a documentary on Moorcheh Khort was produced and nationally broadcast in 2011, as well as posters, post cards and brochures printed on different occasions to raise awareness, and encourage public involvement.

4.2 Importance of continued study

Funding is a major concern of almost all research projects. Lack of proper funding has pushed many historical sites to the verge of destruction. Agreements made by academic entities are only a small part of this national and international program devised for the protection of this historical site. Continued drought and lack of private and international funding are major obstacles for this project.

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LOCAL SOCIO-CULTURAL KNOWLEDGE SYSTEMS AND ASSOCIATED INTANGIBLE HERITAGE PREVALENT IN UGANDAN EARTHEN ARCHITECTURE

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Theme 5: Local and Regional Knowledge, Intangible Heritage and Social Impact
Keywords: Local knowledge, earthen architecture

Abstract

At this time, the subject of local and as well as regional socio-cultural knowledge systems, and associated intangible heritage prevalent in African earthen architecture is seldom regarded as a worthwhile focus to warrant attention of academics, professionals and public-private sector partnerships in Africa. Yet these knowledge systems and attendant intangible heritage proliferated productive impacts towards the sustenance of indigenous education and related social-cultural values, customs and traditions of pre-Colonial African societies. Apparently, African earthen architecture provided the medium for transmission of knowledge systems together with intangible heritage. Their resilience has continued to date but at a much-reduced level of significance. In this connection, African earthen architecture is among the continent's heritage fabric currently undergoing obsolescence and severe decline in enriching new generations with timeless knowledge systems.

In instances of the above-noted obsolescence, the connection between intangible heritage and the African people has likewise diminished and become increasingly confused. Concomitantly, uni-dimensional globalization has taken its toll and the new generations have been left adrift. They are increasingly disconnected, and attempting to understand themselves. Consequently, their cultural landscapes and earthen-built ensembles are also threatened with disintegration.

Hence, this paper highlights the compound threat to local African socio-cultural knowledge systems and associated intangible heritage prevalent in earthen architecture by means of a case study with Ugandan examples. Thereafter, the paper unfolds 'best-practice' pathways for mitigating against the vulnerability of these socio-cultural knowledge systems prevalent in the earthen architecture, so as to ensure their continuity.

1. INTRODUCTION

For background since time immemorial, African socio-cultural and ethnographic knowledge systems in their diverse artisanal, symbolical, mythological, magical, metaphorical, proverbial, and poetical configurations are profusely transmitted through oral and artisan traditions of rock art, textile design, infusion in ceremonial objects, decorative drawings, tattoos, rites, masks, figures, legends, fables, metaphors, proverbs, etc. Since the knowledge systems on their own are, in fact, invisible, African civilizations best converted some of them into tangible form by communicating, expressing, and representing them architectonically. In an investigative context, it is this category that is captured in this paper. In this regard, African earthen architecture, in general, and the Ugandan earthen ensembles, in particular, are customarily imbued with a good amount of these knowledge systems by means of artisanal inclusion in the walls of most traditional human habitations. Semioticians make their reflections on this occurrence and applaud the artisans for this ethno-instinctive vocation synonymous with a corporate mouthpiece for indigenous knowledge systems and associated intangible cultural heritages (Cobley and Jansz, 2004).

Thus, apart from providing shelter, this merit makes Africa's and, case-specifically, Uganda's indigenous earthen architecture double as a materially energical and artifactual infrastructure for these knowledge systems to physically exist and 'live' on. This permits earthen architecture to gain an almost unparalleled status of one among the continent's biggest 'social resources' for communicating knowledge systems, sustaining indigenous education, related customs and traditions accumulated right from pre-Colonial times. In its intrinsic simplicity, Ugandan earthen architecture is, hence, a foremost material embodiment and reflection of people's values, perceptions, identity, aspirations, goals, etc.

Fig.1 Earthen architectural wall semiotics at Kitintalo, Tirinyi District, Uganda (credits: Allan Birabi, 2010)

Despite its declining potency and level of significance, earthen architecture continues to act as one of the most reputed mediums for transmission of Uganda's local indigenous knowledge systems. Yet it is fast disappearing due to flimsy patronage for its continuity, together with the disorienting adaptation to globalization and a number of other erosive forces. In fact, some of those knowledge systems have already been lost forever. Hence, it became a point of justification to write this paper in order to contribute to awareness about these knowledge systems as an urgent trigger for documenting and revitalizing their continuity. The lynchpin of this endeavor is the subject matter of the next subsections by means of some selected Ugandan cultural landscapes, rich in these knowledge systems, and related built environments.

Methodologically speaking, the paper developed out of combined qualitative social approaches of the Investigator/Theoretician (External Mode) and the Local Community Mode (Internal Mode) of investigation and interpretation. The Investigator/Theoretician Mode was the source of theoretical perspectives upon observing the community for some time, coupled with exploration of theory and related literature on the subject. Alongside, the Local Community Mode produced socially constructed experiential and/or practice-based explanations of how people add meaning or value to their architectural configurations. Within this combination, data-collection techniques spanned a scan of primary and secondary sources, interviews, participant observation, physical information, and photography within the Ugandan cultural landscapes that were selected for their richness in those knowledge systems.

Fig.2 A close-up detail of Figure 1 showing abstract floral and faunal elements (credits: Allan Birabi, 2010)

2. NATURE AND CHARACTER OF THE SOCIO-CULTURAL KNOWLEDGE SYSTEMS PREVLENT IN EARTHEN ARCHITECTURE

By means of the information-oriented sampling technique rather than direct random sampling, a series of explorative field trips across salient localities with surviving earthen architectural ensembles were scrutinized. In this connection, apparent owner-occupiers of the samples gained the status of potential interviewees on grounds that they were a source of primary data concerning the targeted earthen-architectural fabric and related knowledge systems' embodiments. Since the narrative, explanatory and descriptive account about the nature and character of those earthen architecture-driven knowledge systems necessitated accompaniment of considerable visual interpretation, the main text of this paper is juxtaposed with a corresponding photographic illustrations.

Embarking on this main focus, therefore, creators of this knowledge-radiating architecture, who in most instances are self-taught indigenous 'artist-architects', have experientially and intuitively evolved what Barabanov (1997) refers to as an imaginative, socio-spatial, resourceful, and productive accomplishment of depositing indigenous-knowledge systems in walls of earthen architecture. By means of the exceptional power of engaging their artistic expertise, such indigenous excellers also double as socio-ethno-cultural communicators. The illustrations below depict one such exemplar of a house at Kitintalo, in Tirinyi District of eastern Uganda, with picturesque wall semiotics of bright muralist distinction and graphic accomplishment rooted in typical mixed African ethno-mathematical and decorative aesthetic. The bands of combined rhythmic, pluralistic and gently undulating lines stir up a tranquil musical sensation. The multiplicity of the lines is organically synonymous with plurality of contrapuntal voices and cross-rhythms, in juxtaposition with silent 'offbeat' and the sounded 'on-beat' instrumentals of indigenous Ugandan music (Collins, 2004). It is a sort of musical multiplicity infused in the wall semiotics. Notably, the alliance between indigenous African music and architectural semiotics is traditionally instinctive and free of any compartmentalization between the two specialties.

Fig.3 Floral and dot semiotics at Nakalama, District, Uganda (credits: Allan Birabi, 2010)

Fig.4 Floral semiotics dominated by sensual red at Muwayo, Busia District, Uganda (credits: Allan Birabi, 2010)

It is no surprise that this artisanal syncopation and 'jazzing' of Ugandan earthen-architectural semiotics with such musical impulses enriches this extravaganza of visually recognizable knowledge systems. As represented in detail, the inclusion of varied abstract faunal and floral elements, each radiating a message but mutually contributing to an overall bigger knowledge-driven meaning, draws parallels with modern know-how of multimedia communication as well. The essence of adorning the house with this whole wall of semiotics is the artisan's skill for drawing in the viewer to circle the entire building for maximum enjoyment. Through their practiced minds, hands and eyes, the artisans turn earthen-architectural ensembles into living socio-cultural encyclopedic depositories, open-air galleries and/or museums rich in a vast array of indigenous-knowledge systems.

It is apparent that subject matter is wide-ranging across aspects of beauty, fertility, birth, marriage, love, family-hood, appreciation for nature, music, gender, heavenly bodies, social order and status, social ceremonies/customs/traditions, hunting, agriculture and political power. It also spans religion, fortunes and misfortunes, excellence, proficiency, talents and others.

Expression of these varied subject matters is frequently augmented by ethnomathematical imaginativeness that is also cross-pollinated with organic geometry. For instance, from dialogue with the artisans who executed the wall semiotics, the subject matter was in respect of love for nature. In fact, nature appears to be the most influential source of subject matter for Ugandan earthen-architectural wall semioticians. Accomplished at times from a palette of pure traditional earth colors, and in some instances from a combination of the traditional pigments and some modern industrially prepared paint, the earthen-architectural wall semioticians also propagate a considerable bulk of color-driven knowledge systems that are characteristically tools of instant emotional, psychological, and inspirational communication. In this context, a variety of neutral tones of gray, beige, and taupe are often in rich dramatic concert with considerable shades and values of red, orange, brown, green, blue, purple, etc. In fact, local Ugandan clays are a source of diverse colors ranging from dark volcanic vertisols, and oxidized reds, to luminous creams as well as sparkling white kaolins. They are commonly retrieved from flood plains, mountain slopes or deposits.

Coined by Brazilian mathematician Ubiratan D'Ambrosio in 1977, ethnomathematics is essentially defined as the cognizance of mathematics that considers the culture in which the given mathematical contexts arise by understanding the reasoning and the very mathematical systems in use (Ascher, 1991; Zaslavsky, 1991). What came forward from the observations in the field is what can best be termed 'African ethnmomathematics' rich in its own peculiar fractals. A fractal is a pattern that repeats itself at different scales. Noted for its wide application in Africa for several centuries, the realization is that the fractal element is a strong and popular component engaged by indigenous Ugandan architectural semioticians not only in their earthen wall semiotics' compositions but also in other artistic design pursuits such as pottery, mat-weaving, ironmongery, sculpture, beadwork, jewelry, leather crafts, furniture making, hairstyling, basketry, tapestry, mat-weaving and more.

Within the earthen-architectural wall-semiotics context, the illustration below is one among numerous other exemplars traced on a house at Bugiri, Eastern Uganda. With a powerful intuitive sense of fractal ethnomathematics arranged with meticulous strip patterns, repetition is by means of combined vertical, horizontal, or glide reflections. Glide reflections are the result of the artisan maneuvering a fractal or unit of design in one direction for a definite amount of distance. This process is then repeated to cover the predetermined wall area.

To gain insight into the intricate ethnomathematical and

Fig.5 Detail of some floral wall semiotics in a house (credits: Allan Birabi, 2010)

ethno-geometrical-knowledge systems behind the respective fractal-strip patterns, an abstract synthesis of the semiotics led to the interpretation depicted above. The top row is based on a two-color rectangular pattern, which without reflection or rotation, is plainly reproduced or glided to the right over the length and direction of the arrow. The sequence is then repeated over and over again. The same arrangement is applied to the pattern work in the second row. In the third row, the red box is representative of the unit of design as an ethnomathematical concept of the artisan. In a tri-color pattern, it comprises of eight triangles adjacent to one another in reverse directions. A horizontal but alternately flipped translation to the right of the eight triangles, as indicated by the curvilinear arrows, propagates the pattern.

Another stylish exemplar of Ugandan earthen ethnomathematical-wall semiotics was reviewed at Magodes in Tororo District. With sophisticated tessellation geometry, coupled with design elements of line, color, dramatic contrast, and organizational ethnomathematics, the artisan registers a commendable degree of superb interplay of mixed color pattern and textural charisma to turn the mere flat wall into a somewhat 'wise', energetic, musical, and educative surface.

The above exemplars of both fractal and non-fractal geometrical wall semiotics are but just a sampling of the extensive socio-cultural knowledge systems that prevail in Uganda's rural countryside. To the artisans, fractal geometry is a kind of 'instinctive mathematics', which modern formal engineering expertise now endeavors to decode. Validating this observation, Eglash (1999) substantiates that while fractal geometry has contemporarily opened up great heights of high-tech science in many parts of the world, its roots are startlingly far-reaching in indigenous Afro-centric designs, and a considerable amount of its codes are elementary among most African socio-cultural knowledge systems. Hence, while fractal designs prevail beyond Africa as well (Celtic knots, Ukrainian eggs, and Maori rafters have some excellent examples), they are not everywhere. Their conspicuous incidence in Africa (and Africa-influenced southern India) is quite explicit.

Fig.6 Strip-pattern semiotics at Bugiri Uganda (credits: Allan Birabi, 2010)

2.1 The value of earthen architecture-driven socio-cultural knowledge systems

Holistically, the walls of Ugandan earthen architecture are 'loaded' with semiotic messages beyond the basics of architectural functionality and firmness. They offer lessons, amusement, and inspiration. With their given intensity, vigor and magnitude, they also create a sense of pride and honor to the owner-occupiers of traditional earthen-built environments. Bred among communities that have come to learn how to compensate for some of their past non-writing, non-reading and/or non-formal educational legacies, the Uganda artisans organically transform bare earthen walls into sort of graphical multi-narrative 'painted books', which constitute open-access community libraries. Thus, as a unique community-based, community-centered, and community-driven cutting edge of indigenous-pedagogical excellence, Ugandan earthen architecture is a unique symbolic resource with which the locals discover, recreate and exchange ideas, experiences, meanings, and add avenues of social interaction (Halliday, 1977; Kress and Van Leeuwen, 1996). In an intriguing relationship, while the inherent knowledge systems are bound in the earthen architecture and so can educate and enrich the onlooker, they also double as propagators of 'information value' of what would otherwise be barren earthen walls of this architectural fabric (Van Leeuwen, 2001). It is, therefore, apparent that local Ugandan earthen architecture is a special 'encyclopedic deposit' of indigenous-knowledge systems through semiotics' monumentalism, iconism, and/or symbolism. It remains the most powerful medium by which their creators inter-disciplinarily double as philanthropic social scientists. They engage their work in a moral contract between architecture, citizenship, indigenous knowledge and education, society and development.

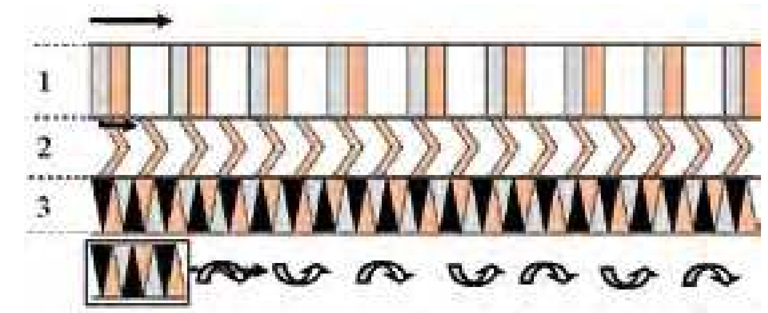

Fig.7 Abstract synthesis of the ethnomathematical knowledge systems present in Fig. 6's strip-pattern semiotics (credits: Allan Birabi, 2010)

2.2 Threats to the knowledge systems and to earthen architecture

These knowledge systems are under severe threat, however. This observation unfolds the realization that the conditions that made these knowledge systems likeable and effective in the past are no longer prevailing. Among the threats is the fact that it is practically hard to conserve the earthen-wall semiotics because of the very nature of non-permanence of this architectural fabric vulnerable to both organic and inorganic deterioration. The semiotics are eroded, for instance, by Uganda's heavy torrential rains. Furthermore, frequent flooding directly curtails the perennial nature of earthen-architectural ensembles and their wall semiotics. There is also the problem of mechanical injury to the walls containing the semiotics particularly by domesticated animals, which are common in most Ugandan earthen-architecture homesteads. For instance, cows and goats frequently rub their bodies on the walls and in so doing the precious wall semiotics are destroyed. Also, it is a popular move to renew the walls with fresh clay to rejuvenate homesteads. Consequently, faded semiotics are replaced with new ones without documenting previous schemes of wall semiotics. At times, there is no replacement at all and all this valuable knowledge just disappears. In addition, hardly any technology for preserving whole-wall fragments exists. Furthermore, threats also arise from ignorance and obsolescence connected with mindsets, fast-paced globalization, eroded artisan-craft skills, altered cultural tastes and preferences.

Notwithstanding the above-enumerated threats, the earthen-wall semiotics represent material and symbolic depositories of ideological and functional values established over past centuries, and are lynchpins for granting a given neighborhood with distinctive physiognomy, i.e. making a given neighborhood more attractive and different from others (Gospodini, 2002). Apparently, physiognomy cultivates satisfaction/enjoyment to owner-occupiers and/or visitors for each given neighborhood, thereby transforming some neighborhoods into 'cultural-heritage landscapes'. Such landscapes are characterized by knowledge systems manifested by attendant architectural semiotics by way of

Fig.8 Earthen-wall tessellation semiotics at Magodes, Molo, Tororo District, Uganda (credits: Allan Birabi, 2010)

visual consumption, and celebrating something that strong heritage components remind them about themselves and their past. In this regard, without necessarily ranking them, Throsby, in Avrami et al (2000) corroborates associated-value embodiments to include:

1. Educational: imbedded knowledge, messages, information;
2. Aesthetic value: beauty, harmony;
3. Spiritual value: understanding, enlightenment, insight;
4. Social value: connection with others, a sense of identity
5. Historical value: connection with the past and/or evocation of the notions of memory and time;
6. Commemorative/symbolic value: a repository or conveyor of meaning;
7. Technical and intrinsic: architectural or artistic merit;
8. Inspirational: artistic, scientific, philosophical, poetic insights and innovations, visual ambience, cultural vitality, post-conflict identity reestablishment;
9. Intrinsic value: imbedded in the walls respectively, architectural semiotics and attendant knowledge systems arouse intrinsic value as the fabric of human achievement essential to the wellbeing of the 'soul' and culture of a given host community.

Looking back, therefore, the case for documenting socio-cultural knowledge systems prevalent in earthen architecture is plausibly an urgent matter, which is the focus of the concluding section of this paper.

3. CONCLUSION: THE URGENCY OF DOCUMENTING THE SOCIO-CULTURAL KNOWLEDGE SYSTEMS PREVALENT IN EARTHEN ARCHITECTURE

In the contemporary modern context, it cannot be doubted that sound documentation lies at the heart of the urgency of preserving and utilizing the indigenous-knowledge systems harnessed in earthen architecture that have emerged in previous sections of this paper. As a conclusion, therefore, now is the time for more in-depth studies coupled with protecting and publishing about these neglected architectural semiotics. By means of this strategy, preserving Ugandan earthen-architecture-driven indigenous-knowledge systems is poised to become a pragmatic experience replicable in other cultures with similar or comparable knowledge resources. Local knowledge gurus would then have a tangible basis for accurately uploading their formal education enterprises with indigenous-knowledge templates. In this regard, Ma Rhea (2004, p.5) states:

> *"Accurate documentation also enables nations and other interested parties, such as national systems of education, to enter into agreements and contracts with traditional knowledge holders that will strengthen the capacity of these communities to develop economically sustainable livelihoods and see their knowledge included in national education systems."*

However, documentation of these knowledge systems requires patronage from political intelligentsia, educational policymakers, and academics, all of whom at the moment seem to be passive on this matter. In a related synergy, managers of Uganda's postal services, who take charge of producing postal stamps, could champion a publicity drive for some of the exemplary local indigenous semiotics' design splendor by using their respective images on postage stamps. It has often been an odd occurrence in the past to see Ugandan and, indeed, other African countries produce postage stamps with images celebrating knowledge systems and/or monuments of, for instance, their past Colonial masters, instead of bringing forward such powerful heritage of their own.

It is the opinion of this author as well, therefore, that it would pay off to co-mingle the above-enumerated synergies with some modest-scale public prototype-building projects in modern contexts that stand out to radiate knowledge or developmental messages to the people. Such archetypes can be commissioned by governments in collaboration with architecture schools, artisans, museologists, social scientists, conservators, etc. Furthermore, cultural departments of the State can liaise with museologists in unfolding regional heritage buildings, museums or galleries that promulgate the conservation of outstanding earthen-architectural semiotics, as well as other diverse heritage material. It is no doubt that such synergies would trigger greater spin-off influences that would further augment the character of stylistic contemporary and future culturally driven built environments.

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SURFACE PROTECTION: CONSERVING THE RELATIONSHIP BETWEEN ARTIST AND MATERIAL IN ISFAHAN AND TCHOGHA ZANBIL, IRAN

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Theme 5: Local and Regional Knowledge, Intangible Heritage and Social Impact
Keywords: Surface protection, intangible heritage

Abstract

Surface protection of Iranian earthen architecture has been continuously accomplished with a variety of decorative covering materials based on traditional symbolism and vernacular aesthetic, which reflect two general principles: high flexibility and sacrificial decorative material for protecting the inner meaning (the spirit) of the architectural space. This cultural phenomenon enjoys strong theoretical foundations, as well as technical skills that are transferred by generations of traditional artists through specific training patterns in the process of repair and maintenance of historical buildings. Considering this issue is essential to achieve a holistic approach towards the tangible and intangible dimensions of historic earthen architecture. This paper presents the experiences of conservators and local craftsmen in evaluating the state of transferring this intangible heritage during the conservation programs in historic (Tchogha Zanbil) and traditional (Isfahan) environments. A four-year program of evaluation and cooperative interviews shows that the conservation workshops have provided a supportive field for rethinking vernacular knowledge of construction.

However, in the absence of a common language among younger and older generations of local artists and conservators for exchanging the ideas about cultural values, their cooperation may be reduced into a few technical details. In order to present the intangible values of traditional maintenance to the conservators, promoting these traditions among the younger generation of craftsmen, and recognizing the craftsmen not as technicians but as creative agents in the conservation system, practical measures were proposed. These measures include participation of local artists in developing conservation-management plans and publications, dedicating virtual spaces for introducing local repair systems to the public, and promotion of creative and critical approaches towards conservation technology through the joint participation of local artists and conservators in training workshops.

1. INTRODUCTION

Surface protection – covering the adobe structure with sacrificial materials, such as mud plasters or decorative ceramic layers – has been frequently used by Iranian traditional architects in order to maintain earthen buildings from environmental degradation, e.g. rain, abrasive sand particles in desert winds, etc. (Houben and Guillaud, 2003, p. 334).

Due to gradual deterioration, these coverings need to be replaced at certain intervals, which depending to the type of the covering or its location in the building, vary from a few years to decades. This continuous maintenance is a part of its architectural style (Falamaki, 1986, p. 26). Therefore, the vulnerability of adobe has become an opportunity for manifesting intangible forms of heritage through the relationship between local artists' ideas and the dwelling spaces of earthen material. Establishing such a relationship would not be possible without a comprehensive knowledge of architectural space, decorative-preservative layers and the dynamic interaction of the two in the passage of time. During the recent decades, social changes and fading of the local cultural values in design of contemporary architectural forms has led to the neglect and loss of traditional maintenance methods, which affects the continuation of social life in historic urban textures and the conservation of outstanding cultural monuments.

Because the most important characteristic of intangible heritage is their reproduction from time to time, training and transferring the concepts necessary for the accomplishment of these reproductions became the concern of conservators, especially after the definition of intangible cultural heritage

(2003). The research that is presented in this paper has concentrated on the cultural values of these traditional conservation methods, the importance of the still-active local artists' knowledge, and the problem of transferring it to the future generations.

2. RESEARCH METHODOLOGY

Cooperative interviews with artists in their conservation workshops was the main strategy for gathering data in this research, in addition to analyzing the content of literature on Persian traditions of art and architecture. Opinions of experts, who have worked with local artists as supervisors or planners of conservation programs, were also evaluated.

2.1 Selected historical sites

During the last century, two distinct approaches enjoying different cultural backgrounds were established in the conservation of the historical city of Isfahan. and the archaeological sites of Tchogha Zanbil and Haft Tappe. These have attracted national support and had great influence on conservation of earthen architecture in other parts of the country. The earthen structures in Khuzestan province are the remains of a kind of life style, which has lost its dynamism for a variety of social-historical reasons (Talebian, 2003, p. 570). The modern conservation of earthen architecture in this area was started during the excavations at Tchogha Zanbil by Ghirshman with a team of master builders who had come with him from Kashan (Ghirshman, 1994, pp. 14-15). The importance of relying on a local human resource, skilled in surface-protection methods, was first recognized during the excavations at Haft Tappe (Negahban, 1991, p. 10), and thereafter was the main topic of studies in conservation in the aforementioned area. In the beginning of the 20th century, development of Isfahan as a centre of tourism with an outstanding 400-year architectural tradition was highly considered by the city governors, as well as architects and conservation researchers (Shirazi, 1974, pp. 590-591).

2.2. Scope of study: diversity of decorative-preservative coverings

Decorative-preservative coverings of earthen architecture consist of a variety of technical types with distinct aesthetic characteristics that require years of practice to gain the skill for their implementation. Continuing this legacy, without knowing these different types, relationships between them, and the rules for using them in vernacular buildings would be impossible. This wide range of methods is categorized in three main classes as follows:

- Mud plasters (coatings) – at least two types of these diverse coatings has been studied comprehensively up to now: Kahgel and Simgel (Galdieri, 1979, p. 62);
- Gypsum plasters (Ibid. p. 61);

a) b) c)

Fig.1 Experience of surface protection in Isfahan, a) and b) French School, Jolfa, before (2002) and after the repair of Simgel decorations (2011); c) application of tile and brickwork in combination with gypsum plasters and mud coatings in the façade of a house in the neighborhood of Meidan Emam (credits: Reza Vahidzadeh, 2011)

Fig.2 Surface protection and visual reintegration of the peak of Tchogha Zanbil Ziggurat by Kahgel (credits: The World Heritage of Tchogha Zanbil, 2004)

- Ceramic coverings, including brickwork, simple monochrome tilework, polychrome mosaic tilework (Moarraque) and painted tiles (Haft-Rang).

There is historical evidence of the application of all these three classes of coverings in the two selected historical sites. The adobe structure of the Tchogha Zanbil Ziggurat was covered by layers of brickwork, glazed bricks and tiles. Other parts of the site were mainly protected by mud coatings and gypsum plasters. From the time of excavations up to now, brick and Kahgel has been used for surface protection of the Ziggurat and other parts that were exposed to rain. The main decorative covering of the architectural body of Meidan Emam are brick-workings and outstanding fine colorful tile-workings which are very stable against the humidity and abrasive matters. Isfahan is still the main centre of Iranian tile-making with more than one hundred and forty active workshops (ICHTO, 2008, pp.190-195). However, mud coatings and gypsum plasters and stuccos have also been widely used in the adjacent residential and trading areas such as "*Posht-e Masjid*" district and "*Qaisarieh*" bazaar. These kinds of decoration created a sense of visual unity with respect to the territorial landscape and regional characteristics.

Because the authors have the experience of working in the Research Centre for Conservation of Tchogha Zanbil and Haft Tappe, the interviews were held in a very intimate space and the interviewees expressed their beliefs and findings without any hesitations. It took more time in Isfahan to reach to a common language and better understanding of the interviewees. Seven workshops with significant

Field of Experience	Name & Location	No.
Restoration of brickwork and Kahgel coating	Tchogha Zanbil Conservation Workshop	1
Kahgel coating	Haft Tappe Conservation Workshop	2
Restoration of brickwork and Moarraque tilework	Naghsh-e-Jahan tile making (Isfahan)	3
Restoration of Moarraque and Haft-Rang tilework	Restoration of tilework of Ali Qapu (Isfahn)	4
Restoration of gypsum stuccos	Restoration of stuccos in Jameh Mosque of Oshtorjan (Isfahan)	5
Simgel and Kahgel coating	Tech-Civil Office of Art University of Isfahan (Isfahan)	6
Restoration of Moarraque tilework	Esfehantile-Art (Isfahan)	7
Restoration of Haft-Rang tilework	Haj Reza Fuladi (Isfahan)	8
Restoration of Moarraque tilework	Ostad Kamal Pakdel (Isfahan)	9

Table 1. Characteristics of the surveyed workshops

history in conservation of the historical monuments in the area of Meidan Emam were selected for the interviews (Tables 1 and 2).

Interviews started from 2008 and continued for nearly four years. Eight main subject areas were considered during the interviews in Tchogha Zanbil and Isfahan as follows:

a) ritual origins and theoretical foundations of the decorative covering of earthen architecture; b) the place of repair and renewal of decorative coatings in the history of conservation of earthen architecture; c) the current status of local artists active in the field of decorative-preservative coatings; d) methods of training and transferring knowledge necessary for the repair and renewal of decorative coverings; e) apprenticeship as the training method for surface protection of earthen architecture; f)current strategies of master artists to make the training programs more effective; g) the role of conservators in managing conservation projects towards the holistic protection of intangible and tangible aspects of earthen architecture; and h) achievements of joint collaboration between conservators and local artists in order to use modern methods for safeguarding of vernacular architectural knowledge.

3. RESULTS

Haj Ahmad Qanbarpour (1933-2007), a great traditional architect of the Tchogha Zanbil workshop, frequently reminded his apprentices, "*Clay particles are made of a heavenly essence. We all have clay particles in ourselves.*" Some of the researchers have considered the presence of man (craftsmen) in the continuous activities for maintenance and plastering of earthen architecture as breathing a spirit into the earthen body (Jayhani and Omrani, 2003, p. 462). The historical experience of local artists in the maintenance of monuments shows that there is no clear boundary between the spirit and body of an adobe structure. About 400 years ago, the Iranian philosopher, Sadra, questioned the dualistic approach toward distinction of body and soul, and described the inseparable coherent Being (Khatami, 2003, pp. 17-26). This idea can be considered in assessing the attempts for making earthen architecture sustainable. The earthen structure (body) is the unique possibility by which a definite architectural place comes out of infinite space and takes its coordination and orientation. Despite the physical changes taking place in time, such a body still retains the character of place and manifests the historical evolution of its inner meaning as a monument. Even the recalling of the monument in man's mind is not possible without imagining a body for it. Therefore, the interaction between human and the monument should be directed toward sustaining the meaning (spirit) by preserving the body, not by interrupting or falsifying it. The covering of earthen architecture is not only a preservative and sacrificial matter but also considered as a decorative element.

This dual function is conceptualized as the interpretation of preservation and decoration, which are influenced by each other. The artist during the redoing of surface protection attaches a layer, which belongs to our time and to the old body of the architecture. Therefore, he approaches the monument in an intimate mode so that what is placed on the surface will not affect its historical existence. Such an approach requires a hermeneutic study of the monument. The man who repairs or renews the decoration must inherit the sense of creativity and consciousness of the artist who created them first. This requires a comprehensive recognition of the architecture, its decoration and the relationship between the two. He must be able to restore or recreate these relationships with respect to the time-varying values of the architecture. Haj Ahamad in one of his last lessons said, "*The world is totally in change … the true nature of the world is its changes.*" Incompatibility of post-excavation interventions with the authentic building culture (workmanship) of Tchogha Zanbil, especially in the form of the poor accomplishment of surface protection, has led into intense deterioration, which became a real disaster in the

Work experience years	Responsibility in the workshop	Birth date (year)	Education	Name	No.
55	Traditional Architect	1944	--	R. Salamatifar	1
12	Traditional Architect	1971	--	M. Hajivand	2
18	Conservator	1969	Conservation (BA)	B. Heidarizadeh	3
12	Quality-Control Researcher	1976	Geology (BA)	Rahim Banna	4
12	Workshop Manager	1972	Civil Engineering (BA)	A. Khenifar	5
11	Assistant Craftsman	1978	Primary school	S. Al-Kasir	6
11	Assistant Craftsman	1978	Secondary school	D. Dinarvand	7
12	Assistant Craftsman	1978	---	S. Abdolkhani	8

Table 2. Interviewees in the Tchogha Zanbil Workshop

inner wall (Guillaud, 1998, p. 6). Since 1999, a continuous and developing dialogue has begun among the local artists under the supervision of Haj Ahamad and Haj Nezam Ardeshirzadeh (1944-2010) and conservators, which led to the formation of a sustainable conservation pattern for the site. In Isfahan, the arts for decorating/preserving the earthen structures were well-preserved in continuous cycles of master-apprentice training until the beginning of the age of modernity – the Constitutional Revolution. In this period, when the historic urban fabric was altered by new wider main streets to introduce modern traffic into the old city, the artists were still able to adopt the local methods for decorating the façades of the houses built on the sides of the main streets, in order to link the lifestyle of the middle-class residents of these houses to the vernacular architecture of the city. By substituting parts of the humble and uniform layers of mud coatings (Kahgel and Simgel) with colorful tilework they also made the old fabric ready to play its role in the social life of modern Isfahan (Montazer, 2006, pp. 14-15). During the next decades, in parallel with the rise of modernism in training of arts and architecture in universities and the irregular development of the city, resulting in serious damage to the historic urban fabric, attempts were made for the recomprehension of local artists specifically as the keys for decoding the forgotten secrets of creation of new forms of architecture in accordance with regional resources and ecological consciousness (Owlia, 2009, pp. 8-9).

Comparing with interviewees in Isfahan, fewer people in Tchogha Zanbil can recall what was taught by the old master builders. Despite the apprentices coming from rural areas, traditional patterns of life seem exotic to them. Traditional diverse agriculture was substituted with the single-product cultivation of sugarcane in the area and most of them have had the experience of working for the sugar factory as simple workmen. Therefore, some of the young apprentices were not ready to accept their new roles as younger generations of local artists, not skilled workers (or technicians). The traditional atmosphere of Isfahan, especially in the bazaar of handicrafts, and the attention that is paid from tourists to these markets, act as a motivator for apprentices to learn more about the theoretical basis of their traditional arts. In Isfahan, training of traditional principles is done practically in the process of analyzing the past experience of great masters accompanied with the usage of artistic media, such as poems, stories and myths, to find new methods for creating art. Nowadays, in the workshops of Isfahan, masters who accomplished their training before the revolution in the old master-apprentice system work with the younger generation of artists that are mostly college graduates due to the expansion of higher education in recent decades. Attending modern schools, traditional training for these young people was limited in time. Therefore, some of the ancient traditions, which require closer familiarity between master and apprentice to be trained, were not fully learnt by them. For example, among the new generation of craftsmen, poetry, knowledge of local resources of raw materials, and the history of profession is at a lower level than the previous generation. Changes in their livelihood concerns, due to their level of education and labor laws that sometimes act to bolster them against the workshop laws, have resulted in an evolution of the cooperation of art masters with their apprentices.

Compared to the limitations in the transfer of theoretical doctrines, progress in building the practical skills was more acceptable. This may be due to the fact that the successful application of traditional techniques can rapidly return the order to the appearance of a damaged historic site. However, it should be noted that in traditional art, the practical know-how, which may be interpreted as the "knowledge by presence" (Ha'iri Yazdi, 1992, p. xii and p.1), is to bring the spirit of artisanship to the mind of the artist and unifying the mind with this spirit. Therefore, it is not possible to define a boundary between the ancient ritual forms and the technical aspects of vernacular know-how. That is why the old artists believed that the technological approaches towards traditional construction methods, even from conservators or young artists, would only be partially successful. In Tchogha Zanbil, art masters attempted to show the moral effects of vernacular arts to encourage the apprentices to continue their training. For this reason, they explained the close relationship between the traditional practice of architectural decorations on one hand, and the spiritual promotion of the practitioners benefiting local society on the other hand. In Isfahan due to the greater dynamic nature of the historic urban fabric and diversity of entrusted works, art masters own their personal workshops, in spite of depending to the government, and are able to pay their apprentices themselves. As a result of the debates about the intangible heritages associated with Iranian vernacular architecture in recent years, attempts have been made to propose new patterns of cooperation between local artists and college-graduate conservators who are the supervisors of government-sponsored conservation plans for historic monuments.

Fig.3 Transferring the responsibilities from masters to apprentices in the Tchogha Zanbil Workshop; a) Morteza (left) during his apprenticeship under the supervision of the late Haj Ahmad, b) Morteza as a master builder training a new apprentice (credits: The World Heritage of Tchogha Zanbil, 2004)

4. PARTICIPATION OF CONSERVATORS IN TRANSFERRING THE VERNACULAR KNOWLEDGE: THE USE OF MODERN METHODS

In 2004, the official internet website of Tchogha Zanbil in the Persian language was launched. In this website for the first time, comprehensive information about craftsmen and local artists working at the historic site was included. It was the first time that they were regarded as a creative potential and not only labor force for conservation. In Isfahan, although the older generation of artists does not rely so much on modern media, younger artists have become used to software for design and the internet for professional communication. Older masters tend to publish papers and memoirs related to their outstanding achievements. They are also interested in partnering with conservators to produce training materials, which can be used for the next generations. In its first step towards these interdisciplinary collaborations, the Research Centre for Conservation of Tchogha Zanbil planned a glossary of technical terms of the local architecture in the Dezfuli dialect. At present, the "Master plan for documentation of living heritage of architectural craftsmen of Khuzestan province (with emphasis on Dezful, Shushtar and Shush cities)" is in progress (Vahidzadeh, Frhadpoor, Heidarizadeh, and Razavian, (2011). This program consists of identification of retired and active master builders, documentation and publishing of their experience in the form of videos, photo collections, books, and devoting webpages on the official internet site to this subject. In Isfahan, an attempt is being made to shift the interest of young craftsmen to collecting data on successful past experiences (i.e. photos, maps, drawings, poems and more) from their personal digital archives towards creating a more comprehensive public archive. ICHTO has founded a database for identification of active artists and workshops, and evaluation of their work, which can be very important in awarding conservation projects to them. Because the documentation of the experiences of these artists is a very professional task, the most acceptable results in this field has been obtained from research that was supervised by conservators acquainted with the artists' histories, their technical methods, as well as social and economic concerns. These collaborations have resulted in the presentation of academic papers (Enayati and Vahidzadeh, 2011; Pedram, Owlia, and Vahidzadeh, 2011, p. 26-27), and the holding of a joint-training workshop for restoration of architectural decorations with the support of the Meidan Emam Site Office (Vahidzadeh, Enayati, Mosadeghzadeh, and Hemmatyar, 2010).

5. CONCLUSION

This study shows the feasibility of developing different approaches to the continuation of traditional methods of

Fig.4 Examples of Moarraque, a method for surface protection of earthen architecture in Isfahan: a) brickwork in David's House; b), c) and d) design, cut and installation of mosaic pieces on earthen walls; diversity of approaches in the early 20th century in e) Sadr Madrasa and f) Harunieh alley (credits: Vahidzadeh et al., 2011)

surface protection for earthen architecture as an intangible heritage at different levels of craftsmanship and workshop-management systems. In the Tchogha Zanbil workshop, craftsmen have used new forms of interaction with apprentices to sustain this tradition. In contrast, the improvement of the social status of art masters in Isfahan through receiving funding from tourism, conservation and traditional society have led to the reproduction of historical patterns of apprenticeship. The generation gap and declining of the quality and quantity of entrusted works in both of the regions were limiting factors, while independent and private workshops have made it possible to continue the traditional art creation. The younger artists working in private workshops of Isfahan show a great tendency to the usage of modern technology in practicing vernacular architectural decoration. The older generation of artists in both regions are willing to document and publish their experiences in the form of classic media. Holding joint educational and research programs, dialogue and cooperation between conservators, younger artists and older art masters, has increased in order to achieve a common language for transferring the vernacular knowledge in its most comprehensive forms to future generations in recent years, especially after the definition of intangible heritage in 2003. There is a slight shift in the debates from recording and understanding the technical properties of traditional architectural materials to the protection of vernacular knowledge as an existential wisdom of interaction with the environment and an alternative lifestyle based on cultural diversity.

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PROTERRA INTERNATIONAL INTER-LABORATORY PROGRAM

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Theme 6: Research in Materials and Technology for Conservation and Contemporary Architecture
Keywords: Inter-laboratory program, adobe, testing methodology

Abstract

At the end of 2007, the PROTERRA Iberian-American Network began an international inter-laboratory program aiming at establishing test procedures and control parameters for materials and products for earthen architecture construction.

This paper reports the development and presents the results of the first stage of this program, which aimed to define the most appropriate procedure for determining the compressive strength of adobe. For this, two types of sampling and three different dimensions were established. The summary of the work plan, participating institutions, and details relating to the development of work in each laboratory are presented, along with the first considerations based on the results obtained. The test results for the earth characterization, the development of the samples preparation and the procedure for implementing the compressive-strength test are highlighted. At the end, the importance of the inter-laboratory program for the establishment of procedures and for testing products' qualification are reviewed, highlighting those produced with earth, and the effect of the inter-laboratory program at the PROTERRA Iberian-American Network.

This activity, as well as others developed within the scope of the PROTERRA Iberian-American Network, is an example of how it is possible to develop joint activities of international nature, solely with the involvement of interested professional volunteers, and disseminating knowledge gained on earthen architecture and its construction.

1. INTRODUCTION

PROTERRA is a network of international and multilateral technical cooperation that promotes the transfer of technology in earthen architecture construction. PROTERRA began in October 2001 as a temporary research project of four years, from the Iberian American Science and Technology for Development - CYTED, in order to encourage the use of earth as building material, using demonstration projects, publications, courses and other events. In February 2006, when the research project PROTERRA/CYTED was concluded, the PROTERRA Iberian-American Network was created, with almost all members of the project, along with other interested professionals. The aims and directions of action were similar to the ones of the concluded project.

At a first stage, PROTERRA's attention was focused on social housing, whose proposal was to have a group of Iberian-American experts provide technical support for building programs to be developed in different countries. Then, it was understood that the use of earthen construction for social-housing programs had not been occurring. With the formation of an international team of professionals, which already existed in each country, competent professionals could provide the necessary technical support. However, it was necessary to promote and to disseminate the use of earthen materials through other actions, in order to provide scientific support to earthen architecture and its construction, including the development of an appropriate updated bibliography applicable to the current circumstances of each country and region.

One of these actions corresponds to the identification and recommendation of tests, and the parameters for the classification of products, such as adobe and CEB (compressed earth block), as well as masonry walls and other different building systems using earth.

A collaborative program began in late 2007, whose first activity was the definition of test procedures to determine the compressive strength of adobe and the parameters for its qualification. Several papers and published documents described the results or limits of the compressive strength of

a) b)

Fig.1 Samples: a) Cube; b) Cut adobe with the halves reunited (credits: Obede B. Faria, 2008)

adobes, but references to the test procedures were scarce or nonexistent. The following references are highlighted in the Iberian American context, mentioning test procedures and product qualification:

- Building Technical Standard E.080 Adobe (RNC, 2000) establishes the adobe test using cube-shaped samples, whose sides equal the smaller size of the adobe (Fig.1a). Using at least six samples, it sets the breaking strength as the value above which 80% of the results occur. It also indicates that this should be 1.2 MPa at least. No loading speed or test time is specified.
- Faria (2002) adapted from Brazilian standards NBR 6460 (ABNT, 1983) and NBR 8492 (ABNT, 1984) for testing adobe. The samples correspond to two parts of an adobe that is cut in half, and then the halves are reunited with cement and gypsum mortar (4 parts cement and 1 part of gypsum) (Fig.1b). In the test, the loading rate is around 10 MPa/minute.
- Varum, Costa, Pereira, and Almeida (2006) used cylindrical samples with a diameter between 70 mm and 90 mm, and a height of approximately twice the diameter. They do not mention the loading speed or test time.

Since the tests do not present the same procedures, it is not possible to compare the results mentioned in various publications. With the completion of the Inter-Laboratory Program, the PROTERRA Iberian-American Network expects to propose a standardized procedure to determine the compressive strength of adobe that, if adopted by all researchers and professionals responsible for product qualification, could provide consistent data to identify one of the main characteristics of adobe and to establish the requirements for its qualification as a masonry product. This paper presents the results of the first stage of the PROTERRA Inter-Laboratory Program, which consisted of using the same tests procedures, necessary to determine the compressive strength of adobes, in laboratories indifferent countries.

2. METHODOLOGY

The methodology of the inter-laboratory program corresponded to the preparation of the work plan, the invitation of different laboratories to participate in the program, and afterwards, the analysis and discussion of the results, and the preparation of the proposal for an Iberian-American test procedure for determining the compressive strength of adobe. The work plan was comprised of the following stages: selection of earth materials, production and preparation of test sampling, conducting tests and recording the results.

2.1 Earth selection

The use of earth with the following composition was established: the sand content exceeded 55% and the clay content needed to be about 30%. If the earth available did not meet this requirement, its modification was made possible by mixing two or more different soils, until the grain size obtained was as indicated.

For selecting earth materials, the following tests were used to characterize the available soil: grain size composition (sieving and sedimentation), Atterberg limits, bulk density of loose earth, and earth-moisture content. The tests to determine the grain-size distribution and the Atterberg limits (liquid limit – LL, and plastic limit – PL) were carried out in accordance with current regulations in each country, that were used in the laboratories of soil mechanics. For loose soil-density determination tests (Fig.2) and moisture content, the procedures followed by Faria, Oliveira, Tahira, and Battistelle (2008) were proposed.

2.2 Preparation of samples

To assess the influence of the manufacturing and cutting processes of adobe in compressive strength, two types of samples were taken, all of which were cube-shaped: the cube

Fig.2 Determining loose soil density (credits: Obede B. Faria, 2008)

cut from the adobe and the molded cube. In order to do this, the following were produced:

- At least 20 adobe units, made in molds with interior dimensions of 7.5 x 15 x 30 cm;
- At least 20 adobe units, made in molds with interior dimensions of 10 x 10 x 10 cm; and
- At least 20 adobe units, made in molds with interior dimensions of 15 x 15 x 15 cm.

For sampling of each type of cube, the following procedure was proposed:

- Withdrawal, at random, of 10 adobe units for the preparation of the cut samples. Each adobe was cut in half, and each half was cut twice, so as to have eight cubes of adobe with approximately 7.5 cm/side (Cube 7.5) corresponding to the height of the adobe produced.
- Withdrawal, at random, 10 units of cubes with 10-cm sides (Cube 10) and 10 units of cubes with 15-cm sides (Cube 15).

2.3 Execution of tests

10 copies of each of the three samples, including Cube 7.5 (trimmed), Cube 10 and Cube 15 (both molded), were placed in an oven at 100°C for 24 hours, aiming at standardizing the moisture content of the samples manufactured in different regions and climatic conditions. After drying, the bulk density of the samples was obtained through the determination of the ratio of dry mass and volume. The samples underwent compressive tests, with a load of a voltage-increase rate of 0.29MPa/min. Data was recorded on sheets prepared for the automatic calculation of results, according to the methodology proposed by Faria et al. (2008).

2.4 Analysis of the results

Initially, each of the laboratory's results was analyzed separately to identify possible relationships between the values of compressive strength and the size of samples, and the range of values for each sample, using the standard deviation and coefficient of variation. Then, the results obtained among different laboratories were compared by analyzing the behavior of the resistance values and the size of the samples.

3. RESULTS AND DISCUSSIONS

The following institutions participated in the Inter-laboratory program:

- CECOVI-Research and Development Center for Construction and Housing, National Technological University, Regional Faculty Santa Fe, Argentina (1)
- CEPED-Research and Development Center, Brazil (2)
- Department of Science and Techniques for settlement processes, Faculty of Architecture, Polytechnic Institute of Torino, Italy (3)
- Faculty of Engineering, Paulista State University –Bauru campus, Brazil (4)
- Civil Engineering Laboratory, National Technological University, Regional Faculty of Rafaela, Argentina (5)
- The results presented below are not identified by the respective institutions, but as laboratories A through E.

3.1 Physical characterization of earth samples

The establishment of a range of particle sizes for the inter-laboratory program had two purposes: to work with earth of similar grain size and avoid using additions in the preparation of the samples. Initially, some of the laboratories faced difficulty obtaining the specified earth type, even with the possibility of mixing two or more types of soils. The proposed grain-size distribution did not require the addition of straw or other additives in the preparation of the samples. Table 1 shows the results of the grain-size distribution and Atterberg limits obtained by the five laboratories.

Property	Laboratory A	B	C	D	E	Proposed Grain size
Grain size						
Gravel (%)		3				
Sand (%)	65	62	72	71*	15	? 55%
Silt (%)	9	23	22	29*	56	
Clay (%)	26	20	6		29	≤ 30%
Atterberg limits			**	**		
LL (%)	25	47			42	
LP (%)	18	21			20	
IP (%)	7	20			22	
Soil composition	2 floor	1soil	2 floor	2 floor	1soil	

* Corresponds to the content of silt + clay
** The Atterberg limits for the mixture of two soils were not determined.

Table 1. Grain-size composition and Atterberg limits of the earth materials tested (credits: Obede B. Faria, 2008)

3.2 Production of the adobes and the cubes

The laboratories executed molds for the production of adobes and cubes, according to the following interior dimensions: 7.5 cm x 15 cm x 30 cm for the adobe unit; and two cubes with sides of 10 cm and 15 cm each. The molds were made of wood, except for those executed by Laboratory D, which developed metal molds.

Each laboratory reported how the molds were developed and their use. All described having more difficulty filling the cube molds, due to their lower opening in relation to their height. Release from the molds of the 10-cm/side cube was also complicated, despite the use of sand, ashes or other mold-release agents.

D and E laboratories commented on the difficulty of cutting the dried adobes with a handsaw to prepare the trimmed samples, something that Faria (2002) also noted, since the handsaw lost its sharp edge very quickly. After several unsuccessful attempts, an electric saw blade was used.

Laboratories B and E described the amount of added water to prepare the clay for bricks and cubes, which coincidentally was about 35% (the ratio between the mass of water added and the dry earth mass). A few samples produced in one of the laboratories are shown in Fig.4.

	Parameters	Laboratory A	B	C	D	E
Cube 7.5	Average (kg/m³)	1860	1580	1860	1610	1900
	Standard deviation (kg/m³)	270	60	30	120	20
	Coefficient of variation (%)	14.5	3.8	1.6	7.5	1.0
Cube 10	Average (kg/m³)	1740	1760	1950	1680	1940
	Standard deviation (kg/m³)	70	50	90	50	20
	Coefficient of variation (%)	4.0	2.8	4.6	3.0	1.0
Cube 15	Average (kg/m³)	1750	1730	1950	1750	1930
	Standard deviation (kg/m³)	30	50	20	90	10
	Coefficient of variation (%)	1.7	2.9	1.0	5.1	0.6

Table 2. Bulk Density (ρap) of the samples tested (credits: Obede B. Faria, 2008)

Fig.3 Molds for sample preparation (credits: Obede B. Faria, 2008)

Fig.4 Some steps for the preparation of samples (credits: Obede B. Faria, 2008)

3.3 Physical and mechanical characterization of adobes

Table 2 shows the results of the bulk density of the samples, which corresponds to the relationship between the dry mass and the volume calculated by the measurement of the sides of each sample.

So as to isolate the variables that relate to the type of earth used in each laboratory and the method of preparation of the adobes and the samples, the bulk densities were calculated in relation to the average values of the corresponding samples of the of 7.5-cm/sidecube (Table 3).

Type of sample	Laboratory A	B	C	D	E
Cube 7.5	1.00	1.00	1.00	1.00	1.00
Cube 10	0.93	1.11	1.05	1.04	1.02
Cube 15	0.94	1.09	1.05	1.09	1.02

Table 3. Bulk density of different samples (credits: Obede B. Faria, 2008)

The analysis of the results presented in Table 3 show that the bulk density of the 7.5-cube sample (trimmed) is smaller than that of the cubes of 10 cm/side and 15 cm/side, except for Laboratory A's samples. This shows that despite the difficulty of filling the cubes during the molding process, this did not affect the compactness of the mixture. The values of bulk density of the molded samples are also close to each other.

Table 4 presents the average results of the compressive strength from different laboratories and Table 5 shows the loading rate for each sample type.

	Parameters	Laboratory A	B	C	D	E
Cube 7.5	Average (Mpa)	1.24	0.45	1.24	6.41	5.99
	Standard deviation (MPa)	0.10	0.04	0.25	0.63	0.35
	Coefficient of variation (%)	8.1	8.8	20.2	9.9	5.8
Cube 10	Average (Mpa)	1.21	0.43	1.50	4.67	5.70
	Standard deviation (MPa)	0.20	0.03	0.21	0.38	0.36
	Coefficient of variation (%)	16.5	7.3	13.9	8.1	6.2
Cube 15	Average (Mpa)	1.13	0.43	1.71	4.88	5.42
	Standard deviation (MPa)	0.05	0.02	0.24	0.58	0.24
	Coefficient of variation (%)	4.4	5.0	14.2	11.9	4.4

Table 4. Compressive strength (credits: Obede B. Faria, 2008)

Sample	Effective Load (per laboratory) A	B	C	D	E	Proposed Load
Cube 7.5	163	500	168	380	160	163
Cube 10	289	615	300	490	287	289
Cube 15	650	488	660	1160	663	650

Table 5. Proposed and effective loading rates (kgf/min) (credits: Obede B. Faria, 2008)

Laboratory D did not test 10 units of each sample, as stated in the procedure, since the layer prepared to regularize load surfaces came off during the handling of some of the samples. Laboratories B and D did not meet the proposed loading rates, corresponding to a rate of voltage increase of 0.29 MPa/min, as the available equipment did not allow adjustment. Table 6 presents the results of compressive strength based on the average values of 7.5-cm/side cube samples from the corresponding laboratories.

Type of sample	Laboratory A	B	C	D	E
Cube 7.5 cm	1.00	1.00	1.00	1.00	1.00
Cube 10 cm	0.98	0.96	1.21	0.73	0.95
Cube 15 cm	0.91	0.96	1.38	0.76	0.90

Table 6. Compressive strength off the different samples in relation to the 7.5-cm/side cubes (credits: Obede B. Faria, 2008)

Except for Laboratory C's results, the results show a trend of reduction in compressive strength when increasing the size of the sample. The difference between the average data, except for Laboratories C and D, reaches a maximum value of 10%.

Laboratory B further determined the compressive strength of samples corresponding to half of adobes with an application area of sizes of 15 cm x 15 cm and a height of 7.5 cm. The average values of the compressive strength were 0.59 ± 0.06 MPa, with a coefficient of variation of 11.0%. Comparing this outcome with that of the 7.5-cm/side cube from the same laboratory, there is a 31% higher value, probably due to the lower rate of slenderness of the non-cubic sample.

The results also allowed drawing the conclusions below:

- There was no evidence of a relationship between the grain size and the compressive strength of the samples;
- The high values of compressive strength obtained by Laboratories D and E are unexpected;
- There was no significant variation in compressive strength in relationship to the dimensions of the cubic sample.

4. CONCLUSION

Inter-laboratory programs are carried out in order to obtain and compare test results, by adopting the same procedures, usually with the same raw material. In the case of the PROTERRA Inter-Laboratory Program, the use of the same raw material was discarded, due to the complexity of shipping earth between countries. It was decided to establish the requirements (content of sand and clay) for the selection of the raw materials in the samples, and to establish procedures for characterization, preparation of samples, and experiments. Later, each laboratory should complete a study of the repeatability of results, as there are many other earthen-characterization variables, for example, the mineralogical composition, that should also be taken into account.

The aim of this first stage of the PROTERRA Inter-Laboratory Program was to define test procedures to determine the compressive strength of adobe. The results allowed the establishment of the first conclusions, especially concerning the size and shape of the samples.

Since there were no significant differences in the results of compressive strength resulting the method of sample preparation, or its dimensions, using cubic samples trimmed from adobe prepared with the dimensions of each side as suggested is also specified in the Peruvian standard (RNC, 2000).

Considering the test-loading rate, it was not possible to verify its influence on the results, since it would be necessary to carry out tests with the same materials and adopt different rates. In order to avoid undesirable variables, and until data is available on the subject, the adoption of a loading rate for testing compressive strength of adobes is recommended, keeping a rate of increase in tension of 0.29 MPa/min as indicated in the PROTERRA Inter-Laboratory Program test procedure.

Excluding Laboratory A, which has been conducting trials of adobe since 1997, the other participants had no background in the preparation of samples to test the compressive strength of earthen blocks. The PROTERRA Inter-Laboratory Program provided the establishment of systematic procedure for the characterization of adobes in those laboratories. In addition, Laboratory A continues with the research in adobe using, whenever possible, the test procedures set out from the PROTERRA Inter-Laboratory Program. Laboratory D has also begun a sequence of tests of compressive strength with adobes using different types of earth, while adopting the same procedures.

Therefore, the PROTERRA Iberian-American Network intends to:

- Institutionalize the test procedure for characterizing compressive strength of adobe;
- Follow up with the inter-laboratory program, by putting forward test procedures for small adobe walls, to evaluate the behavior of adobe masonry, including the analysis by the finite-elements method.

Other laboratories are expected to adopt this procedure as well, in order to determine the compressive strength of adobes, and to collect data from different sites. This will improve the knowledge on the physical and mechanical characteristics of adobes, an ancient, but not completely understood building material.

Notes

(1) CECOVI staff members: Ariel González (coordinator), Santiago Seghesso, María Eugenia Germano and Jeronimo Silva.
(2) CEDED staff members: Célia Neves (coordinator), Ivo Oliveira, Clementino Passos and Adelson Profeta.
(3) Torino staff members: Roberto Mattoni and Gloria Pasero.
(4) UNESP staff members: Obede B. Faria (coordinator), Bruno M. de Oliveira, Margareth Tahira and Rosane Ap. G. Battistelle.
(5) Rafaela University staff members: Mirta Sánchez, Hugo Begliardo, Susana Keller, Saida Caula, Fiorela Morero and Juan Pretti.

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NOVEL MICRO-SCALE TECHNIQUES TO ESTABLISH A LIFE-CYCLE ANALYSIS OF EARTHEN-BUILT STRUCTURES IN SCOTLAND, UK

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Theme 6: Research in Materials and Technology for Conservation and Contemporary Architecture
Keywords: Micromorphology, image-analysis, luminescence dating

Abstract

The rapid changes in climate predicted for the 21st century presents a clear threat to the continued conservation and maintenance of historic vernacular buildings constructed with earth materials. With custodians of such vernacular heritage requiring a strong evidence base in order to prioritize the maintenance of such fabrics, it is clear that experimental studies considering the decay of earth materials correlated to their provenance or lifecycle in future environments is required.

This paper reports on a set of scientific initiatives designed to facilitate an evidence-based proactive approach, rather than an anecdotal and reactive approach, to the future repair and maintenance of such structures. Since climate change is manifested in different ways according to geographic location, process-led understandings are paramount. Two major techniques are used. First, thin-section micromorphology is an established technique for analysis of microscopic-structural features, as well as more extensive matrices of soils. It allows spatially-related observations to be linked to physical and chemical measurements at scales relevant to exchange processes in these materials. Second, a novel form of luminescence dating, allowing rapid on-site relative chronologies to be established, has been developed to permit temporal aspects and, hence, rates of change in the structures' lifecycle to be determined.

Using these techniques to analyze the wide range of constructional materials across a variety of regional environmental contexts in Scotland allows a multi-way comparative analysis. Sites considered include the dry internal structures of a stone-clad 18th-century merchant's house in Brechin, Angus; water-saturated earth-infill of wall from a house in Leetown, Perthshire, and exterior walling materials rich in cereal husks taken from Fladdabister, Shetland. Preliminary findings show differences in composition, internal matrix features, and relative age of these materials. This provides the basis for lifecycle analysis of these materials to be outlined in relation to climatically-related factors.

1. INTRODUCTION

The present paper outlines several techniques developed to help enable two complementary research projects on Scottish earthen structures that are being undertaken by the authors. The background to these projects spans two major themes. First is the need to understand processes of building decay in a manner relevant for the understanding of conservation needs and the development of conservation practices for historic earthen-built structures in Scotland. The number of past academic studies on such buildings is small and encompasses a wide array of approaches, including field observations of specific buildings (e.g. Walker, McGregor, and Little, 1996), ethnography and folklore (Fenton, 2008), and actualistic experimentation using trial walls, such as that reported by Morton (2011). Second is the overarching issue of climate change and the response of different types of earthen-built structures to such changes. In doing so, conservation needs and priorities for both scheduled (protected) buildings and those that are not subject to legislation can be identified and prioritized. The two research projects are in their earliest phases of development. They span the investigation of building histories, experimental examination of earthen-building materials subjected to predicted future climatic conditions, and development of practitioner-relevant advice.

2. HISTORIC AND GEOGRAPHIC CONTEXT

2.1 Earth buildings in Scotland

There has been a great variety in the use of earth as a structural element in Scotland's past buildings, reflecting the diversity of building types found historically in the Scottish landscape and the range of functions for which they were constructed. Clays were essential to the construction of great prehistoric stone-built monuments, such as Maes Howe in Orkney, whereas the Roman-built Antonine Wall was composed of expertly cut and laid turf. These are examples of well-known structures that are now designated World Heritage sites. The vast majority of Scotland's historic earthen buildings were, however, of the vernacular type, with people utilizing the products of their local landscapes to build functional homes, byres and walls without employing formal architectural conventions. This is not to say that earthen building was necessarily reserved for the lower elements of society, a notion that was perpetuated from the 18th century through the diatribe of 'improvement,' which frequently denunciated earth buildings as being temporary or 'backward'. Indeed, in Medieval England, successive archbishops of Canterbury were happy for earth to be used in the construction of ancillary structures at Lambeth Palace (Dyer, 2008). Improvement ideology and the associated physical and social reorganizations that took hold from the 18th century precipitated a drastic downturn in the employment of earthen-building practices in Scotland and, ultimately, the loss of a vernacular tradition whose geographically widespread history was far longer and more significant than would appear if the number of remaining examples was reflective of their original quantity.

Given the long history of earthen building in Scotland, the majority of such vernacular earthen-built structures have since returned from whence they came as a result of abandonment, decay and their inherent 'recyclability'. The consequent invisibility of these structures somewhat belies their previous ubiquity as a result. There is no doubt, though, that the use of unfired earth and turf as everyday building materials stretches back over millennia in Scotland, and archaeological evidence can be used with historic and ethnographic corroboration so as to testify to the continuity of the earthen-building tradition from the Neolithic (or earlier) through to the 20th century (Loveday, 2006).

2.2 Construction methods in Scotland

A range of construction techniques using earth have been employed throughout Scotland's history. A number of the known surviving examples of historic earthen-walled buildings can be said to be of a similar type to the 'cob' buildings that still abound in Devon in the south of England, the walls of which are constructed through the laying down of successive 'lifts' of clay-rich earth intermixed with straw and gravel. A

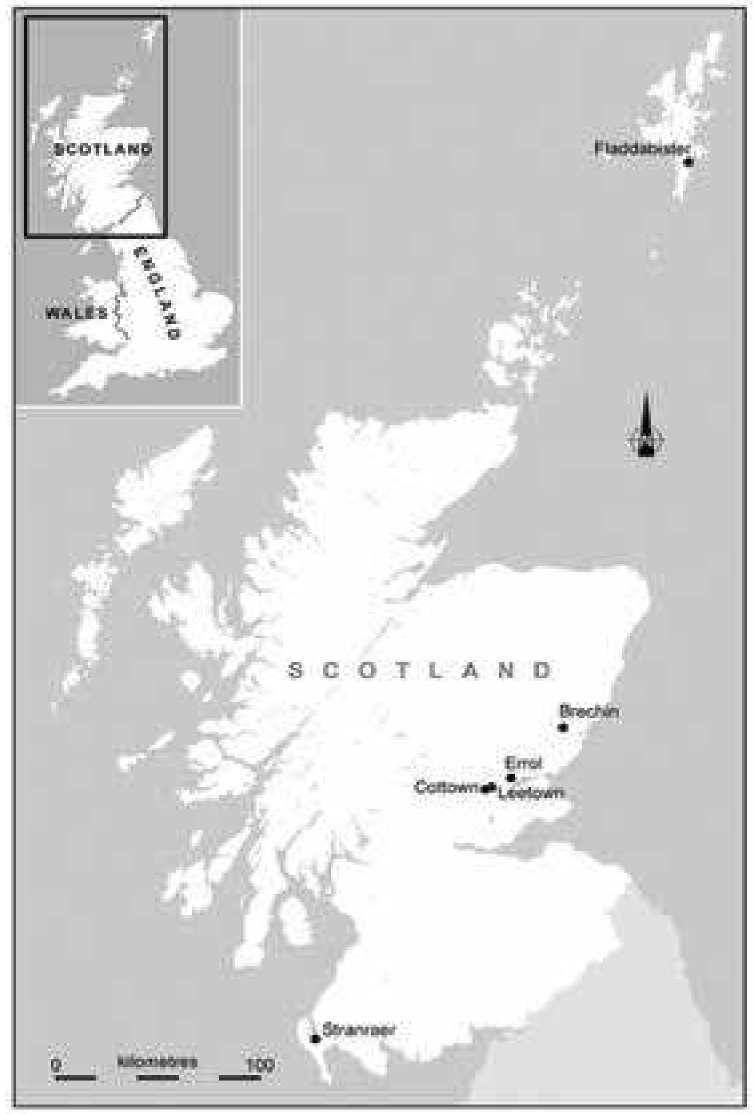

Fig.1 Map of Scotland showing location of sites mentioned in paper. The three sites in close proximity, Cottown, Errol and Leetown, are all located on the Carse of Gowrie, an area rich in marine-derived hydrous-mica clay deposits (credits: Paul Adderley, 2012)

diverse range of additional substances, differing from building to building and dependent on what was available at the time of construction, could be added to this basic mix of ingredients so as to augment the key elements. This is corroborated by the samples taken from Brechin and Fladdabister, which contain hair and cereal husks, respectively. Mass earthen-walled structures are typically referred to in Scotland as being 'mudwall' or 'claywall', although it is likely that since-forgotten regional terminologies once reflected the localized variations on this general theme (Walker, 1979). 'Clay and bool' walls (known as 'Auchenhalrig work') are an example of a local variation on the solid clay wall, incorporating larger, rounded stones into the earthen mix, and found only in Morayshire in northeast Scotland. Structures built with mass earthen walls, which also include those that used formwork in a method similar to pisé, are of primary importance to the wider project to which this piece is associated. Nevertheless, it is essential to note that there was a vast array of different structures that

could be raised using earth or turf as an essential component.

In addition, earthen mixes were commonly applied to wooden skeletons in a variety of forms such as on the exterior of wattle work or between upright timbers (Walker et al., 1996). Earth was used as an infill in the dry-stone walls of the blackhouses of the Western Isles, whilst clay was applied at the wallheads for waterproofing. The blackhouse can be seen as a relative of the turf-walled farmhouses of the North Atlantic building tradition, and can still be found in Iceland. Although turf structures were deemed the lowliest type by 18th and 19th century Improvers, this notion undermines the skill with which turf has been employed as a building material in Scotland's history. The range of turf cuts and variations in the way it was incorporated as a structural element in a range of building types serves to demonstrate a high level of craftsmanship (Walker et al., 2006).

2.3 Geographic spread

It would be difficult to underestimate the extent to which earthen-built structures were formerly spread across the Scottish landscape. It must be noted, however, that enclaves with a greater concentration of surviving earthen buildings would seem to correlate with local geological and geographic circumstances that determine the increased suitability of clays, for example, to mass earthen-construction techniques. Indeed, many past studies have focused on sites such as Cottown and Errol in the Carse of Gowrie. Some areas are relatively undocumented with the Rhins of Galloway near Stranraer in southwest Scotland having evidence of a rich, yet relatively unstudied, history of earthen-built construction.

2.4 Climate

Scotland is associated with a maritime-climate regime typified presently by frequent (i.e. intra-daily or weekly) changes between mild warm and dry conditions to mild warm and damp conditions. With detailed historical climate records extending to 1757, climate changes relative to long-term mean values can be evaluated throughout Scotland. Until the mid-20th century, mean annual precipitation varied little compared to the long-term mean, but from the 1970s has increased markedly (Smith, 1995). This annual countrywide increase in rainfall is marked by significant localized shifts in weather patterns with some regions experiencing pronounced seasonal shifts (Mayes, 1994). Comparison of 30-year monthly climate normals, e.g. 1941-1970 vs. 1961-1990, provides evidence of winters having become wetter coupled with dryer summer periods, with the greatest contrast seen in northern central regions.

Past evidence of climate change is a useful test of climate models. A range of different climate predictions have been made using modeled data for northern Europe over the last decade. The latest sets of scenarios modeled by the HAD CM3

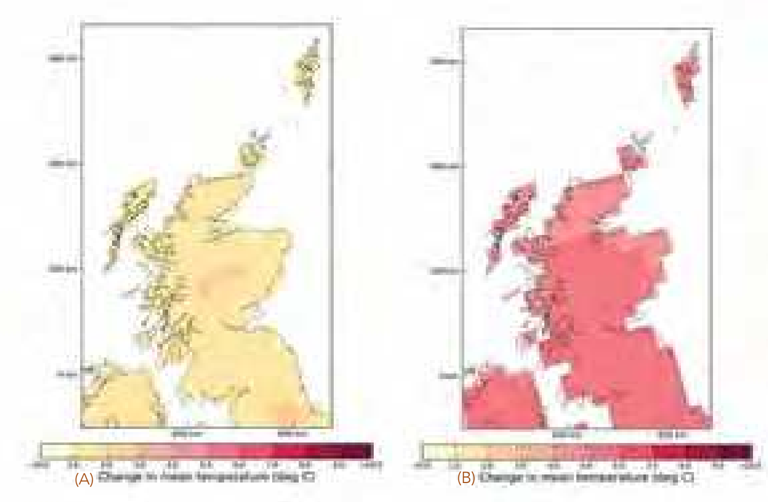

Fig.2 UK Climate Prediction (UKCP09) projections for the increase in temperatures for Scotland and northern Britain over the course of this century with continued "high emissions" of greenhouse gases. Scenarios for the 2020s (A) and 2080s (B) are shown. The 'high emissions' scenario shown would be of the greatest threat to historic earthen buildings. The data is based on HAD CM3 climate-model predictions (1) (credits: © UK Climate Projections, 2009)

model are widely accepted and form the basis for the most recent IPCC report (Metz, Davidson, Bosch, Dave, and Meyer, 2007). For Scotland and northern Britain, these predictions have been mapped at a resolution of 25 km² resulting in a series of possible outcomes.

The interaction of different weather events (rain, frost, dry weather) with earthen structures in northern Europe has many determining factors. While external forces, such as raindrop impact and frost-induced cracking, are obvious, internal surfaces of closed but unheated building structures are subject to more subtle effects. A recent study by Lankester and Brimblecombe (2011) measured thermo-hygrometric climates within a historic house in southern Britain, and has proposed a series of dose response, or so called 'damage' functions for assessing the fate of the coverings of internal walls. While a basis for such functions to be modeled in respect of earthen-built structures exists, their development and application requires suitable techniques for deriving starting parameters and model validation.

3. SUSTAINABILITY OF SCOTTISH EARTHEN BUILDINGS

The sustainability of existing earthen-built properties in Scotland depends upon adequate responses to the issues raised by climate change. These include increased flooding, water movement through the earthen matrix of walls, and more rapid changes between wet and dry conditions. This coupled with general increases in air temperatures will lead to changes in the rate and nature of movement of water and soluble salts in earthen-built structures. To understand these processes requires the pore-geometry of the sediments to

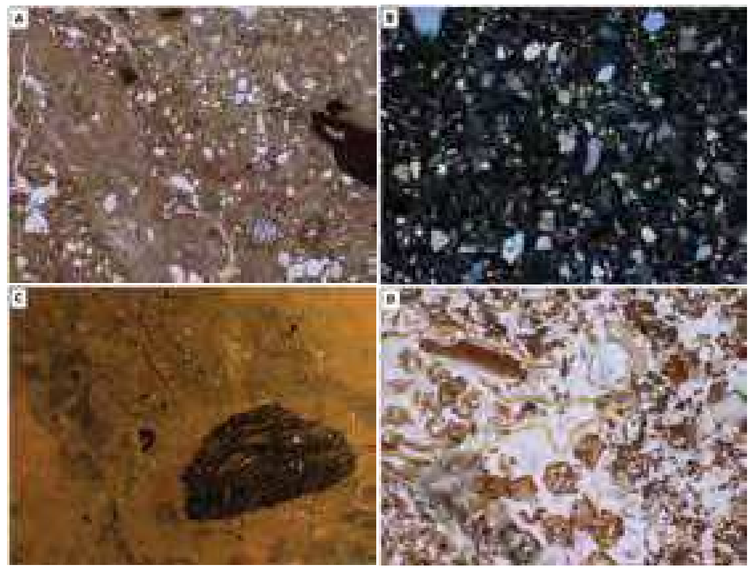

Fig.3 Photomicrographs taken using different illumination techniques; plane-polarized (PPL) and oblique-incident illumination (OIL), (A) Cereal straw used as an organic amendment within an earthen-built school house wall, Cottown, Perth and Kinross (PPL), (B) Highly organic materials and mixed mineral component, sand-rich turf-built walls, Newtonmore, Inverness-shire (XPL), (C) Charred wood fragments within mud-wall construction, Leetown, Perth and Kinross, (OIL), (D) Open structure and organic materials with wall material, Newtonmore, Inverness-shire (PPL) (credits: Paul Adderley, 2012)

be characterized at an appropriate scale; in this paper, we outline an approach using soil thin-section micro-morphology. Furthermore, given the need to establish rates of change, chronological assessment through either relative or absolute dating is a key parameter. An approach to rapid relative dating of mineral materials is described.

4. MICROMORPHOLOGY AND IMAGE ANALYSIS

4.1 Characterization of materials through micro-morphology analysis

The use of microscopic analysis of materials from historic earthen-built structures is a particularly important analysis tool for investigation of historic earthen structures. When combined with complementary analyses, such as electron microprobe or X-ray elemental analyses, spatial relationships between the different components (clay, gravel, organic materials) can be identified and measured. Investigations from buildings in Scottish contexts have so far revealed a wide variety of fabrics and organic additions.

4.2 Spatial descriptions of porosity

Comprehending the porosity characteristics of the materials used in earthen-built structures is essential if process-based models and understandings of water and salt movement are to be advanced (Grossi et al., 2011). The description of water movement, i.e. percolation, in porous media, such as soil, requires knowledge of the relationship between soil-water content and the pressure head of the water moving through the pore space. Many models of percolation in porous media have been developed that are based on capillary behavior, i.e. how does water move through an unsaturated capillary pore during wetting or drying? Such simple models, typically, assume the pore spaces in the media are a uniform set of capillaries running in parallel. Soil materials are, however, inherently more complex and the porosity of the soil materials can be better described as a network of pores connected by "throats" or constrictions between them (Kodešová, 2009; Fig. 4A). The geometry of the network, i.e. the size of capillaries and the minimum size of these throats, is a key determinant in the rate of water percolation.

Direct measurement to characterize these networks by methods, such as mercury porosimetry, are common on solid materials, such as stone, but are more problematic when applied to softer materials, such as soils (e.g. Fiès and Bruand, 1990). Artifacts in measurement emerge due to the need to dry the sample prior to analysis, which may lead to clay-drying cracks. The intrusion of mercury may also result in very high pressures deforming the soil fabric. If water and soluble-salt movement in earthen-building materials is to be modeled through deriving rates of percolation, the size, distribution and arrangement of pores and throats must be established. Image analysis of thin-section materials allows their characterization in two dimensions and the development of such models.

4.3 Quantitative analysis of porosity through mathematical morphology

Quantitative analysis of materials seen in soil thin sections through image-processing techniques has become well established in soil science. Quantification of the relative contribution of different components of the fabric of an earthen wall can be readily achieved, but image processing is essential to quantifying and characterizing the porosity of the material (Whalley et al., 2005). While porosity can be simply measured by the area of the thin section covered by pores, if transport processes are to be considered then an assessment that measures throats is required. One method is to use a mathematical analysis using "closing" and "opening" functions in a repeated sequence until the throat closes (Fig. 4D). By keeping the mathematical operators applied constant, the method can be applied to different images; the number of iterations of opening and closing required to close all the throats in an image provides a robust measure of the pore geometry.

5. MEASUREMENT OF THE STORED-DOSE LUMINESENCE CHARACTERISTCS OF EARTHEN–BUILDING MATERIALS

Luminescence dating is a recently established method in geomorphology and cultural-heritage studies. It is based on the fact that there is a constant flux of naturally occurring ionizing

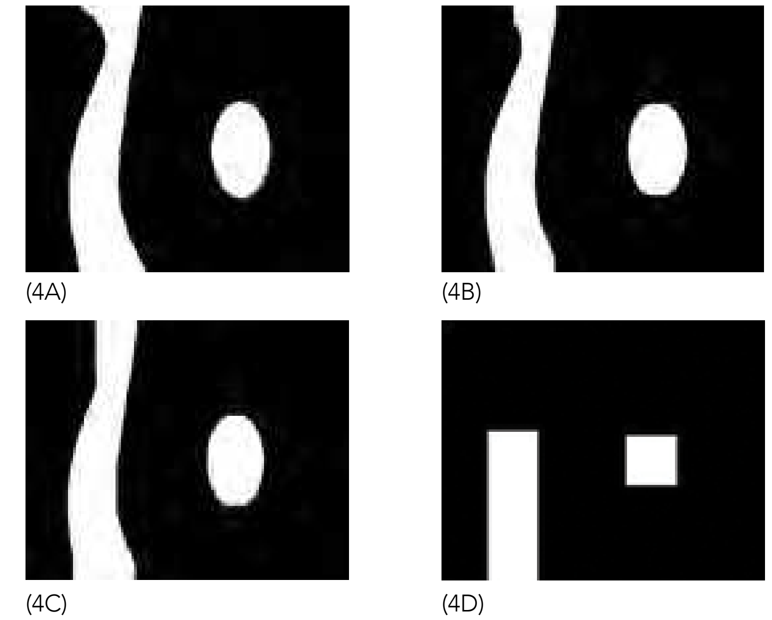

Fig.4 Starting with a schematic pore network of an open pore and closed pore (A), sequential application of mathematical-morphology opening and closing functions (B, C) allows quantification of the step when the 'throat' of the open pore closes (D) (credits: Paul Adderley, 2012)

radiation in the environment, and that many silicates can act as a dosimeter of this radiation. This stored dose can be released by heat or light. This means that the amount of luminescence emitted from a sample (e.g. quartz) is proportional to the accumulated dose since it was last exposed to either heat (e.g. pottery) or light (soils, sediments). If both the background-dose rate and the stored dose are known, a date since firing (pottery) or last exposed at the ground surface (soils) can be calculated. Among many factors, however, the results are conditioned by the nature of the sediment or fired material examined. By accepting that the measurement of stored luminescence in unfired clays and other silicates is conditioned by the material itself (mineralogy, bulk density), it is possible to examine the use of a novel portable instrument to rapidly examine stored-dose measurements. Using examples from the Carse of Gowrie it is illustrated how such data can be interpreted.

5.1 Instrument

The SUERC portable luminescence-reader instrument was developed by Sanderson and Murphy (2010). It is designed to prioritize conventional dating measurements by allowing an assessment of mineralogical properties and sensitivities. It measures both infra-red (λ 880 nm) stimulated luminescence (IRSL) and blue-light (λ 470 nm) luminescence (OSL) stimulated luminescence. The greater the OSL count, the greater the age of sediment since last resetting by light or heat. Changes of the IRSL:OSL ratio are a possible proxy of mineralogical differences. To test the use of such an instrument for earthen-built structures, materials from an internal rammed-earth wall at Cottown Schoolhouse (Morton, 2011) and from the local clay source at Errol have been examined.

Fig.5 Portable luminescence-measurement apparatus comprising sample chamber with attached photomultiplier, control box, and laptop PC; sample in foreground (credits: Paul Adderley, 2012)

5.2 Measurements

Luminescence measurements are reported in Table 1. From historical records, the processed clay material at Errol was last exposed in c. 2004, and the interior matrix of the Cottown schoolhouse is likely to date from AD 1745. It is clear that both IRSL and OSL measurements reflect these periods. It is also clear that the action of processing a bulk-clay body from brick-making is sufficient to reset the luminescence. This suggests that if similar manipulation of earthen materials occurs during vernacular construction, the luminescence signal will be reset. This would suggest that full luminescence dating of such structures is possible. The contrast in materials from the wall in Cottown Schoolhouse is presumably due to past exposure of the surface during interior decoration; however the IRSL:OSL ratio may suggest mineralogical differences due to surface treatments.

6. CONCLUSION

We have successfully developed and demonstrated, using a small set of case studies, methods for laboratory-based field sampling and monitoring initiatives. These methods are presently being integrated into a wider set of site-based and experimental studies assessing climatically related processes of decay in historic earthen-built structures found across Scotland. By establishing quantitative methods, rates of decay and modeled 'damage' functions can be established. The use of the portable OSL system has provided valuable information that may help direct sampling for detailed chronological assessment, for example, the dating of building repairs. These data may also direct sampling for assessment of mineralogy and for thin sections of structures. Through the latter, the initial composition of the matrix of the earthen structure, as well any repair materials can be characterized. Combined, these analytical tools allow a deeper process-led assessment of the life-cycle of earthen-built structures.

Sample	IRSL Counts/second	OSL Counts/second	IRSL:OSL ratio
Errol Brick Works – fresh exposed surface	332	533	0.62
Errol Brick Works – processed (2004) clay material	339	624	0.54
Cottown Schoolhouse Interior wall – immediately beneath surface covering	5584	6139	0.91
Cottown Schoolhouse Interior wall – 4-cm deep below wall surface.	14732	11300	1.30

Table 1. Results of luminescence analysis of clay-rich materials from Errol Brick Works and from an original wall in Cottown Schoolhouse)

Notes

(1) UKCP09 climate-prediction datasets are available in various formats at the following URL: http://ukclimateprojections.defra.gov.uk (Accessed, 20 August 2011).

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THE COMPRESSIVE STRENGTH OF LIGNOSULPHONATE-STABILIZED EXTRUDED-EARTH MASONRY UNITS

Daniel Maskell, Peter Walker, Andrew Heath

Theme 6: Research in Materials and Technology for Conservation and Contemporary Architecture
Keywords: Masonry, extruded bricks, novel stabilizers, compressive strength

Abstract

Earthen (unfired-clay) bricks offer several distinct advantages over conventional fired-clay bricks and other high-energy masonry units. Most notably, there is significantly lower-environmental impact, including carbon emissions during manufacture, than comparable products, with unfired-clay bricks having an estimated 14% of the energy of fired bricks, and 25% of concrete blocks. Earthen construction is able to provide passive-environmental controls, including the regulation of temperature and humidity, which can be utilized in unfired-clay masonry to improve internal levels of comfort.

The commercialization of unfired-clay masonry as a structural material is dependent on several factors. Modern earthen-construction methods need to fit in with demands of contemporary construction, compete commercially and provide a high-quality consistent performance. To ensure that thin-walled unfired-clay masonry can be used in a load-bearing application, it is important to consider the effect high-moisture content, due to accidental and intentional wetting, has on the strength of the material, as well as the building unit.

This paper presents initial findings from an investigation into the development of low-impact alternative stabilizers. Cement and lime are widely used in some countries, but both have an associated embodied energy and carbon emissions that may hinder the benefits of unfired clay as a mainstream building material. The use of lignosulphonate was chosen as a way of minimizing the adverse environmental impacts while improving water resilience, an essential requirement for thin-walled load-bearing masonry using earth. Unconfined-compressive strength of extruded-soil samples, which were stabilized with three types of lignosulphonate, were tested both dry and wet as a basis for comparing loss of strength due to exposure to a wet environment.

1. INTRODUCTION

Within the UK, the heritage of earthen construction largely ended during the 19th century, which is attributed to the industrialization of the construction industry (Morton, 2008, p. 17). There has been a renewal of interest in earthen construction within the past 30 years due to the increasing interest in sustainable forms of construction (Walker, 2004, p. 249).

For the beneficial effects of any sustainable form of construction to have a significant and widespread impact, then factors in addition to the embodied energy and carbon should be considered. The form of construction should also be easily adopted into current construction practice with a minimum shift in the end use by society. In this regard, any sustainable construction should be comparable to current materials with respect to durability and maintenance.

The focus of this paper is on modern earthen masonry that is commercially produced. This enables the benefits of earthen construction to be delivered to the mass market with improved quality control. Earthen bricks can be produced following the well-established manufacturing procedure as commercially produced fired bricks but without the firing. This allows the commercially produced extruded-earthen units to have about 14% of the embodied carbon of equivalent fired-clay bricks (Morton, 2008, p. 4). Based on typical figures in the Inventory of Carbon and Energy (Hammond and Jones, 2011), it can be shown that a 225-mm thick un-stabilized earthen-masonry wall has the similar embodied energy to a 100-mm thick commercially produced dense-concrete block. It is, therefore, environmentally and financially desirable to keep walls as thin as possible.

The compressive strength of extruded-earthen masonry measured at ambient temperature and humidity levels ranges from 2.8 to 5.1 MPa (Heath et al., 2009, p. 110). Therefore, there is scope for these units to be used within a 100-mm thick load-bearing wall in a two-story domestic application.

Heath et al. (2009, p. 108) developed and demonstrated the exponential relationship between compressive strength and water content for extruded unfired-clay masonry units. With increasing moisture content, the compressive strength of the units decreased. This reduction in compressive strength is critical for thin-walled load-bearing masonry. Accidental or intentional wetting would clearly create an elevated moisture content, which would significantly reduce the strength of the material, as well as the masonry that would ultimately lead to collapse.

Typically, cement can be added to improve strength and reduce water susceptibility. Using the data in the Inventory of Carbon and Energy (Hammond and Jones, 2006), it can be shown that a cement content of 5% in an earthen block will increase the embodied energy to a level similar to dense-concrete blocks, eliminating one of the environmental benefits.

There has been a growing interest in using alternative low-embodied carbon stabilizers. Lignosulphonates are natural polymers derived from lignin that binds cellulose fibers together and is typically a byproduct from the paper industry (Brandon et al., 2009, p. 12). These materials are commonly used in commercial brick manufacture to provide sufficient 'green' (wet) strength to prevent damage during handling.

The objectives of the work presented in this paper were to study, compare and report on the strength characteristics of extruded-earthen masonry. Following a review of the stabilization mechanism of lignosulphonate, an experimental program of compressive strength was completed using scaled extruded-earthen bricks made of the same brick clay with varying types of lignosulphonate.

2. STABILIZATION MATERIALS AND METHODS FOR CONSTRUCTION

Stabilization offers a method of improving the inherent properties of soil. Many of the traditional and non-traditional methods of were developed for the stabilization of unpaved roads (Tingle and Santoni, 2003, p. 72). Typically, this has focused on improving the Unconfined Compressive Strength (UCS), Californian Bearing Ratio and erosion characteristics of the roads. The outcomes of the literature concerning the use of non-traditional stabilizers for road improvement can be transferred for the possible use in building structures.

Potential mechanisms by which stabilization of the soil can occur have been summarized by Tingle and Santoni (2003, p. 74) and include:

- Encapsulation of clay minerals;
- Cation exchange;
- Chemical breakdown of the clay;
- Absorption of organic molecules into the clay interlayer.

The non-traditional additives are either byproducts of an unrelated process or, alternatively, they have been developed specifically. Lignosulphonates are byproducts that have a wide variety of uses, including acting as a plasticizer for making concrete. Lignosulphonate (C20H26O10S2) is an anionic polyelectrolyte that form salts typically with sodium, calcium and ammonium cations.

Lignosulphonate stabilizes soil by physically binding the soil's particles together with minor chemical effects (Tingle et al., 2007, p. 61-62). Individual soil particles can become coated in a thin adhesive-like film that acts to cement the particles together. Lignosulphonates are ionic and, therefore, there is the possibility for cation exchange that can alter the molecular structure of the soil. This has the potential to reduce the surface charge that can lead to flocculation, close packing and hydrophobic characteristics (Xiang et al., 2010, p. 886).

Santoni, et al. (2005, p. 34-42) tested lignosulphonate on a compacted silty-sand material. The addition of 3% lignosulphonate solution caused a 22% reduction in UCS compared to an un-stabilized sample at seven days. Lignosulphonate specimens were tested under the 'wet' conditions. In preparation, specimens were placed for 15 minutes in an inch (25.4 mm) of water. When tested in this method at seven days, the lignosulphonate stabilized specimens showed, as expected, a decrease from the dry specimens' UCS. When compared to the equivalent un-stabilized specimens tested using the 'wet' method, the lignosulphonate-stabilized specimens were on average 620% stronger and gave a UCS of 1.1 MPa.

The effect of lignosulphonate on low-plasticity soils resulted in a greater UCS (Tingle and Santoni, 2003, p. 78). An optimum concentration of 1.5% powdered lignosulphonate resulted in a UCS of 7.3 MPa, while a UCS of 4.8 MPa was achieved under 'wet'-testing conditions. Within the same test matrix performed by Tingle and Santoni (2003, p. 78), lignosulphonate stabilization achieved a 30% greater UCS than a 9% cement addition under dry conditions, and a marginal increase in strength under 'wet' testing.

Although the literature has been limited, it has shown that there is potential for lignosulphonate to be used a soil stabilizer. The potential ion-exchange mechanism warrants further research with varying types of lignosulphonate to investigate if there are any noticeable effects. The unique method of brick production by extrusion with the benefits of stabilization using byproducts may yield an unfired-masonry unit suitable for a load-bearing application without the risk of potential mechanical wetting.

3. EXPERIMENTAL MATERIALS

All the experimental bricks were produced using the same brick clay. The soil is described as a brick clay, as it is used for commercial fired-brick production. The brick clay was chosen rather than blending materials, as this is the material that is currently used for production; therefore, any stabilization method would be required to work with fundamentally the same material. The grading and Atterberg characteristics are outlined in Table 1. The soil can subsequently be described based on grading as a dark-brown slightly sandy silt with the plasticity of a low-plasticity clay. The clay mineralogy was identified by XRD as containing 39% kaolinite and 2% montmorillonite with significant amount of quartz and minimal amounts of other minerals.

For this study, sodium (Na), calcium (CA) and ammonium (Am) lignosulphonate were supplied in dry-powder form. The clay was stabilized by adding 2.5% (by dry mass) of the dry-powder lignosulphonate.

Property	
Grading (by mass)	
Fine gravel fraction (2–6 mm) (%)	5
Sand fraction (0.06–2 mm) (%)	33
Silt fraction (0.002–0.06 mm) (%)	46
Clay fraction (<0.002 mm) (%)	16
Atterberg Limits	
Liquid Limit	24
Plasticity Index	8

Table 1. Soil characteristics (credits: Daniel Maskell, Pete Walker, Andrew Heath)

Fig.1 Laboratory vacuum pug-mill extruder (credits: Daniel Maskell)

4. EXPERIMENTAL PROGRAM

The bricks were manufactured within a laboratory environment at the University of Bath. This was achieved using a vacuum pug-mill extruder able to produce bricks at 1:3 linear scale, thus 1: 27 volumetric scale as shown in Fig.1. This machine creates a similar production process as full-scale extruded bricks. Clay that has been pre-mixed with the required water content is fed in to a series of augers that help to homogenize the mixture. Under a vacuum, the clay is effectively compressed by reducing the cross-sectional area at the point of extrusion to 72 mm by 34 mm. This produces a column of clay that is then cut into 22-mm thick bricks.

Initial testing was undertaken to determine the optimum-moisture content (OMC) for the extrusion of the bricks. This was achieved by adding varying amounts of water to the clay mixture and feeding it through the extruder, then measuring the water content and dry density of the bricks that were produced. This was compared to the modified Proctor method of determining the OMC. Extruding at a moisture content less than the plasticity limit caused notable cracking in the brick surface, and extrusion was not possible at a moisture content less than 14%. The OMC for extrusion is, therefore, at the plasticity limit of 16%. It is clear from Fig.2 that the modified proctor is unsuitable for determination of OMC for extrusion. The addition of the various lignosulphonate did not change the plasticity limit and, therefore, did not change the OMC for extrusion.

Each sample was prepared by first dry mixing 2.5% of the powder lignosulphonate into the brick clay. Water was then added to achieve a mixture with moisture content of 16%. This mixture was then transferred and fed through the extruder under a vacuum of 0.5 bar. The extruded column of clay was cut to form the bricks of dimensions 72 x 34 x 22 mm, and the bricks were immediately weighed while additional samples of extruded clay were taken for moisture-content measurements.

The drying regime, curing time and testing condition were varied to independently assess the effect on stabilization mechanism. The drying procedure was varied to investigate if any stabilization effect would be facilitated or accelerated by variation in the drying regime. All of the bricks were dried within the laboratory for two days; following that, the drying procedure varied. Random samples of bricks continued to be dried in the laboratory environment (average of 21.5°C at 61% relative humidity) while the drying of other bricks was accelerated. One sample of bricks was artificially dried in an oven at 60°C while another was dried at 105°C. Following two days in the ovens, they were then removed and stored within the laboratory until testing. To investigate the development of strength, bricks were first tested at 14 and 28 days. Finally, testing occurred on dry and wet samples. The wet-testing regime involved fully immersing the bricks in distilled water for 24 hours prior to testing. This meant that in total, 12 different test methods were considered.

Block dimensions, dry density, uniaxial compressive strength were determined using a representative sample of six specimens for each of the 12 tests. Brick compressive strengths were measured by crushing specimens in their normal aspect without any capping. The load was measured with an applied constant-displacement rate of 2.5 mm/min. The results were averaged for each testing method and the methodology repeated for each different stabilizer. Each brick was compressed until peak load was reached.

5. RESULTS

The results of the compression test on the stabilized sample, as well as an un-stabilized sample for control is provided in Table 2, Fig.3 and Fig.4. The control sample consisted of the same brick clay with no additional stabilizer added and prepared to the same moisture content. All the bricks were extruded at an average moisture content of 15.6% and gave an average dry density of 1928 kg/m^3. There was no significant

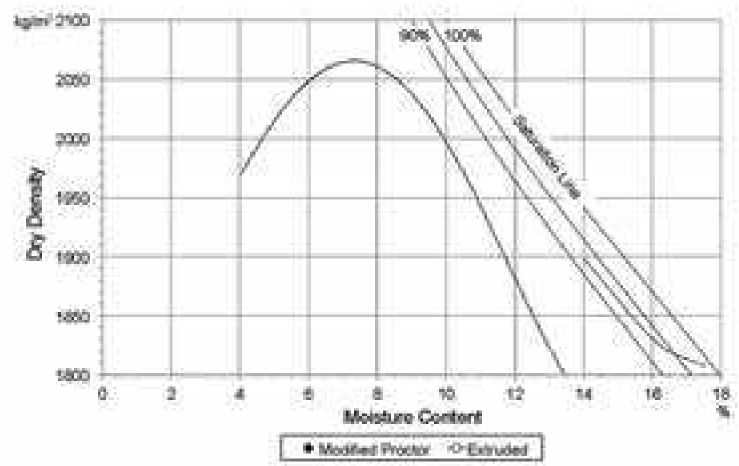

Fig.2 OMC of clay soil (credits: Daniel Maskell, Pete Walker, Andrew Heath)

variation in these measurements between the different tests, therefore, assumed to be constant in terms of the contribution to strength gain. The effect of stabilizer type, drying regime and curing time can be independently analyzed.

5.1 Effect of lignosulphonate type

The effect of stabilizer type was evaluated by testing three different types of lignosulphonate. The results show that the addition of any lignosulphonate-based stabilizer will not have a detrimental effect but can significantly improve the dry compressive strength of the bricks. All of the bricks, including those stabilized, that were tested under the wet regime disintegrated and, therefore, were not tested.

Calcium lignosulphonate was the most effective stabilizer, and achieved the maximum compressive strength of 7.65 MPa when oven dried at 105°C, representing a 126% increase over the equivalent un-stabilized samples. The improved performance of calcium over sodium and ammonium may be due to the process of cation exchange. The monovalent sodium cation (Na+) is present, along with water molecules, within the double layer of certain clay minerals. Therefore, cation exchange would be limited. The higher-valence calcium cation (Ca2+) preferentially will exchange with the cations present within the clay structure. Ammonia ions (NH4+) may also exchange with some of the metal cations present in clay and adhere to the negative edges of the particles. Cation exchange has the effect of a reduction in the size of the double layer, as well as leading to increased flocculation (Prusinski and Bhattacharja, 1999).

Cation exchange would be particularly prevalent with the montmorillonite fraction but limited with kaolinite. Considering the percentage weight of these minerals, cation exchange of the whole sample may be dominated by kaolinite and, therefore, limited. Bell (1996) comments that "very small amounts of certain clay minerals may exert a large influence on the physical

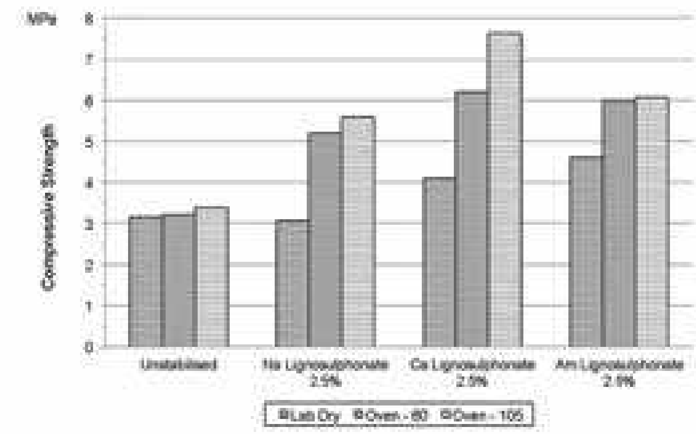

Fig.3 14-day compressive strengths (credits: Daniel Maskell, Pete Walker, Andrew Heath)

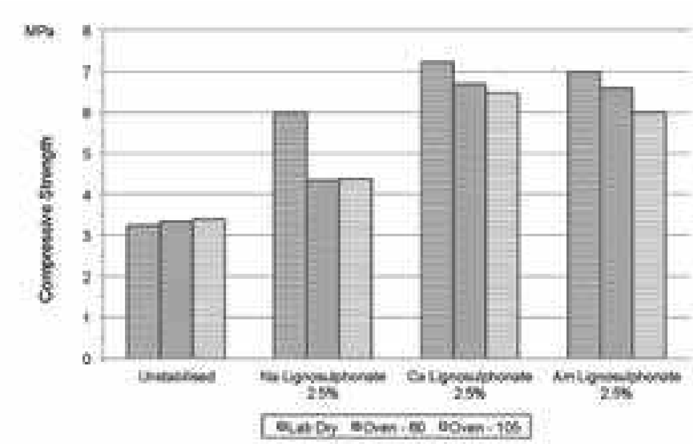

Fig.4 28-day compressive strengths (credits: Daniel Maskell, Pete Walker, Andrew Heath)

properties". The alternative source of strength increase may be due to the adhesive properties of the lignosulphonate. If only the anionic lignosulphonate is involved in the adhesion process, then the strength increase would be uniform. If the cation is involved in the process, then it may be reasonable to assume that varying the cation will vary the adhesion and, hence, compressive strength. Alternatively, the cation present may cause a change in pH of the water that may lead to slightly different reactions to occur that cause the variation in compressive strength.

5.2 Effect of drying regime

Testing all the samples of lignosulphonate stabilised clay, but accelerating the drying, evaluated the effect of drying regime on performance. A sample was cured within the laboratory environment and acted as a control to compare the drying regime. The compressive strength of the unstabilised sample showed a negligible increase in compressive strength. However the accelerated drying of the lignosulphonate stabilisers showed a increase in strength at 14 days but a decrease at 14 days. The increase in temperature from 60°C

Curing Regime	Age	Moisture condition at testing	Unstabilised		Na Lignosulphonate 2,5%		Ca Lignosulphonate 2,5%		Am Lignosulphonate 2,5%	
			UCS MPa	MC %	UCS MPa	MC %	UCS MPa	MC %	UCS MPa	MC %
Lab Dry	14 Days	Dry	3.17	2,23	3.08	3.19	4.11	3.09	4.62	2.89
	28 Days	Dry	3.24	1.84	6.01	1.67	7.23	2.05	7.00	1.84
Oven - 60	14 Days	Dry	3.19	1,27	5.21	1.46	6.19	1.61	6.00	1.10
	28 Days	Dry	3.33	1.35	4.34	1.36	6.69	1.61	6.57	1.22
Oven - 105	14 Days	Dry	3.39	1.44	5.59	1.14	7.65	1.11	6.07	0.69
	28 Days	Dry	3.39	1.42	4.38	1.28	6.45	1.42	6.01	1.35

Table 2. Compressive strength and moisture content at testing (credits: Daniel Maskell, Pete Walker, Andrew Heath)

to 105°C resulted in an increase in compressive strength for all 14 day samples. This was most noticeable with the calcium lignosulphonate that resulted in a 24% increase in strength from the 60°C to 105°C. Increased drying temperature over the first few days resulted in a decrease of testing moisture content at 14 days. By 28 days the stabilised samples left to dry in the laboratory environment achieved a greater strength than those subject to accelerated drying. There appears to be a time dependent effect related to the effect of the initial acceleration of drying.

5.3 Effect of time curing

The effect moisture content on the strength, and how this varies over time and with different drying regimes should be considered. There were marginal changes in strength for the un-stabilized samples from 14 to 28 days. This suggests that these samples achieved equilibrium-moisture content by 14 days. The lignosulphonate-stabilized samples' change in strength was dependent on the initial drying regime.

The effectiveness of lignosulphonate for increasing dry-compressive strength may be related to the rate of drying. The rate of drying would increase due to an increased hydraulic gradient due to a higher-surface temperature than core temperature of the brick, causing water to move through the pores at a greater rate. This movement would allow the dissolved lignosulphonate salt to move through the brick enabling cation exchange and coating of the particles with the adhesive. If this effect was accelerated, then it might be expected that the 14-day strength would be greater as more lignosulphonate adhesive would precipitate out of solution. By 28 days the laboratory-dried sample would have lost more moisture giving the gain in strength. The slower drying rate would have meant that the movement of the dissolved salt could happen over a greater amount of time allowing for more reactions to occur, which results in strength gain. There is a significant increase in moisture content for the lignosulphonate samples dried at 105°C, which would account for the general decrease in strength. The effectiveness of lignosulphonate to stabilize extruded-unfired earth is potentially dependent on moisture content and, therefore, dependent on drying regime and curing time.

6. CONCLUSIONS

Although the exact type of lignosulphonate varies, it has shown that lignosulphonate will not have a detrimental effect on the compressive strength and, in most cases, leads to significant dry-strength increase when compared to un-stabilized samples. Maximum strength increase was achieved with calcium lignosulphonate that was dried for two days at 105°C and tested at 14 days. The greatest improvement of strength at 28 days was achieved when the curing period did not involve elevated temperatures. There is clearly scope for further research to optimize the drying regime to possibly achieve further strength gains. In addition, there is scope for further research into optimum stabilizer quantity. Considering the mechanisms involved, it is likely that calcium lignosulphonate will remain the stabilizer that gives the greatest strength improvement. The long-term performance of lignosulphonate-stabilized earth, and the relationship to moisture content remains unknown and should be investigated.

All of the bricks that were fully immersed in water were unable to be tested as they had completely disintegrated. An increase in concentration of stabilizer may provide enough adhesion; however, solubility of the material remains a concern. The method of testing by full immersion could be considered to harsh and was the conclusion of Tingle and Santoni (2003). As saturated performance of earthen masonry remains one of the greatest barriers to commercial adoption, then it will be required to meet this testing method.

This work has shown that there is significant potential for strength increased with lignosulphonate. Lignosulphonate was shown to be ineffective at stabilizing against elevated-moisture contents. Earthen bricks are targeted for domestic application where an increase in strength is not required compared to moisture resilience. Therefore, stabilizing earthen masonry with lignosulphonate has been shown to be ineffective.

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THE FEASIBILITY OF USING SCIENTIFIC TECHNIQUES TO ASSESS REPAIR-MATERIAL SUITABILITY IN EARTHEN BUILDING CONSERVATION

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Theme 6: Research in Materials and Technology for Conservation and Contemporary Architecture
Keywords: Earth, sacrificiality, wychert, compatibility

Abstract

The application of scientific techniques to conservation work has in recent years grown as a discipline, driven by a desire within the field of building conservation to better understand historic building materials. Wide ranges of historic materials are now analyzed to determine behavior and performance characteristics, which has led to advancements in the implementation of conservation work. However, the area of earthen building conservation has not yet been investigated in great detail; there is at present a large lacuna on how to select earthen repair materials, especially in terms of sacrificiality of interventions. This study directly addresses this fact by carrying out laboratory analysis of earthen materials in order to assess the feasibility of using repair materials to specify conservation work.

A case study from Buckinghamshire in England was chosen; a wychert-cob ecclesiastical building that had recently undergone repair and conservation. An identical program of material classification and performance tests was carried out on two sample materials from the building; one historic and one repair material. Through the study of laboratory results, the material characteristics and mechanical behavior of the two earthen materials were compared, and a critical analysis of the compatibility of the historic and repair material carried out. The findings of the study concluded that the repair material was unsuitable for use in this case, being incompatible with the original material. The achievement of the work was twofold; firstly it serves as verification for using these techniques to obtain comparable results that can be used to appraise material sacrificiality, and secondly it demonstrates that earthen materials are of a complexity whereby compatibility cannot be assumed using basic techniques. Work such as this highlights the need for analytical investigations in earthen building conservation, in order to ensure appropriate repair materials and techniques are used.

1. INTRODUCTION

There is currently very little scientific basis behind the methods used for repairing earthen structures, with factors, such as availability of materials and traditional building techniques, usually taking precedence. It is particularly rare for analytical investigations to be undertaken on repair and historic materials, and subsequently there is at present no standardized protocol to follow in order to understand whether a soil (adobe, rammed earth, etc.) will behave sacrificially when inserted in the historic fabric. Failure to consider this vital aspect of conservation work is in direct contradiction to the guidelines set out by the ICOMOS Charters, used to guide the selection and detailing of repair work. This work addresses this issue at a fundamental level by undertaking such an investigation on the material used to repair a historic cob earthen building in England.

Cob is a material consisting of unbaked soil, mixed to quite a wet consistency and placed directly onto the wall. Walls are built without the use of shuttering and, as such, rely on self-consolidation for strength. Following their construction, cob walls consolidate through drying and by virtue of their own weight (Ashurst and Ashurst, 1988). As the material dries the necessary cohesion to produce a hard, strong, monolithic body is achieved. Their strength is, therefore, dependent on the proportion of materials used, the thorough mixing of those materials, and the compaction of the mix through treading.

For the purposes of conservation, comparative analytical studies require work to be carried out on both new and historic material, with an approach to testing that encompasses investigation into the interaction of these materials. Furthermore, any intervention and associated technical specification must take account of the principles that guide conservation work, and that consider important factors, such as reversibility of the work and authenticity of the historic structure in question, as described in the Nara Charter (1994). Realistically, the concept of reversibility is not often possible, and so the principles of compatibility and retreatability are referred to and sought for (Van Balen, Papayianni, Van Hees, Binda, and Waldum, 2005), where compatibility requires that the intervention will have no negative consequences on the historic fabric, and for retreatability, that the present intervention will in no way hinder any future required intervention. In considering compatibility in this way, the concept of sacrificiality of repair is implied, in that when the historic and repair fabric are put under duress by exposure to environmental and other factors, the repair material is required to promote and preserve the historic fabric, and so in itself be subject to greater amounts of decay and damage.

It is this explicit sacrificial relationship that this work looks to analytically appraise, with a view to developing a methodology for the work. One such suggested methodology has been developed for repair mortars by Schueremans, Cizer, Janssens, Serre, and Van Balen (2011), which looks to overcome the disparity between specified and applied repair work that comes as a result of the many stages through which conservation work passes before completion. Here the clear process from authenticity to conceptual requirements and, finally, functional and technical requirements are addressed in an attempt to develop a methodology for satisfying and achieving the compatibility criteria above, defined and based on the original and repair mortars. It is this type of methodology, now relatively established in other fields of conservation that this work seeks to promote for the field of earthen heritage.

2. THE CASE STUDY OF HADDENHAM METHODIST CHURCH

2.1 Architectural history, building form and materials

The village of Haddenham, in which the Methodist Church is situated, presents the highest concentration of wychert buildings in the country, containing over 100 surviving examples. The material has been used throughout the village, for a range of structures from humble dwellings and boundary walls, to manor houses, villas and chapels (Pevsner and Williamson, 1994), with the Grade II listed Methodist Church (1822) being one of the tallest. The church is regarded as "an entirely standard composition (three bays, two storeys, arched windows, and a big pediment across)..." (Pevsner and Williamson, 1994). A stone facing with brick quoins up to internal balcony height articulates the façade wall, after which the wychert construction is used to produce the upper wall with its three arched windows, and finally the pediment up to the roofline. The remaining flank walls are made entirely of wychert, apart from a stone plinth used for approximately the first 3 feet above the ground. The church stands at over 7.6 m in height (McCann, 1983), and the outer flank walls are almost entirely unsupported laterally. As such, spreading from the roof and any other horizontal loading would have to be withstood by the walls in bending. The loads are likely to be substantial due to the span of the roof, showing how impressive wychert is as a building material.

The first important characteristic of wychert is that the material is predominantly clay and has high chalk content (Ashurst and Ashurst, 1988; McCann, 1983). One fact repeatedly mentioned in the literature is the very high inherent strength that wychert naturally exhibits, being held in very high regard and raised in un-shuttered lifts without requiring much strengthening and improvement (Keefe, 2005). The material is said to be particularly strong and durable if kept dry, and once dug from the ground, only fiber and water would need to be added (Pearson, 1992).

2.2 History of conservation

The history of the conservation of the Methodist church is quite complex and so, in order to give a clearer overview, is divided into three phases.

2.2.1 Phase 1: 1822 – 2003

Following its construction in 1822, the first serious recorded process of repair to the church was prior to 2003, when the internal plaster was replaced in places with cementitious materials. Furthermore, fluid-irrigation treatment against dry rot was also carried out, and this contributed to the collapse of the southwest flank wall. What had been viewed, as simply failing render was in reality a symptom of a far greater problem existing within the wall, that of excess moisture and its related effects. Removal of the internal plasters during building works disturbed the sensitive equilibrium of the wall in its dilapidated state, ultimately bringing about collapse (Oxley, 2003).

2.2.2 Phase 2: 2003 – 2008

The University of Bath became involved with this conservation work in 2007. By that time, the building had undergone a significant transformation. The collapsed wall had been rebuilt using adobes, and the whole building (apart from the façade wall) had been rendered with a mud-scratch coat and a lime based skim coat. The use of these natural breathable materials would suggest that the problems highlighted earlier had been overcome; however, the render continued to fall away from the walls. The red bricks have the advantage of being easily distinguishable as new, satisfying the requirement of readability of conservation intervention (ICOMOS, 1964), but it is felt here that a more adequate repair material could have been selected, especially considering the highly concentrated use of wychert, in England.

2.2.3 Phase 3: 2009 Onwards

The final portion of conservation work was undertaken during April and May of 2009 when a pair of trial render patches were applied to the southwest flank in an attempt to find a more suitable render mix for the building. This period of inspection highlights several possible programs of analysis

Fig.1 Haddenham Methodist Church (credits: Victoria Stephenson, 2003)

applicable to the building. Firstly, the causes of failure of the render could be inspected, looking at both material compatibility and quality of construction, to determine which is the dominant factor. Secondly (and that on which this particular investigation focuses), is the repair of the original wychert-cob wall with a cob blocks, using material sourced outside of the sphere of wychert construction. Here it needs to be determined whether this seemingly incompatible material and construction method could be classified as a successful intervention in a historic structure. Additionally, through analysis of the material, it could be possible to specify suitable earthen materials based on behavioral characteristics; the feasibility of which will be assessed following this analysis.

3. TESTING PROGRAM AND RESULTS

The section provides detailed methodology information for the suite of tests carried out, the design of which was referenced to British Standard publications, but also to the work of Walker and Standards Australia (2003), Houben and Guillaud (1994), Teutonico (1988), and Fodde (2007), and is split into characterization and performance testing.

3.1 Sampling and materials

3.1.1 Historic Wychert samples (HW)

The wychert material received by the laboratory was taken from the portion of collapsed wall that had been repaired with cob blocks, and so had been piled in a near-by agricultural field. As such, the material contained a substantial amount of organic and insect contamination. A representative sample was taken from the core of the heap. Upon arrival at the laboratory, the material was sifted by hand and the contaminants removed. The material was also of very high moisture content and so, it was partially dried to prepare it for testing.

3.1.2 Repair earthen cob-block samples (rcb)

The laboratory received one repair cob block of dimensions 450 mm long x 215 mm wide x 100-mm deep. The block appeared to have been manufactured using the extrusion method, and was very dense and solid in appearance. It also appeared to have a very high fiber content.

3.2 Characterization tests

3.2.1 Mineralogy and color

A full mineralogical investigation of the samples was beyond the scope of this investigation; however, from geographical and geological information, along with some visual analysis of the samples, it is possible to give a very basic interpretation of the mineralogical origin of the material. Kimmeridge Clay, Portland Limestone and Chalk are the most likely geological sources of the material. The origin of manufacture of the repair cob block is unknown and so, color is the strongest indication of the mineralogical origin available to this investigation. Visual analysis of the linear-shrinkage samples was carried out in accordance with BS 5930:1990, Code of Practice for Site Investigations, Table 13. Firstly a hue was identified, followed by a description of the chroma of the hue, and finally, identification of the lightness of the color.

Color testing does not give an indication of physical sacrificiality of the material; however, testing was necessary to identify whether the ICOMOS principle of readability of conservation interventions was satisfied. In this case, the readability is also addressed by the instantly recognizable use of pre-dried cob blocks within monolithic cob. In summary the RCB material does satisfy the requirements, although it is this authors' opinion that a more suitable local wychert source could have been found.

3.2.2 Granulommetry analysis through sieving and hydrometer sedimentation

Gravel particles are those greater than 2 mm, sand particles from 2 mm to 60 µm, silt from 60 µm to 2 µm, and clay less than 2 µm (BS 5930:1990). The tests were carried out in accordance with BS 1377-2: 1990 Clause 9 (Methods of Test for Soils for Civil Engineering Purposes. Part 2: Classification Tests). As for sedimentation analysis, it was carried out in accordance with BS 1377-2: 1990, Clause 9.5, on material passing the 75-µm sieve.

The particle-size distribution graphs show correlation between the RCB and HW samples, and also a generally high quality of grading of the samples, without gap grading occurring. Closer inspection of the materials does, however, reduce the initially assumed compatibility of the RCB and HW, as the cob block has a clay fraction over double that of the wychert, and a combined-fines proportion of nearly 10% greater. The RCB material will, therefore, be more durable than the HW, which is unsuitable for a repair intervention, as it provides no protection for the historic fabric. The RCB material will not, therefore, act sacrificially towards the HW, making it unsuitable for use.

3.2.3 Plasticity analysis

The measurement of soils plasticity categorizes its behavior in relation to its moisture content. Measurement of the Plastic and Liquid Limit was carried out using the Atterberg Limit tests as described in BS 1377-2: 1990, Clauses 4 and 5, using the portion of the soil finer than 425 µm. The RCB and HW samples have both been classified as of intermediate plasticity by the British Standards. Alternative analysis can be found in Clifton and Wencil-Brown (1978), where the relationship between plasticity index and expansion potential is quantified. The data, taken from Seed, Woodward, & Lundgren (1962), is used for particles smaller than 2 µm, but can be used to quantify the maximum potential for expansion, accounting for the reduction in that value due to the presence of less-expansive silts and sands. From it, the expansion of the HW will be up to 4.5 %, whereas the RCB will expand up to approximately 12 %. The high clay fraction of the RCB means this value is likely to be quite accurate. In this respect, the higher expansion of the RCB

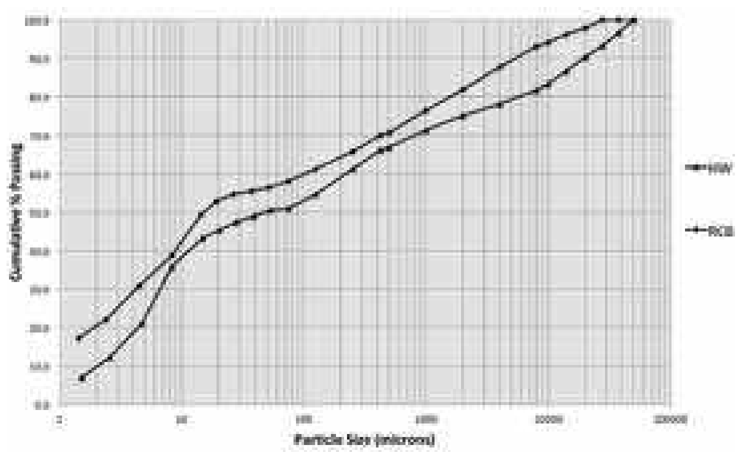

Fig.2 Granulommetry analysis of repair and historic earthen material

makes it unsuitable for use next to the HW, where it is possible it may induce stresses in the HW due to the RCB expansion in the wall; this is not sacrificial behavior. In summary, the RCB does not have behave sacrificially when assessed for plasticity and so, does not prove a suitable material for intervention in this case.

3.2.4 Chemical testing and soluble-salts analysis

a) pH analysis

Each of the samples tested were found to be alkaline in nature, indicating they contained no or very little organic material. Clifton and Wencil-Brown (1978) suggest that for compatibility of repair and historic fabric, the pH value of a repair material should be within +/- 2 pH units of the original, an indication of a difference of a factor of 100 in the concentration of hydrogen ions. The values of pH for the RCB (7.56 pH) and HW (8.39 pH) material satisfy this criterion and so, the RCB material is found to be compatible. Preservation treatments can drastically alter the pH values of soils, however, which limits the validity of the isolated test carried out in the laboratory, a factor that should be accounted for. In general, the RCB sample was found to be compatible with the HW, and thus is more likely to act sacrificially, although a rolling program of in-situ testing at Haddenham would strengthen this argument.

b) Carbonates analysis

The presence of salts in earthen-building material is generally the product of efflorescence, a deterioration mechanism common to many forms of masonry, stone and earthen construction. Most of these salts are soluble in water, with the exception of calcium carbonate, a normal constituent of calcareous stones (Teutonico, 1988). The tests carried out at the University of Bath have been adapted from Experiment 16 of the Teutonico Laboratory Manual, and determine the presence of carbonates in soil. The analysis is only qualitative, but they can give an indication of the nature and extent of deterioration potential in a soil.

Carbonates act in two different ways when present in a soil:

firstly, as a cementing agent when present in clay material of <2 µm, and secondly, as an aggregate when present in sand and gravel. In this test material classified as sand, silt and clay was tested, meaning that some discrepancies in the results can be identified. A significant difference between the carbonate content of the RCB and HW samples was found, with the repair material having no perceptible amount, and the historic containing a significant quantity. The RCB contained far less carbonates than the HW, and the very high concentration observed in the HW sample can be partly attributed to the presence of chalk in the material. Again, there will be a net migration of carbonates from the HW to the RCB until equilibrium is achieved, which will prolong the life of the historic material by reducing the salts content of it. This test indicated that the RCB will behave sacrificially, and the fact that the soluble salts and carbonate results agree supports this hypothesis.

c) Soluble-salts analysis

Analysis of soluble salts is a widely recognized component of testing for decay in traditional building materials, such as earth and fired-brick masonry. The method used here follows the test detailed in Clifton and Wencil-Brown (1978). The accuracy of this test relies on two criteria: firstly, that the moisture content of the dry sample is consistent at all times during weighing, and secondly, that the filtering system used prevents the loss of clay particles into the water containing the dissolved salts.

The soluble-salts content of the RCB sample at 0.88% is lower than that of the HW 2.42%, suggesting that when in place in the wall, migration of salts would be in the direction of the RCB. In this respect, the salts will accumulate in the RCB and this is the material likely to decay quicker through salts attack. However, the sample does not meet the criteria put forward by Garrison (1990) that repair material should contain less than 0.1 % soluble salts. The RCB material has been shown to behave sacrificially towards the HW, although a lower percentage of soluble salts would be desirable.

3.3 Performance tests

3.3.1 Erosion testing

Erosion rates in earthen architecture are used as a parameter for determining the durability performance of the structure. In earthen conservation, this behavioral characteristic is useful in determining the sacrificiality of repair material, and can be achieved through comparison of repair and historic material-erosion rates. The most comprehensive test methodology available for earthen-erosion resistance is set out in the Accelerated Erosion Test covered by the Australian Earth Building Handbook. The test uses a water-spray erosion system and "performance, in terms of erosion rate (mm/hour), is determined on the basis of pitting depth or time taken to completely penetrate the sample" (Walker and Standards Australia, 2003).

The HW samples performed better in the accelerated-erosion test, with an erosion rate of 16 mm/hour compared to the RCB erosion rate of 21 mm/hour. This indicates that the RCB material will erode faster over time, supporting preservation of the HW. These results are, however, contradicted by the fact that more weight was lost during the test in all of the HW samples, suggesting greater amounts of erosion in the wychert, which is unacceptable for conservation interventions.

3.3.2 Freeze-thaw testing

The freeze-thaw cycles carried out in this testing framework have not been designed using any previous testing methodologies; rather, they are the product of material, timetabling and equipment constraints. Reference was made to the testing carried out at Krasnaya Rechka (Fodde, 2007), and the method of wetting used here is similar, although the availability of material at that site was far in excess of that available in this case study, and the scope of the testing carried out reflects this. Furthermore, tests carried out at Krasnaya Rechka analyzed wetting and drying cycles, and freeze-thaw cycles independently. It was not possible to carry out this type of testing here due to a shortage of material, although it is advised that wherever appropriate, the tests should be separated.

In the cycles, the HW samples performed consistently worse, losing on average 2.7% more material over the course of the test. However, at Haddenham the application of a render will protect both the RCB and HW from much of the environmental conditions, so long as the render is successful. The limited availability of material determined that these tests would primarily act as preliminary work, but even here, contradiction is observed. When considering weight loss, the tests concur that the RCB would not behave sacrificially towards the HW.

3.3.3 Compression testing

Tests were carried out on a series of cubes to give an indication of the compressive strength. The pre-manufactured nature of the RCB on arrival at the laboratory meant that it was more appropriate to test cubes of the material, as opposed to cylinders, is now the accepted standard test in Britain. To ensure continuity of testing, cubes were also manufactured out of the HW sample. The test does comply with BS1881-116: 1983 (Method for Determination of Compressive Strength of Concrete Cubes), although this document has been superseded by the relevant cylindrical-compression test.

When analyzing the peak strengths of the RCB and HW material, the HW is consistently stronger, suggesting that the RCB would behave sacrificially to protect the historic fabric. However, the profiles of the compression tests suggest that the HW cubes demonstrated brittle failure at the peak load, whereas the RCB cubes behaved in a far more ductile manner. Ductility is always preferred in engineering situations, to prevent sudden and catastrophic collapse of structures. The lack of fiber in the HW cubes is, undoubtedly, significantly responsible for their brittle nature, as fibers will act to reinforce a soil mix by providing links between the soil particles that are capable of withstanding tension. Other influencing factors include the particle-size distribution of the mixes and the age of the blocks. Furthermore, the reality of the case study is that pre-dried cob blocks constructed with a mortar material will structurally behave very differently to monolithic cob. In this respect the compression testing carried out in this investigation can yield only indicative results. Preliminary results show that the RCB material is weaker than the HW, which suggests it would behave sacrificially, however the brittle nature of the HW is a cause for concern and overrides the trends in peak values. The scope for further more detailed testing is extensive within this area.

3.3.4 Shrinkage testing

Linear shrinkage and the measurement of shrinkage during manufacture using DEMEC studs were both undertaken. DEMEC measurements are regularly taken of relative movement over short gauge lengths of cracks in structures (Clayton, Simons, and Matthews, 1982). Studs are placed either side of a crack using a standard length bar and glued into place using epoxy resin. Once the glue is dry, the two points of the DEMEC gauge are placed on a standard Invar bar and a zero reading taken. The points are then placed in the studs and a reading recorded. This procedure is repeated over a period of time, and the relative movement of the studs calculated.

It is desirable that a repair material expands no more than the historic fabric, when exposed to the same moisture-content increase, as this would induce excess stresses on the historic fabric and cause considerable further damage. This is somewhat overcome by the pre-drying of the cob blocks, although the effects of water ingress post-construction will highlight this incompatibility. The linear shrinkage tests demonstrate the repair material shrunk by 3% more than the historic fabric. The higher level of shrinkage in the RCB could lead to failure of the repaired wall along the interface between the cob blocks and wychert cob, subsequently damaging the historic fabric of the building. If this were the case then the intervention of the cob block repair would be inadequate in satisfying the principles of conservation. However in general greater levels of shrinkage would be desirable in a repair material, as this is the material more susceptible to cracking. In this respect the RCB behaves sacrificially.

4. CONCLUSIONS

4.1 Assessment of the feasibility study

The structure of this testing framework has been designed in such a way that the requirements of a repair material and its relationship with the historic fabric can be addressed logically and systematically, in the hope that specification of the repair material can be clearly obtained. The tests were carried out using well-established procedures, and these can be easily referenced and repeated by other technicians. It has been shown that laboratory analysis of earthen materials can yield clear results suitable for compatibility analysis, and subsequently, a judgment over the susceptibility of one material to suffer and deteriorate because of its proximity to another can be made. The analysis has also shown that while one parameter or test may determine a repair material to be unsuitable for use, another test may contradict this. This highlights the complex nature of earthen building materials and shows that for clear evaluation over suitability to be made, specific conditions for each case study must be taken into account.

In order for this testing to move forward and become the framework for a methodology, clear testing parameters would need to be stipulated prior to testing, ideally in order of priority. A checklist of tests and behavioral characteristics could then be clearly set out, and the suitability of a material investigated in a logical and progressive manner. Results should be displayed in a technical format so that third parties can easily access the data and findings. Further work might possibly combine the test results to produce one qualitative parameter that defines suitability.

4.2 Scope for further work

This testing framework was carried out in a university laboratory, in a civil engineering department. This obviously puts constraints on the scope of tests that could be carried out, with the most important shortcoming of the tests being a lack of detailed mineralogical and chemical analysis of the samples, which is so important to understanding the behavior of earthen building materials. The first step for any further work would be to repeat the above procedures to validate the results, through the selection of different case studies with different parameters, such as geographical location or construction method. Notable areas where further work could be carried out is in the detailed analysis of organic material using thermal analysis and polarized light, the investigation of porosity and permeability using quantitative stereometry, and mineralogical analysis using X-Ray Diffraction (Houben and Guillaud, 1994). Such analysis was unavailable to this testing framework, but would form core components of any methodology to assess suitability and sacrificiality, by looking closer at micro-composition.

It was highlighted that homogeneity between constructional forms used together in the same building cannot be assumed in earthen construction, and there is further work to do here. The study of how and why conservation fabric changes over time brings a new dimension to investigation in this discipline. The development of prediction criteria for material behavior, in order to act preemptively to preserve historic fabric, would present a more complex level of methodology-protocol work.

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TECHNOLOGICAL INNOVATION FOR SEISMIC-RESISTANT HOUSING OF REINFORCED ADOBE WITH TRUSS BEAMS OF GALVANIZED STEEL

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Theme 6: Research in Materials and Technology for Conservation and Contemporary Architecture
Keywords: Integral masonry, seismic-resistant, reinforced adobe

Abstract

This paper describes the advantages of the Integral Masonry System (IMS) for adobe houses, which consists in the use of an earthen filling in a lattice of pre-welded or properly bonded frame, which transmits exertion between each other to sustain the walls. The prefabricated frame consists of bars of galvanized steel, which are organized in the form of trusses of 24-cm to 30-cm wide and 6-m long. These intersect in three spatial directions, thereby achieving a frame that forms the skeleton of walls and ceilings, as the trusses are very light and easy to install by hand. Subsequently, the gaps are filled in with adobe, rammed earth, or other materials, including recycled materials, to build the walls. These can also incorporate planks on the horizontal-lattice trusses to form the floors.

After an earthquake, re-plastering is recommended due to the cracks that occur in the direction of the frame, as was demonstrated in the prototype test of a ½-scale study in 2008, in the seismic-simulation table at the Structural Laboratory of the Pontifical Catholic University of Peru. Four movements were carried out (20 mm, 50 mm, 80 mm and 130 mm), which coincided with ground displacement according to the degree of earthquake of 2, 5, 8, and more than 10, respectively, on the Richter scale. The end result was a stable structure that withstood these movements. As has been demonstrated, the construction process is simple, the building is resistant to earthquakes, and the reconstruction process can reduce time and costs once the disaster has occurred.

1. INTRODUCTION

During the 2005 Sismo Adobe Congress held in Lima, self-construction of adobe housing in seismic prone areas was proposed, with a new type of pre-welded truss-like frame. Also, in 2007 at the International Symposium on Earthen Structures (ISES-2007) held in Bangalore, India, the paper "The Integral Masonry System with earth-based materials: rubble based earthquake resistant construction" was presented. Being an unconventional system, its effectiveness needed to be experimentally proven, and following this, a research project was planned.

The 2007 earthquake in Pisco, Peru highlighted the need to implement an earthquake-resistant alternative building system, allowing for the reconstruction of collapsed or damaged houses in such a manner as to be secure from any other possible occurrence. Following the earthquake, actions were initiated to develop a research project, in a joint effort between the Universidad Politécnica de Madrid (UPM) and the Civil Engineering Section of the Department of Engineering at the Pontifical Catholic University of Peru (PUCP).

2. BACKGROUND

Earthen building has led to construction systems of mixed walls in which the wooden, cane or concrete-reinforcement structure is responsible for the flexible framework, acting thus complementing and strengthening the earthen materials against forces it would not otherwise withstand. Aiming at solving the problem of resistance to seismic activity, reinforcement techniques have been put forward in Peru, which can be divided into two:

- Improving quincha trusses (studies at the National University of Engineering of Lima on the resistance of quincha panels under earthquake action);
- Strengthening of adobe walls by applying a geogrid. Based on the seismic-simulation tests conducted in PUCP, geogrid behavior resembles that of an elastic material, resulting from the influence of the grid on the adobe.

Naturally, the recommendations issued for decades are also reiterated: a suitable foundation, confinement of masonry, and walls in both directions of the plan, with particular attention drawn to the building of closure elements. Coincidentally, the greatest loss of life was caused by the collapse of façades in the earthquake of May 1970.

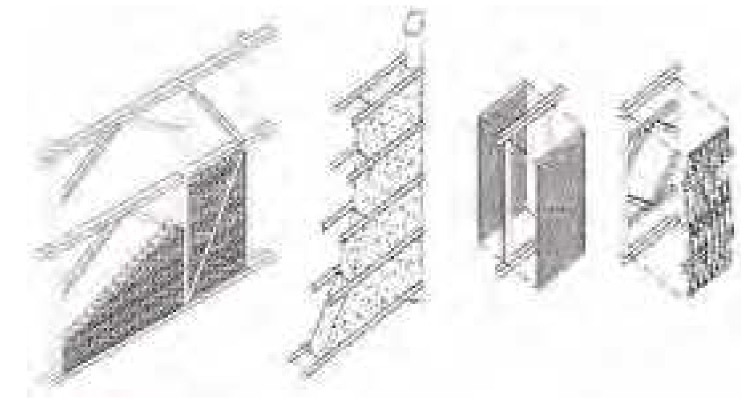

Fig.1 Types of timber and cane frames (credits: Monjo, 1998)

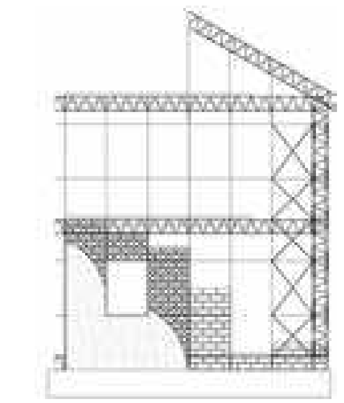

Fig.2 IMS with galvanized-steel trusses (credits: Adell et al., 2007)

This research intends to cover the vulnerabilities registered with earthen construction, i.e. reinforced adobe with galvanized steel. The traditional wooden lattices are filled with gypsum rubbles, bricks, or cane mixed with clay. Construction systems based on ceilings, joists and studs are replaced with steel trusses.

3. AIMS

The main and immediate aim of the project was to experimentally verify the seismic behavior of adobe houses as an alternative for individual or massive programs of housing construction. The concept was for adobe houses to be both economically viable and able to ensure structural safety during the occurrence of an earthquake. In addition, if successful, the intention is to apply it to other building types (schools, workshops, etc.).

4. SELECTION OF A PROTOTYPE

From the six housing types reviewed in 2005, Type 5, a two story-high structure with 3 bedrooms and 72 m^2 built area (58 m^2 of usable area) was selected. Its cubic volume of 6 m/side is perfectly conform to the possibilities of the 4.40 m/side square seismic-testing table at the Seismic-Resistant Structures Laboratory of PUCP, which allows testing of the whole house, although built to half scale.

5. THE BUILDING SYSTEM

The reinforcing technology applied consists of a prefabricated truss-shaped braided formwork, with longitudinal and transverse wires welded together and a galvanized coating preventing their corrosion. The connection between these prefabricated 6-m long trusses is accomplished by hand using specifically designed screws, welding or tie wires. Together with the lightness of these wire-frame structures (about 3 kg for a 6-m truss), this allows for easy self-construction of a simple earthquake-resistant structure for walls, ceilings and roofs.

The novelty of this construction system is that the exertion between the frames is not conveyed through a collaboration of with concrete, since none is present. Nor is it due to the adobe, which contributes little. Instead it is the connections that enable cohesion between all of the horizontal and vertical trusses of the building, the latter in-filled with adobe. In terms of seismic action, the calculations performed for, the implementation of this new technology offers a very promising theoretical result, as each of the metal elements were previously tested separately in Europe.

6. REINFORCED ADOBE

The characteristics of the materials used for the reinforced adobe construction system are:

- Adobe compressive strength: 0.3 to 0.5 MPa
- Adobe weight: 18 kN/m^3
- Steel: B-500-S, fs = 500/1.15/1.54=282 N/mm^2
- Steel weight: 78 kN/m^3

The dimensions selected were as follows:

- Frame of the test model (3 m x 3 m x 3 m): Two longitudinal wires of 5 mm to each side of a zigzag wire truss of 5 mm, 150 mm apart. The arrangement of the wall and ceiling frames were configured with a vertical and horizontal module of 45 cm/side. The adobe-wall prototype tested was 15 cm of section
- Frame of a building of 6 m x 6 m x 6 m: Two longitudinal wires 10 mm to each side of a zigzag wire truss with two wires of 5 mm, 300 mm apart. The adobe wall tested was 30 cm of section.

The arrangement of wall and floor frames of a 45-cm prototype corresponds to a module of 90 cm in reality. It is module that allows for openings for doors and windows, as well as stairs in a habitable building.

Fig.3 The unreinforced corner had no major complications. Note that the rack truss, which functions as the ceiling joists, also functions as a perimeter beam (credits: Adell, 2008)

Fig.4 Prototype before Phase 1 testing (credits: Adell, 2008)

7. EXPERIMENT PLAN

The model under experiment consisted of a module at half scale, depicting a two-story adobe house with a square plan of 2.70 m/side and a height of 2.70 m, both nominal dimensions. Steel beams of 8" x 8" formed the base, which acted as the foundation of the module. The beams were welded to create a square frame of 3 m/side (external dimension). Gussets were added, not only to give rigidity to the element, but also to be the accessories required for the transfer and attachment to the earthquake simulator platform.

For practical reasons, erection of a corner (two vertical L racks) was first accomplished, and then the horizontally middle rack was connected to it. Subsequently, the other two vertical racks were placed, ending with the top horizontal rack. During assembly, cuts and folds necessary at the ends of the trusses were performed to generate connection and welding points, responsible for maintaining the stability of the structure.

As a solution, four rows of adobe were erected with a standard horizontal joint of 15 mm, plus a fifth row with lower height adobes, which were cut with manual tools from slightly larger units (leftovers from other projects). The adobe units used presented nominal dimensions of 28 cm x 15 cm x 8 cm ("whole") and 14 cm x 15 cm x 8 cm ("halves"). Both dimensions were needed to enclose the walls. 810 adobes and 690 halves of adobes were manufactured. The mixture used was a combination of soil, sand and straw (grass) in a 5:1:1 proportion by volume. The soil was clay of low plasticity typically known as tierra de chacra.

Furthermore, a 10-mm hollow geogrid attached with raffia ties on two sides of the prototype coincided with the frames. This was done to show whether or not a plaster or earthen finish of 20-mm thick could avoid cracking during the dynamic test of the walls (MD and MA), one longitudinal and another crossing the movement simulator. This masonry prototype was completed one month before the date of the trial to ensure that the earth would be dry before the test on the simulator.

The module was weighed before the walls were plastered, to ensure that the load limit of the simulation table was not exceeded. A value of 86.86 kN was obtained, allowing for sufficient margin to add the finish (after drying, the weight was registered 94.71 kN), as well as the placing of the additional overload. Fig.4 illustrates the characteristics of the finished prototype. The total weight, including overload, was 102.35 kN.

8. SEISMIC EXPERIMENT

8.1 Description of the experiment

The standard command signal (register shift that defines the simulator platform's motion) of the laboratory comes from the longitudinal component (N8°O) of the acceleration measured in Lima during the earthquake of Ancash on May 31, 1970. The original record, obtained from an analog accelerometer, was given by the United States Geological Survey (USGS) to obtain a corrected digital acceleration, which served as the basis for generating the command signal named "mayo70". For this experiment, because it uses a half-scale model, a compressed version of "mayo70" time was used, in order to modify the content of the predominant frequencies of the signal, in accordance with the variation of the structure's fundamental frequencies, as a result of its scale.

Compression was the method used to overcome the original signal at 133.3 points/second by 100 points/second in the modified signal, according to the physical half-scale factor of the prototype. As a result of this operation, for a given movement, the compressed signal ("mayo70co") produced higher accelerations than the original signal. The movement and acceleration on the uncharged platform of the simulator, when "mayo70co" was activated, was also foreseen.

The dynamic experiment consisted of a sequence of movements (phases) of increasing amplitude, but with the same command signal. Also, the absolute maximum movement reached defined each phase. Initially, the execution of three phases were planned, each one associated with an increase of intensity of what would be a frequent (slight), occasional (moderate), and rare (severe) earthquake. In the case of "mayo70co", these movements corresponded to a maximum displacement of 20 mm, 50 mm and 80 mm, respectively. The expected accelerations on the base of the module from those movements were 0.3 g, 0.7 g and 1.1 g, approximately.

Assuming that the prototype remained in good condition after the execution of the three stages mentioned, a fourth phase was performed repeating the simulation of a severe earthquake (a maximum movement of 80 mm). However, during the test performance for fourth phase, the original command signal of "mayo70" was used with a breath of 130 mm (the maximum capacity of the simulator). The intermediate horizontal rack was not functioning as a mezzanine, by which the structure would behave if it were a full-scale model, hence it was desirable to refer to a signal containing the appropriate frequency for such a model, "mayo70". Table 1 depicts a summary of all movements made to the test module.

8.2 Testing equipment

Eight accelerometers and ten movement transducers (LVDT) were used to measure the movement and the damage to the walls. In addition, movement and acceleration of the simulator platform were recorded, as well as the pressure (Fa) transducer, which allowed calculation of the shear force induced by the equipment onto the steel-module base set.

9. RESULTS

The prototype exhibited a behavior that can be characterized as earthquake-resistant insofar as it bore all the movements without the structure collapsing. There was neither any local collapse (loose adobes in the corners did not fall out), nor was there any major structural damage. The worst effect was on the MP wall trusses delimiting the door and window openings of the first level, which suffered out-of-plane deformations. The cracks on the walls, as indicated below, related mainly to the separation of adobes from the trusses that contained them.

After each stage, the presence of cracks on each of the walls of the prototype and the appearance of any damage in the structure was noted as follows:

MOVEMENT	SIGNAL	BREATH (mm)
Initial free vibration	ondarec	1.5
Phase 1	mayo70co	20
Free vibration post-Phase 1	ondarec	1.5
Phase 2	mayo70co	50
Free vibration post-Phase 2	ondarec	1.5
Phase 3	mayo70co	80
Free vibration post-Phase 3	ondarec	1.5
Phase 4	mayo70	130

Table 1. Movements of the seismic-simulation experiment (credits: PUCP Seismic Resistant Structures Laboratory, 2008)

- Post-Phase 1: Very small damage was observed only on MP and MD walls, which could almost be confused with those produced by the shrinkage of adobe when drying.
- Post-Phase 2: MI and MD walls presented vertical cracks in the corners, and horizontal cracks between adobe fabric and trusses. The same was observed on the MP wall, but only at the first level. The MA wall did not present any cracks.
- Post-Phase 3: On the MI and MD walls, in addition to the cracks between adobes and trusses, which had increased, there was also some damage inside the enclosure throughout the mortar and adobe. In the MP wall, the existing cracks were aggravated and new cracks were visible on the second level. The MA wall showed the first wall cracks, both horizontal and vertical, corresponding to the adobe/truss adhesion surfaces. The vertical truss that delimited the door opening on the MP wall suffered slight out-of-plane deformation.
- Post-Phase 4: This was the last phase. The two trusses delimiting the doorway on the MP wall are deformed, as well as the one at the window opening of the first level. The elevations illustrate the location of cracks following the fourth phase (130mm). Notwithstanding, the prototype remained standing.

10. CONCLUSIONS

In this research, the prototype model proved to have seismic-resistant behavior against the dynamics of the earthquake simulator. Not only was collapse averted in the final state of the model, but also in the case of a real house, only a modest repair would be necessary to re-endow the structure with adequate strength. In addition, the construction system was easy to implement as demonstrated by the erection of the model, in which the workers executed the procedure without major difficulty, thereby also providing the possibility of self-reliant and rapid construction after a disaster occurs.

However, the production of adobe pieces compatible with the structure was required, along with partial reinforcement with geogrid mesh. In any case, the total surface assembly can prevent cracks from occurring, provided that a true bond is created between the dissimilar materials, earth and steel. This constitutes, therefore, a future line of research. Finally, the construction system resembles the building tradition of half-timbering, which also provides a basis of repair for the architectural heritage of adobe.

Fig.5 Detachments and cracks of the geogrid-reinforced plaster coating on the side perpendicular to the direction of the earthquake-movement simulation, after the fourth phase (displacement of 130 mm) (credits: Adell, 2008)

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HYGRO-THERMO-MECHANICAL PROPERTIES OF EARTHEN MATERIALS FOR CONSTRUCTION: A LITERATURE REVIEW

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Theme 6: Research in Materials and Technology for Conservation and Contemporary Architecture
Keywords: Earthen materials, hygro-thermal properties, mechanical properties, literature review

Abstract

Although earth has been used in construction for millennia and is still one of the most widely used building materials in the world, it is difficult to find reliable values of hygro-thermal and mechanical properties of earthen materials. Little scientific research has been conducted on this material compared to the huge amount of literature available for cementitious materials. Considering the literature on earthen materials, a majority of studies deal with cement stabilized earth for compressed-earth blocks or rammed earth. Less has been done about natural unstabilized earth.

The only existing comprehensive overview on the properties of earthen materials was authored by CRAterre-ENSAG and published 25 years ago. For the second time in its 30 years of existence, CRAterre-ENSAG has undertaken the task of re-actualizing this synthetic knowledge by writing a comprehensive review of the existing literature on the subject.

In the present work, we intend to compile the most reliable experimental data on hygro-thermal and mechanical properties of natural earth. We will inventory the performances determined by several research teams for rammed earth, compressed-earth blocks, adobe, cob and mortar. We will discuss the reliability of the experimental techniques used. We will provide an overview on the state of knowledge concerning the different properties, as well as on the lacking data. Finally, this literature review will also give some orientation for further scientific research.

1. INTRODUCTION

Building with earth requires that artisans have a very good knowledge of the material. Yet, there is limited scientific knowledge of the material. While builders develop their knowledge in the field through direct experience, engineering-consulting firms are hampered by a lack of reliable data regarding the properties of earth. Norms and standards are few, partial and often deal with compressed-earth blocks (CEB) stabilized with cement. However, there are many other reliable construction techniques involving earth that do not require the use of mineral stabilizers, as demonstrated through centuries-old examples such as the buildings, mosques and skyscrapers in the towns of Ghadames (Libya) and Shibam (Yemen), some sections of the Great Wall of China, the tulous – large residential complexes of the Hakka in China, or more locally, the many farms built with earth around the Rhône-Alpes region in France (Fontaine and Anger, 2009). These examples show that earth can be used for the construction of sustainable buildings.

This report is an update on the knowledge available on the hygrometric, mechanical, and thermal properties of earth. It deals mainly with the intrinsic properties of the material. This update is an opportunity make an inventory of knowledge and highlight the technical data gaps that could be usefully filled. Documents and information were gathered through CRAterre's Documentation Centre and scientific journals. Only results for which the materials and experimental protocols are described at least briefly have been included; this significantly reduced the number of documents that were used in this survey. In addition, we were interested in non-stabilized earth exclusively, which disqualified a great portion of the scientific data available.

2. DRY DENSITY

The dry density of soil is the ratio between its mass and its volume measured in the dry state, after oven drying at 105°C. This property depends on several parameters, dealing mainly with grain-size distribution, the volume and nature of the binding phase, the water content involved in the implementation of the earthen materials, and the energy involved in compaction of earthen materials compacted for building purposes.

Based on the values found through different documentary sources, we propose to distinguish between two families of techniques for the implementation of earth, leading to different properties of the earth material when dry: implementation by compaction (rammed-earth, CEBs) or plastic-state implementation (adobe, wattle and daub, cob). To these two families, a third category can be added, involving the addition of a high proportion of plant fibers (straw, hemp) into the earth mix, which leads to lighter materials. Table 1 gives typical ranges of variation of the clay content, plasticity index, initial water content, and dry density for these three families (Azeredo, 2005; CSTB, 2007; Bahar, 2004; Barras, 2010; Bui, 2008; Degirmenci, 2008; Goodhew et al., 2000; Goodhew and Griffiths, 2005, Heath et al., 2009, Kleespies, 1994, Laurent et al., 1984, Laurent, 1987; Mueller and Simon, 2002; Vega et al., 2011; Morel et al., 2003; Ola, 1987; Hakimi et al., 1996; Hall and Djerbib, 2004; Jaquin et al., 2009; Kouakou and Morel, 2009; Maniatidis, 2008; Olivier, 1994; P'kla et al., 2003).

Technique	Clay content (%)	Plasticity Index (%)	Initial water content (%)	Dry density (kg/m3)
Compaction	5 - 30	5 - 30	5 - 15	1600 - 2200
Plastic moulding	20 - 40	15 - 35	15 - 35	1200 - 2100
With added fibres				300 - 1200

Table 1. Typical values of dry density for earthen materials (credits: author)

3. HYGROMETRIC PROPERTIES

3.1 Water content

The water content of earth is a parameter of prime importance if we are interested in the mechanical and thermal properties of the material, so it is important to know the normal water-content range of earth in ambient humidity. The water content of soil at equilibrium is higher if relative humidity is high, ambient temperature is low, porosity is high, the accessible surface area of pores is important, the affinity of clay and water is high, the sample state results from de-wetting from a previous higher moisture state. Swelling clays are those that have the greatest affinity to water, due to their large surface area and high cation-exchange capacity.

In normal conditions of temperature and pressure, with a relative humidity below 70%, the water-content percentage in earth walls generally varies between 0.5 and 5%. It can be higher, especially in the presence of swelling clays and aggregates containing micropores and microroughness (Hall et al., 2009; Laurent, 1986; Hansen and Hansen, 2002; Heath et al., 2009; Maniatidis and Walker, 2008; Bourgès, 2003; Holl and Ziegert, 2002).

Eckermann et al. (2007) compared vapor-absorption measurements on various coatings. Although the measurements were not performed at the equilibrium-moisture content, they are helpful in making qualitative comparisons between the different samples tested. It appears that earth generally has a greater capacity to bind water vapor than concrete or gypsum. This water-retention capacity is linked to the porous and microporous structure of soil and to physico-chemical affinity between clay and water.

3.2 Shrinkage and swelling

During the drying phase, the soil undergoes a volumetric contraction or shrinkage, as a result of the withdrawal of water: clay platelets tighten due to the increase of capillary forces caused by the loss of water as suction increases. This shrinkage may in certain circumstances cause cracking, and so, it must be controlled. Conversely, when a dry soil is loaded with moisture, it expands as a result of the relaxation of capillary pressure and the swelling of clays having a high affinity for water.

The amplitude of shrinkage is limited if the water content used in the implementation of the material is low, the surface area and cation-exchange capacity of clays are small, the clay content is low, the porosity is high (the space between grains is not filled with a binding-clay phase), the soil contains vegetal fibers – the addition of straw is an effective way to prevent or limit shrinkage. The presence of salts in the soil can also alter the magnitude of shrinkage (Smith et al., 1985; Bourgès, 2003). The mechanisms involved are complex and dependent on the nature of the ions present.

The shrinkage of soil from its raw state to its implementation as a building material can vary between 1 to 20%. For rammed earth, the shrinkage percentage lies in the range of 1 to 3% (Robiquet, 1983; Gray anf Allbrook, 2002; Bourgès, 2003; Bouhicha et al., 2005; Smith et al., 1985; Heath et al., 2009; Walker and Stace, 1997; Bahar et al., 2004; Degirmenci, 2008; Hall et al., 2004; Kouakou and Morel, 2009; Maniatidis et al., 2007; P'kla et al., 2003; Vega et al., 2011).

3.3 Water-Vapor Permeability

The permeability to water vapor in a building material permits the definition of its moisture-exchange capacity between the inside and the outside of a building. The higher the permeability, the easier the exchange is between outdoor air and indoor air. It is, therefore, an important property to consider regarding comfort inside the house. For building materials, the factor of resistance to water vapor, μ, is used to characterize the permeability of a material to water vapor. It is equal to the ratio between the permeabilities of air and of the sample to water vapor. The higher the factor of resistance, the more difficult the moisture exchange between outdoor air and indoor air becomes.

For hygroscopic materials such as earth, which may fix a certain amount of air moisture, permeability increases with relative humidity. So the factor of resistance to water vapor, μ, decreases as the relative humidity increases. In theory, a single measurement of permeability is not sufficient to fully characterize the hygrometric behavior of earth.

For earth, μ varies between 5 and 13, and mainly depends on the pore-size distribution, the nature of clays and their content. Earth has a permeability to water vapor equivalent to that of cellular concrete, lightweight-aggregate concrete, gypsum and baked earth (Kleespies, 1994; CSTB, 2007; Utz, 2004; Bourgès, 2003; Hall et al., 2009; Volhard and Röhlen, 2009; NF EN 1745, 2002).

4. MECHANICAL PROPERTIES

4.1 Experimental precautions for the uniaxial-compressive test

The main mechanical property of earth that is of interest to builders is its uniaxial-compressive strength. To measure it, there are many available testing procedures, which do not, unfortunately, lead to the same results for the same types of materials. In most cases, experimental conditions influence the results and it is not the intrinsic compressive strength of the material that is being measured. Thus, these values cannot be used in a comparative manner.

The following precautions must be taken in order to properly measure the uniaxial-compressive strength of earth (Morel et al., 2007; P'kla, 2002; Walker, 2004; Olivier et al., 1997; Fontaine, 2004):

- Choose sample dimensions greater than five times the size of larger particles;
- Choose an aspect ratio between 1.5 and 2;
- obtain homogeneous samples;
- Let the samples stabilize in the desired hygro-thermal conditions;
- Coat the samples with a material as rigid as earth (a fine earthen mortar, for example) in order to obtain smooth and parallel surfaces;
- Use a ball joint above the top plate of the press if the surfaces are not perfectly parallel;
- Lubricate the contact between the sample and the press plates to reduce friction.

To measure the constitutive law and the elastic modulus of the specimens, care must be taken to measure the strain in the middle of the samples (using strain gauges for example) to avoid edge effects and the deformation caused by anti-friction systems (Mollion, 2009).

4.2 Elastic modulus

Young's modulus for earth is difficult to measure from a compression test. Its determination requires a sufficiently precise local strain measurement. It is, therefore, very difficult to find written sources with reliable values of the elastic modulus of earth. If surface roughness is imperfect, we can see a phase in which the curve increases progressively at the beginning of the testing, which corresponds to the crushing of surface ridges (Bui, 2008; Kouakou and Morel, 2009). This phase is not characteristic of the material and hides the elastic behavior of the original material.

To our knowledge, the only study that provides reliable measurements of the elastic modulus based on compression tests is that of Mollion who used measuring device adapted to strain measurement. Three strain gauges placed around the sample measure the deformation in the middle third of the specimen (Mollion, 2009). Other authors measure the elastic modulus using techniques based on the resonance frequencies of specimens (Fontaine, 2004) or the speed of ultrasound propagation (Bourgès, 2003). According to data from these studies, Young's modulus for raw earth is between 1 and 5.5 GPa. It gets higher depending on how low the porosity and moisture content are, and on how high the clay content and specific surface area are. However, the relationship between the composition of the earth, its microstructure and elastic modulus is not clearly established. The recommended modulus values vary but always lie below 1 GPa (Walker, 2001; Walker et al., 2005; NZS 4297, 1998; Maniatidis and Walker, 2003). This modulus lacks a clear definition: is the real Young's modulus of interest to builders, or do they just need an apparent modulus measured under certain conditions of stress?

4.3 Uniaxial-compressive strength

Standards often require testing protocols that do not measure the intrinsic strength of the material; the measure is partly influenced by the test devices. This is due in part to the fact that testing procedures for earthen materials are based on standard tests for cement concrete or fired-clay bricks whose mechanical properties are very different.

The most reliable results are listed. The compressive strength of earth viable for construction can vary between 0.4 and 5 MPa. For rammed-earth, the values are narrower from 0.5 to 3 MPa, the most common value being about 1.5 MPa (Azeredo, 2005; Barras, 2010; Bui, 2008; Bullen and Boyce, 1991; Fontaine, 2004; Hakimi et al., 1996; Jaquin et al., 2009; Kouakou and Morel, 2009; Maniatidis et al., 2007; Maniatidis and Walker, 2008; Mollion, 2009; Morel et al., 2003; Olivier, 1994; P'kla, 2002; P'kla et al., 2003).

The following parameters improve compressive strength: a high density, a low water content, a high clay and silt content, a high specific-surface area of the clays, good homogeneity, small grains. Based on the present state of knowledge, it is not possible to predict the compressive strength of a given soil without making experimental tests. Many parameters are involved in the mechanisms of cohesion of earth which determine its strength. The relationship between the microstructure of earth and its macroscopic-mechanical properties is very complex.

Property	Unit	Compacted earth	Molded earth	Fibred earth
Clay content	%	5 - 30	20 - 40	
Plasticity index PI	%	5 - 30	15 - 35	
Initial water content wini	%	5 - 15	15 - 35	
Dry density ρ	kg/m³	1600 - 2200 (1700 - 2200)	1200 - 2100 (1200 - 1700 for adobe)	300 - 1200 (600 - 800)
Ambient water content w	%	0 - 5%		
Drying shrinkage	%	1 - 3 (0.02 – 0.1 for CEBs, 0.1 - 0.2 for rammed earth)	1 - 20 (0.02 – 0.1 for adobe)	near 0
Water-vapor resistance factor μ		5 - 13		
Young Modulus E	GPa	1.0 - 5.5 (0.7 à 7.0 for cement stabilized earth)		< 1.0
Uniaxial-compressive strength Rc	MPa	0.4 - 3.0 (2.0)	0.4 - 5.0	
Tensile strength Rt	MPa	0.1 - 0.5 (0.5 - 1.0 for rammed earth and CEBs)		
Mass thermal capacity c	J/kg.K	600 - 1000 (~ 850)		
Volumetric-thermal capacity C	kJ/m³.K	960 - 2200	720 - 2100	180 - 1200
Thermal conductivity λ	W/m.K	0,5 - 1,7 (0,81 - 0,93)	0,3 - 1,5 (0,46 - 0,81)	0,1 - 0,3 (0,1 - 0,45)

Table 2. Mean values of earth thermal conductivity (credits: authors)

5. THERMAL PROPERTIES

5.1 Thermal Inertia

Inertia is the ability to store heat and release it slowly. It allows to shift variations in temperature inside the house from the outside, and to cushion temperature changes.

It depends primarily on the thermal mass of materials: the higher this capacity, the more the material may provide inertia to the building. Heat capacity, c, is expressed in J/kg.K. It is connected to the volumetric-heat capacity C in J/m³K by the relation C = c.ρ, where ρ is the mass density of earth. Earth's heat capacity, c, varies from 600 to 1000 J/kg.K with a mean value of 800 J/kg.K at 20°C (Laurent et al., 1984; Laurent, 1986; Goodhew et al., 2000; Goodhew and Allbrook, 2005; Hutcheon and Ball, 1949; Hill, 1993; Delgado and Guerrero, 2006; Wessling, 1974; Volhard, 2008; NF EN 1745, 2002).

For an earth-straw composite, x being the amount of straw, the heat capacity is:

$c = (1-x).c_{earth} + x.c_{straw}$

Similarly, the heat capacity of earth depends on its moisture content following a linear relationship, with θ being the volumetric-water content, and Cw = 4.186 J/m³ K:

$C(\theta) = C_{dry} + \theta.C_{w}$

In addition to the intrinsic-heat capacity of the material, the phase change of the water contained in the material contributes to thermal inertia: the evaporation of water causes cooling and the condensation causes warming. The energy exchanged is the latent heat of vaporization of water, which is of about 2400 kJ/kg (Kimura, 1988). This property specific to hygroscopic porous materials makes earth a natural phase-change material.

5.2 Thermal Conductivity

Thermal conductivity, λ, indicates the amount of heat (in W) that goes through an area of 1 sq meter/1-meter thickness when its interior and exterior faces differ in temperature by 1 Kelvin. It is expressed in W/m.K. The lower λ is, the more the material is insulating. Materials with λ < 0.065 W/m.K are considered insulating (Table 2).Earth is a porous unsaturated material. Heat transfer is related to several mechanisms: conduction in the solid, liquid and gas phases; convection; radiation; evaporation and condensation. To define conductivity in such a material is complex. Apparent conductivity is the value of conductivity reached by measure, which results from the combination of all the mechanisms mentioned above. The equivalent conductivity is the conductivity value of a homogeneous material equivalent to the considered material, which would have the same macroscopic-thermal behavior.

Conductivity increases with water content. For earth of about 1800 kg/m³ and suitable for rammed earth construction, it can vary from 1 to 1.2 W/m.K when the water content varies from 0 to 2%. For the same difference in moisture content, the change in conductivity can be more or less strong depending on the type of soil: not all earths have the same sensitivity to water. Earth by itself is not a good insulator, but when mixed with plant fibers and with a sufficient thickness, it can be used for the insulation of a building.

6. CONCLUSIONS

In conclusion from this overview, there is little reliable experimental data on the properties of raw earth for construction. This data is very fragmented as it often deals with one type of earth and focuses on only a few properties. The main properties of raw earth updated through this review are summarized in Table 3 for the three main types of earth implementation for construction: compacted earth, mold earth and earth with added fibres. The values given in the reference (Houben and Guillaud, 1989) are recalled in parentheses for comparison.

The thermal conductivity of dry earth depends primarily on its density and porosity. It varies between 1.5 W/m.K for dense earth (2200 kg/m³), and can drop to 0.10 W/m.K for mixtures of earth and hemp or earth and straw (500 kg/m³). Average values for several densities are shown in Table 2 (Boussaid et al., 2001, CSTB, 2007, Goodhew et al., 2000, Goodhew and Griffiths, 2005, Kleespies, 1994, Hutcheon, 1949, Laurent et al., 1984, Laurent, 1987, Maniatidis et al., 2007, Ola, 1987, Wibart, 2010).

ρ (kg/m³)	500	1000	1500	1800	2000	2200
λ (W/mK)	0.2	0.3	0.6	1	1.2	1.5

Table 3. Synthesis of the main properties of earthen materials for construction (credits: authors)

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SEISMIC RESISTANT ADOBE WALLS AND EARTHEN FRAMEWORK VAULTS AT THE COMPAÑIA DE PISCO CHURCH IN PERU

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Theme 7: Ancient/Historic and Innovative Solutions for Damage Prevention and Performance Improvement
Keywords: Dome, earth, seismic

Abstract

On the occasion of the reconstruction of masonry vaults of the cathedral of Lima in the 17th century, master builders demanded the need for construction systems that would lessen the impact of earthquakes on the building. This situation resulted in an expert debate to determine the nature of damage resulting from earthquakes, the problems validated as being due to horizontal forces, and possible seismic-resistant solutions to be adopted, leading to the eventual introduction of earthen framework vaults. Contemporaneously, La Compañía de Pisco church was destroyed by the earthquake of 1687, which is why the most suitable type of structure was analyzed for erecting the new building, based on the conclusions from the debate on the cathedral of Lima. Finally, both temples had their vaults rebuilt with frameworks in 1691 and 1725 respectively, supporting them on properly reinforced adobe walls. Three hundred years later, the Pisco area was shaken by an earthquake that destroyed La Compañía de Pisco church, which had endured until then, revealing the notions of earthquake-resistance that the builders had used in the earthen construction of churches, but which was forgotten in the modern consolidation interventions of this temple.

1. INTRODUCTION

Since the dawn of the Spanish presence in Peru, stone and brick were materials regularly employed to build vaults and domes, constructed following the method of proportions and stability (Huerta, 2004). Promptly, Hispanic builders noted that the newly settled lands were consistently shaken by earthquakes of a high intensity, causing the collapse of most of the vaults, which until then were not prepared to deal with events of this magnitude (1).

During the 17th century, different ways to build masonry vaults had already been experimented with in many cities of the Viceroyalty of Peru; however, without having found a reasonable response in terms of time, economy and stability against earthquakes. Amid this building landscape, earthen-framework vaults were introduced in the mid-17th century.

2. THE CATHEDRAL OF LIMA AND THE TECHNICAL DEBATE OF MASTER BUILDERS

A crucial moment for the development of framework vaults in the Viceroyalty of Peru was the case of the reconstruction of the vaults and the walls of the cathedral of Lima. The original masonry groin vaults, following the earthquake of 1609, were badly damaged, so an arduous debate between the main builders of the city occurred to determine the best way to repair or even to replace these vaults. The dialogue was focused on how to stabilize the thrust of the vaults towards the walls during an earthquake, by increasing their thickness. The subsequent findings of the damage that earthquakes caused in these types of vaults motivated an anachronistic use of ribbed vaults. The vaults of the cathedral of Lima were rebuilt with this system, with the conviction that the concentrated thrust in a ribbed vault would guarantee their stability during earthquakes. Therefore, it would be sufficient to provide the adobe walls with abutments, located at thrust points, with a thickness sufficiently able to absorb out-of-plane forces (2).

A new turning point was marked by the 1687 earthquake, which caused the collapse of the new vaults, leading again to the reflection on the best way to rebuild the vaults of the cathedral. Then, Fray Diego Maroto offered the Ecclesiastical Council a vision of structural safety from the framework vaults built by himself some years before in the Church of Veracruz and the Church del Sagrario, proposing to reconstruct the vaults of the cathedral using this same system (3). Pedro Fernandez Valdes wrote that adobe abutments could not


a) b)
Fig.1 Lima's cathedral vaults: a) Soffit; b) *Extrados* (credits: Pedro Hurtado Valdez, 2007)

contain the horizontal forces taking place during earthquakes, particularly in the upper parts of the walls. Therefore, it was preferable to decrease weight by building new vaults of earth and cane framework (4).

The Metropolitan Council instructed Maroto, in his competence as master builder of the cathedral, to design the new vaults, which would be made with trusses with camones and contracamones, i.e. curved timber plank, that are overlapped to form an arc, whose meeting points would occur at the edges and the nails to be staggered. The new vaults required the demolition of the old ones, leaving a part of brick or adobe at the start of the wooden structure to introduce greater stability in the lateral direction of the arches. The use of a chained base was also compulsory, in order to tie the walls together, and as a Tas-de-charge, would receive the trusses (wooden beams). Maroto also gave precise instructions to refill the inner parts of the vaults to contain the thrust from the arches (5).

By 1691, three framework vaults had been built, corresponding to the backside of the main façade of the cathedral. Again, the council asked the master builders for an evaluation of the new vaults considering the earthquake of that year, but the majority noted that their structural behavior had been satisfactory (6).

2.1 Lower-height walls

One of the first actions taken to reduce the effect of earthquakes on buildings was to reduce the height of the buildings, and this occurred especially during renovation and consolidation of buildings damaged by earthquakes. The master builders promptly confirmed the substantial importance given to the estimation of the maximum height that the buildings could withstand under the effects of earthquakes (7).

2.2 Larger-dimensioned abutments

Together with the reduction in the height of walls, greater thicknesses was also considered, thus increasing the mass resisting an earthquake, while also decreasing the slenderness of walls. This idea was also considered for the abutments of the walls that supported the thrust of the vaults (8). Subsequently, it would be verified that the increased mass and stiffness of the work by itself would only counteract earthquakes of moderate intensity. When horizontal forces exceeded the strength capacity of the building, the damage is great, due to the lack of ties between walls, facing the risk of immediate collapse.

2.3 Using a single type of vault

Considering that the original vaults of the cathedral of Lima were, in the nave, segmental arches, and on the sides, of ellipsoidal profile, two different thrusts occurred that did not nullifying each other. This caused a thrust at the top of the walls, which was increased during a seismic event. As a result, it was decided that the same building and design features should be applied to the vaults inside the church (9).

2.4 Tying adobe walls with wooden chains

It was also observed that the presence of a continuous wood tether (not only sleepers) at the top of the adobe walls helped to prevent walls from separating. For framing the vaults, the base of support is used as part of this bond, along with embedment knuckles on the wall.

2.5 Maintenance of the structures after each seismic event

The builders recommended that the structure of the cathedral should be evaluated and repaired after every earthquake, to prevent damage in the next one from becoming accumulative. Also particular meaning was given to ensure the continuous maintenance of the insulation and protection elements for walls and vaults, as well as the coatings of earth and gypsum.

2.6 New lighter and more flexible construction systems

The real breakthrough in earthquake-resistant construction in the Viceroyalty of Peru proceeded from the belief of the master builders, who claimed that it was better to find solutions that would absorb deformations, than to continue resisting earthquakes. The result of this insight was the introduction of the earthen framework, which endowed a reduction in weight to the upper parts of buildings, as well as in belfries and churches domes. This solution, not only slowed the incidence of the horizontal forces, but also, due to the characteristics of the construction system, bestowed structures with greater ductility (10).


Fig.2 The *Compañía* Church, in Pisco: a) In 1920, the church had endured the great earthquakes of 1746 and 1877 without collapsing; b) By 2007, before the earthquake, the building had a cement floor, and the paved streets prevented earthen substrate from expelling vapor (credits: Domingo Canepa, 1920; Pedro Hurtado Valdez, 2007)

3. THE COMPAÑÍA DE PISCO CHURCH

The Compañía de Pisco church was a remarkable religious architectural example of the southern coast of Peru. This temple had a Latin-cross plan, formed by two barrel-vaulted naves and intersected on the transept with seven niches' chapels located at the sidewalls of the nave. This church corresponds to the second construction phase that was built in 1704 by Juan de Almoguera, following the recommendations resulting from the discussion around the Cathedral of Lima, after the previous church has been destroyed by the earthquake and tsunami of 1687. In 1719, the vault of the nave and the dome of the church were already prepared, the walls having been reinforced with wooden beams (11). In 1746, a major earthquake struck the central coast of Peru, but the church suffered no major damage.

In 1767, a Royal Decree was issued ordering the eviction of the Jesuits from Peru and the confiscation of their property by the Spanish Crown. Thus, the church and school annex remained closed until the Superior Board of Uses decided to deliver the building to Pisco's parson in 1785, so as to prevent its decay.

In 1826, a decree was issued dictating that the convents that had no more than eight priests settled in them were to be abolished, and the assets of these convents should be applied to public education. In 1877, a tsunami struck the coast of Pisco, following an earthquake that occurred in Iquique, but there is no register that the church was affected. The Peruvian government issued a law on patronage in 1889, and instructed the Public Charitable Societies with the administration of religious property, leaving the church and a small sector of the school for chaplains, which was later administered by the Vincentians Fathers until 1929.

In 1942, a strong submarine movement, near Pisco, caused by an earthquake of 8.1 magnitude was recorded, but the church withstood it. In 1949, a new earthquake affected part of the temple, forcing maintenance work, although those in charge of the work caused the collapse of part of the vault, and even damaged the front wall. The temple became a repository for the construction materials left after the cessation of the work. The building was once again vacant until 1960, when the National Council of Conservation and Maintenance of Historic and Archaeological Monuments performed restoration work on the church. Further interventions incorporated cement coatings within the structure, while the streets were asphalted and the enclosures and the small square opposite the church paved. In 2003, the Municipality performed an intervention on the façades and the base of the walls, sealing cracks and coating detachments with cement and latex paint.

4. BUILDING AND STRUCTURAL FEATURES

The framework vaults built in La Compañía church corresponded to the arch system, which defines a step forward in the evolution of wood and framework vaults (Meschke, 1989; Balboni & Corradini, 2009). This system is characterized by trusses that discharge the weight of the entire roof, to their locking elements (*encadenado*), and are laterally braced by straps.

This building system is self-supporting, unlike lintel or beam systems that have a greater presence in Europe, where vaults are hung from these. Also, the system is not only intended to define an interior space, but to show the outer volumetric shape a building acquires, as the extrados curvature is evidenced on the exterior. To produce this effect, the curved timber plank (*camones*) profile must be cut twice, providing them with both extrados and soffit. Here are generated lateral thrusts that will be received by the locking elements (*encadenado*), which will transmit such exertions to the walls.

The arch system for framing a vault introduces a new element consisting of adobe fillers in the base area, which seeks to support the resulting force. The use of an adobe infill makes a substantial difference to the vaults proposed by De L'Orme, as well as Spanish wooden vaults (12). However, in the Viceroyalty of Peru, far away

Fig.3 The *Compañía* Church, Pisco: a) Adobe walls coated with cement at the bottom; b) Earthen-framework vault and dome left weathering without an earthen coating; c) Adobe arch with cementitious-coating renovation (credits: Pedro Hurtado Valdez, 2007)

from the new European debate about these structures, the sizing of the elements of the trusses continued, as well as constructive solutions dictated by the experience and suggestions of the respective guilds (13). There are no construction contracts or other documents from the time of tests to verify the behavior of earthen-framework structures, perhaps because construction experience had already shown its static reliability when subjected to vertical loads. Besides earthquakes, real and regular testing of the system's function against horizontal forces, served both to check design proposals, providing corrections and permanent adjustments to improve earthquake-resistant behavior.

4.1 Locking system of the walls

Locking Elements (*encadenado*): The connection between the adobe walls and the vaults was given by a perimeter wooden beam (sometimes double), acting as a locking element at the top of the wall, and as a base for the vaults. This locking system provided the effect of a diaphragm, responding jointly to the movement, since the roofs were flexible and weighed little; the top of the walls could vibrate as a free edge, with inertial force acting inside and outside the plane of the walls. The latter case could result in their separation and overturning, if the positive momentum grew large enough, especially when there was a sizable gap between the reinforcement stirrups of the walls.

4.2 Bearing structure

Trusses (wooden arch): These were constructed from curved timber planks camones and contracamones, placed alternately and united by nails to give shape to the projected arch. Sometimes leather straps were also used to tie the camones, which were installed wet so that while drying, they produced greater pressure through shrinkage, preventing the probability of failure of the camón in the direction of the fiber, motivated by trimming its curvature.

Straps: These were wooden pieces placed horizontally and alternating between the trusses to connect them in their full extent, being separated by a variable distance, but preferably about 120 cm. Their function was to transmit and redistribute the loads of the roofs, in addition to maintaining the separation of the trusses and providing lateral stability.

Adobe infill: At the base of the framework along the wall, between the locking element and the strap, struts were placed and this space in-filled with adobe. Thus, a partial diaphragm was formed to help prevent the lateral movement of the trusses and upright the resulting push. It allowed a safer transmission of the loads near the axis of the walls, and avoided risky eccentricities.

4.3 Locking elements

Laying cane: Locking was achieved by reeds woven and joined to each other by leather straps and attached to the trusses with nails through the straps. Complete reeds were placed at the upper surface that served as the substrate for the earthen coating, while at the intrados, the reeds were longitudinally cut and extended, thus increasing the contact surface used as the support for the gypsum plaster. By placing cross straps at the trusses, to which the rods were fixed, a continuous grid was formed, which improved the distribution of loads and forces on the surface of the vault.

Earthen plaster: This was an earthen layer with a thickness of around 10 cm, made with a ratio of 15% clay, 10% silt, 55% sand and 20% water, also incorporating straw or animal hair to avoid excessive shrinkage during the drying process. The combination of earth with wood and cane produced a lightweight structure, permeable to water vapor, as well as flexible and stable over time. Due to its own nature, the earthen coating also allowed easy repair of cracks caused by earthquakes, because it was simple to remove the damaged areas and put a new layer of earth on a grid of rods, which provided continuity to the coating. The layer of earth placed on the vaults is often stabilized by adding lime (14).

The earthen coating provided insulation and protected the various components of the framework from the environment, as it kept wood elements and reeds dry, due to its low equilibrium-moisture content of 0.4% for a sandy earth with 20% humidity air and up to 6% for a clayey earth with 97% humidity, a feature that was aided by the high capillarity of the earth (Minke, 2001, p. 32-36). Under such conditions, plant fibers have a high resistance to attack by insects and fungi, as insects need to be in an environment with humidity between 14% and 18% to survive; and for fungi more than 20% moisture (Navarrete, 1999, p. 8).

5. ANALYSIS OF THE STRUCTURAL BEHAVIOR OF THE *COMPAÑÍA* DE PISCO CHURCH DURING THE 2007 EARTHQUAKE

Damage caused by the earthquake of 2007 in Pisco permitted limited considerations on the behavior of the vaults and walls of La Compañía de Pisco church.

Fig.4 The *Compañía* Church, Pisco: a) Adobe walls with humidity and differential settlement; b) Adobe walls with loss of the original locking elements and the ties between themselves; c) Crack separating the walls of the tower and façade of the nave (credits: Pedro Hurtado Valdez, 2007)

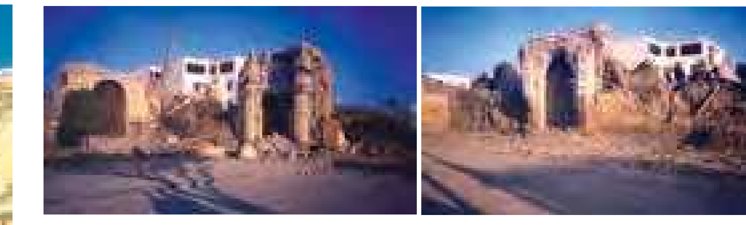

Fig.5 The *Compañía* Church, Pisco in 2007 after the earthquake: a) Area of the main façade and the entrance to the school, already separated from the rest of the wall pre-earthquake; b) Lateral façade also with separation cracks (credits: Pedro Hurtado Valdez, 2007)

5.1 Adobe walls

Up until that time, there was a marked deterioration of the walls from the continuous and accumulated damage of earthquakes in the second half of the 20th century, which had not been repaired. Most of the walls were cracked and separated from each other, making their slenderness increase significantly. Consequently, during the seismic action, each portion of wall acted independently in motion, colliding with each other.

In addition, the walls were sealed with cementitious products, as was the pavement of the patio annex to the temple, and the streets with asphalt. This produced high moisture content in the subsoil, which rose by capillarity up into the walls of the church, causing the moisture content inside the walls to be high, resulting in the softening of the adobes and loss of their bearing capacity.

With increasing humidity, the saline soil on which the church was founded led to the migration of salts and their subsequent crystallization within the walls, causing micro-fractures within them. Also, the wooden elements inside the walls, while in a moister environment, were attacked by wood-eating insects and decay fungi, and thus unable to provide ductility for the walls.

5.2 Earthen-framework vault

The collapse of the earthen framework vault was due to factors related to the state of conservation of the structure. This was firstly motivated by the sharp deterioration of the walls on which the vaults were supported, which, during the earthquake, could not withstand the thrusts, overturning at the top and leaving the locking elements (*encadenado*) without support.

As for the second cause, it was due to the deterioration of the vault wood and cane elements. As the coating had not been maintained, the locking elements and the camones had been exposed to the weather and showed attack from wood-eating insects and fungal decay. Having lost many of the pieces of the original vault, its central section had diminished mechanical ability. In addition, the leather straps had loosened, as the wooden pieces lost their consistency and the nails rusted. As the trusses are not continuous elements, and instead obey the effects produced by the rotation of the joints in the camones, stability was left compromised (Marzo, 2006). Equally, cane enclosures were in an advanced state of decay, and the gypsum plaster seemed to have exceeded its saturation capacity to water vapor, thus beginning to transmit even more moisture to the trusses. During the 2007 earthquake, trusses failed in the central area, incapable of controlling the rotation of the camones, while in the area of the camones abutments tended to rise, but without dissociating from the locking elements, and thus maintaining stability (15).

6. CONCLUSIONS

Faced with persistent damage by earthquakes in colonial buildings, master builders were needed to adapt the original Spanish architecture to the seismic characteristics of the Peruvian territory, although initial construction difficulties were solved through a continuous process of trial, error and improvement. The result of this experience resulted in the correct construction relationship between adobe wall and earthen-framework vault. These considerations were not taken into account in the interventions to the church during the second half of the 20th and early 21st centuries, with the addition of materials incompatible with earth, and the lack of a basic maintenance of the structural elements. The result was that during the 2007 earthquake, the building, already structurally damaged, collapsed. Surprisingly, the temple that had withstood the great earthquakes of 1746, 1877 and 1942, showing the strength between the earth wall and the dome framework was perfectly stable. Therefore, the restoration of these earthen structures using traditional technology is appropriate. However, if the intention is to experiment with new techniques and materials, it is important to recall that the stability criteria revealed by master builders, 300 years ago are still current.

Notes

(1) In the south of the Iberian Peninsula, there are seismically active areas, though not as frequent (Martínez Solares, 2003). On the other hand, Spanish builders met in the Viceroyalty of Peru repeated earthquakes and of large magnitudes. The magnitude of the earthquake of 1746 has been calculated at 8.4 on the Richter scale, with an intensity of X-XI on the Mercalli-modified scale (García Acosta, 1997, p.12). At this time, the 1755 earthquake in Lisbon had not occurred yet.

(2) Original citation from Juan Martinez de Arrona, who mentions: *"que bajar las naves colaterales y hacerlas de crucería es el mejor remedio que puede haber para asegurar la nave principal… y haber pasado por ellas el temblor grande del año quinientos y ochenta y seis y los que más ha habido sin recibir daño porque son de crucería y en nuestra Santa Iglesia se ha visto lo mal que aprueban las bovedas de arista con los pocos que han pasado por ellas las han dejado tan lastimadas…"* [To go down the high of the side aisles and make ribbed vaults is the best remedy to ensure the nave ... and have gone through them the big earthquake of the year five hundred and eighty-six and others tremors more and has been no damage because they are ribbed vaults and our holy church has seen how badly approve the groin vaults with the few tremors who have gone through them have left them so hurt] (ACML, 1614-1615, 1: f.15r).

(3) Original citation: *"…la nueva forma se ha reconocido por experiencia ser fábrica más segura en tan repetidos temblores mayormente cuando las que hizo de esta manera este declarante en la Iglesia de su Convento siendo así que era de pocos fundamentos en lo tocante a la albañilería las bóvedas que hizo encima de los pilares y arcos que han padecido y no las bóvedas por haberlas hecho de cedro y yeso…"* [The new form has been recognized by experience to be safer than masonry one facing to repeated tremors, mostly when he made in this way, this declarant, in the Church of his Convent, being so it was with few resistances, when it comes to ancient masonry vaults that were built on the pillars and arches that have suffered and not the vaults that I have made of cedar and plaster ... "] (ACC, 1688, f.70r).

(4) Original citation: *"Y así mismo le parece a este declarante no ser buena obra la que se puede aplicar abrigando con albañilería el envano de los pilares para recoger las entradas y menor fuga a los rempujos de los arcos particularmente cuando la experiencia ha demostrado en la obra de la iglesia de san Pedro Nolasco donde se aplicó este género con mas cuerpo y asi en lo grueso como en lo largo y se vino con el temblor al suelo…le parece a este declarante que habiendo de ser de madera yeso y caña no necesita de más aplicación…"* [And so it seems to this declarant not be good work that the buttresses can be made with masonry into the pillars because the thrusts of the arches, particularly when experience has shown in the work of saint Pedro Nolasco church where this genre was applied with more mass and thickness, they fell down with the shake of the ground ... this declarant thinks to be the vaults with wood, plaster and cane needs no further reinforcement] (Id., f.71v - 72r).

(5) Original citation: *"…dicha crucería ha de ser de camón y contracamón encontradas las puntas de las cabezas…y para obrara dichas tres bóvedas ante todas cosas se han de obligar a demoler lo que ha quedado de ellas de ladrillo dejando tan solamente dos varas y media de alto en cada movimiento en los rincones sobre que se ha de asentar sobre yeso un tablón de ochava de grueso… como también se han de macizar todos los rincones de las bóvedas por detrás de la crucería de madera para su resistencia y seguridad…"* [This ribbed vault must be of curved timber plank (camón and contracamón) found their heads ... and for doing these three vaults above all things, it has to force demolish what is left of the ancient vaults with brick leaving only two and a half varas (200 cm) high in every movement in the corners of which has to put one strap of ochava (10 cm) thick on a plaster ... and filling all corners of the vaults behind the wooden rib for the strength and safety] (Id.).

(6) Original citation from Pedro de Asensio who commented: *"…con ellas se ha reconocido la seguridad para los temblores pues acabadas de hacer le sobrevino el temblor del día veinte de septiembre del año pasado de seiscientos y noventa que fue tan grande como el de veinte de octubre de seiscientos y ochenta y siete y causó mayores ruinas en otros edificios que los antecedentes y en estas tres bóvedas no recibieron daño ninguno…"* [With them has been recognized safety for earthquakes, finished doing these vaults occurred the tremor of the day on September 20th last year six hundred and ninety, which was as large as the earthquake of October 20th of the year six hundred and eighty-seven and it caused major ruins in other buildings in the neighborhood but the three vaults did not receive any harm] (Id., f.95v).

(7) Fernando de Cordoba and Figueroa argued that damage to the Cathedral of Lima should be avoided: *"… las torres no suban lo que la montea de la planta muestra que se le quite el tercio de su altura…"* [the towers should not raise the height that the building plans show and that it will remove the third of their hieght] (AAL, 1609, leg.6, exp.17). Earlier, it had been agreed that new construction should not exceed 15-ft high (5 meters), a standard that was ratified by the 1552 Carlos V royal decree. In the 17th century this was extended, in regards to the consolidation of buildings damaged by earthquakes.

(8) Alonso de Arenas argued that the earthquake of 1609 did not cause damage to the Cathedral of Lima. On the original citation: *"Y supuesto que el daño recibido fue la causa dicha y es sin duda no le tuviere el reparo de esto consiste en darle fortaleza y la podrá tener añadiendo a los estribos hechos seis pies y medio de aumento de pilar en la salida y de ancho nueve por manera que ha de quedar el largo del dicho estribo de quince pies y el grueso de otros tantos e ir formado juntamente con los dichos estribos las puertas para que toda la obra vaya a un tiempo trabada…"* [And of course the damage received was such cause and it certainly will it have the repair of this is to give strength and may be adding to the existing stirrups six and a half feet in long and nine feet in wide, so this stirrup will have the length of fifteen feet and similar in the thickness and go formed together with these stirrups the doors for doing all the construction work in enchained way] (Id.).

(9) Original citation: *"Y habiendo visto como tengo visto y entendido antes de ahora el cerramiento que está hecho en la misma Iglesia de las capillas de arista y los arcos aovados digo que están sin fuerza ninguna respecto de no tener estribos suficientes para que puedan hacer fuerza la nave menor en la mayor."* [But seeing as I have seen and understood before now the enclosure which is made in the church with the chapels with low groin vaults and high ovate arches I say there is no force because there is no enough stirrups for support the aisle over the nave] (ACML, 1614-1615, 1: f.8r).

(10) The specific weight of a framework vault is approximately 900 kg/m³, while granite from Panama, of which much of the Viceroyalty of Peru was built with, is around 2,700 kg/m³ and coastal brick 1,800 kg/m³. The travelers of the Spanish scientific expedition of 1748, Jorge Juan and Antonio de Ulloa mentioned according to the original citation: *"… jugando todo el Edificio con los estremecimientos de los Terremotos, y estando ligados sus fundamento, siguen enteramente el movimiento de aquellos; y no haciendo oposición la fortaleza, aunque se sientan en parte, no caen, ni se arruinan tan fácilmente"* [Playing all the building with the earthquakes shakes, and being linked its foundation, it follows totally the movement of the earthquake; and without doing a hard opposition, although partly sit, it do not fall, nor do not easily ruin] (Juan & de Ulloa, 1748, p. 43).

(11) Original citation: *"… la obra de la Iglesia que se esta practicando cuyo cañón esta armado rellenandose y la media Naranja labrada y en…la madera nessesaria para acavar dicha Iglesia la clavaran porsian de llevar cal ladrillos adobe y cañas"* [The work of the church that is building is armed with a barrel vault being filled and the dome tilled and ... the needed wood for finish the church and nailed and to carry lime, bricks, adobe and reeds] (AGN, 1713-1745. Leg. 39, Sec.1).

(12) De L'Orme intuited that the distribution of forces in a structure, made up of many in-between parts and with multiple assemblies, enjoyed stability, because if a component failed, the remaining parts would adjust to this new configuration (De L'Orme, 1576, Ch. VI, f.8r).

(13) The first implementation of static in solving masonry-arch problems was accomplished by Lahire in 1695 using the funicular polygon in his analysis (Huerta Fernández, 2004). In 1825, Johan Voit, the construction Minister of Bavaria, refers to the characteristics of existing masonry arches to indicate the nature of trusses (Hahmann, 2006).

(14) Santiago Rosales in 1740 mentions that in the dome of the church of the Hospital San Juan de Dios, *"…también se me ha de dar la tierra necesaria para torta de por fuera sobre la cual he de poner su torta de cal…" [Also must give me the earth needed for mortar of the extrados and then I will put the lime mortar]* (AGN. Protocolos Notariales, escribano José de Torres Ocampo, 1740-1751, prot. 1048, f.17v, 1740-1751). Joseph de Robles recounted that he had to work on that dome (Sagrario Church) with a mixture of lime over a earth cover («*perfeccionando dicha media naranja (iglesia del Sagrario) con mezcla de cal sobre un jarrado de barro…"*) (AGN. Protocolos Notariales, escribano Alonso Martín Palacios, 1680, prot. 1402, f.1528, 1680).

(15) David Gilly can be considered the precursor for the structural study of wooden trusses, although he considered erroneously that they followed the same principle as masonry arches (Gilly, 1797). Also Johann Albert Eytelwein (1764-1848) assumed the edges of *camones* were rigid connections, speculating that the transmission of forces in compression in the trusses was from the same source as those produced in masonry arches (Hahmann, 2006, p. 1506). Zimmermann and Ardant applied to trusses the 19th-century French studies on the elastic behavior of materials, and they observed that these structures failed in shear joints, not as a result of the vertical system of cutting fibers, but rather as shear in the fibers' direction.

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CONSERVATION OF ANDALUSIAN MONUMENTAL HERITAGE: THE CASE STUDY OF THE NIEBLA WALLS IN SPAIN

Jacinto Canivell, Ana González-Serrano

Theme 7: Ancient/Historic and Innovative Solutions for Damage Prevention and Performance Improvement
Keywords: Assessment, risk, conservation, vulnerability

Abstract

The conservation process through interventions in a building requires adequate prior expert opinion. The diagnosis and subsequent safety assessment - raised in ICOMOS guidelines - are suitable mechanisms for the study of a heritage structure. Diagnosis involves a historical analysis of the past, as a tool to predict future responses; qualitative analysis determines the deterioration and the origin of the pathological process; and quantitative analysis characterizes components by observations and experimental measurements. However, in the short or medium term ineffective decisions might be taken if assessing the state of a building using only the aforementioned tools.

The Declaration of Assisi (ISCARSAH, 2000) stresses the need for prevention and the successful management of a risk-prevention program. By completing all assessment reports, in addition to a suitable risk assessment focused on the intervention and design of appropriate preventive measures, ensures a reduction in the vulnerability of a structure by managing a significant improvement in durability and, therefore, the sustainability of conservation and maintenance processes.

In order to verify such vulnerability of different degrees of interventions (comprehensive, partial, or none), the Almohad rammed earth walls of Niebla, Huelva, Spain was considered as a representative case study. It is almost 2-km long and includes 47 towers. The fortification complex currently has heterogeneous characteristics, although an almost entirely uniform appearance has been maintained. Since 1980, there have been several restorations that, from the beginning, reflect mixed results over time. Based on the results of an assessment, current circumstances and risks, a diagnosis was made in order to design and prioritize preventive and corrective measures that will permit greater durability of the walls of Niebla.

1. INTRODUCTION

Andalusian defensive heritage incorporates more than 2,000 buildings, all listed as cultural assets but only a small percentage of which are in good condition. The city of Niebla is one of the few Spanish cities that preserves the entire perimeter of its almost intact city walls, which were declared BIC (*Bien de Interés Cultural*) in 1945. The current layout is considered to be from the Almoravid period, which occurred approximately between 1090-1145, although some scholars believe it is from the Almohad period (1147-1212) (IAPH, 2011). Other sources argue that these are a heightening of pre-existing walls, identifying Roman remains and even Tartessian (paleo-Hispanic). Archaeological studies show traces of an older, much smaller walled enclosure that can be traced back to the first millennium BC (Campos Carrasco, Rodrigo Cámara & Gómez Toscano, 1996). The relevance of the location of Niebla is justified having been a commercial center between Minas de Rio Tinto and Bajo Guadalquivir, especially around the 9th and 10th centuries, acquiring noteworthy historical heritage significance as the Almohad fortification, as well as an urban and landscape element of integration.

Currently, the wall of the town is about 2-km long flanked with 47 towers (most of them rectangular and only two octagonal) enclosing an area of approximately 16 urban hectares, and composed almost entirely in military rammed earth. It does not incorporate any albarrana or barbican towers; however, it maintains a natural moat with the Tinto River in its southeast sector, which is the roughest. The enclosure is completed with the Guzmáns' Castle, rebuilt in the 15th century on top of the old fortress of Muslim origin (Junta de Andalucia, 1991).

Despite its proven value as monumental Andalusian heritage, its present condition is questionable, which substantiates a thorough analysis of vulnerability and the presence of risks.

Fig.1 Aerial view of Niebla showing the identification of its walls and the different phases of intervention (credits: Goolzoom, J. Canivell, & A. González, 2011)

2. HISTORY AND EVALUATION

Before identifying a diagnosis, it is necessary to make a compilation of the clinical history of the wall (anamnesis) that includes a historic, conditions, materials, and metrics assessment, as well as an understanding of its pathologies and, finally, vulnerabilities.

2.1 Sequence and recording of the interventions

These walls have been several times historically and partially rebuilt with inefficient results in the medium term. From the second half of the 20th century, several phases of intervention can be distinguished. An initial phase of several intermittent interventions took place up until the 1970s, including those made in 1957 promoted by the Department of Fine Arts, and others made in 1974. In the 1980s, the Andalusian Ministry of Culture chose to invest in a comprehensive project that continued through the 1990s. Finally, from 2003 until the end of 2010, emergency actions were implemented. Fig. 1 locates different interventions on an aerial view of the city walls of Niebla. Details of those interventions are specified in Table 1.

This research uses the same identification and numbering of towers used by Guarner in his initial project (Martínez Martín-Lucas & Espinosa de los Monteros Choza, 2000), while the parts of the wall are named in alphabetical order, marking sections between every two towers. The designation starts from Tower 1, located in the southern part of Niebla, coinciding with the Puerta del Buey. The scope of this study follows the wall sections between the Towers 1 to 10, since these corresponds to one of the sectors that, due to the degree of deterioration, permits the identification of several types of damage. These are also exposed to adverse weather conditions due to their harsh orientation. Moreover, it is in these sections where four different phases of interventions overlap in time.

2.2 Technical and building characterization

The walls of Niebla are built almost entirely with ordinary rammed-earth. For its building characterization, it is considered under the typological classification developed for the study of historical rammed-earth masonry in the province of Seville (Graciani and Tabales, 2008, p.135-158). In general, all precinct fabric corresponds to monolithic rammed-earth, although the peculiarities of some sections are noted, where there are parts built of natural-stone masonry (exterior castle fabric) wall. Also noteworthy are certain typical Almohad resources, such as lime mortar wrapping rammed-earth joints to imitate the appearance of large solid stone blocks and, perhaps, to also protect these joints. Moreover, most of the towers of the enclosure are quite similar in their building concept. All of them are resolved with rammed-earth reinforced with stonework masonry at the corners and rammed-earth on their façades. Different construction solutions differ at their copping, although all of them are solid, and all lack a compartment in their upper section with the exception of Tower 1, which in fact is a gate and have a inner zigzag corridor.

Specifically within the area under study, stone masonry (probably as a veneer) is identified only in Section A where there is a trace of the old buildings attached to the wall; the other sections, were built and restored using the same type of monolithic rammed-earth (type 1), while the towers present the stone reinforced rammed-earth wall (type 5), according to Graciani and Tabales (2008, p.139). All the elements present in this area were from interventions in 1980.

Specifically, in the area of study of this work, only in the section A it can be identified stone factory (probably as a coating), a trace of the old buildings attached to the wall; the other sections, were lifted and restored following the same type of monolithic wall (type 1), applying the technique in the towers mixed with chained stone wall (type 5) (Graciani and Tabales, 2008, p.139). All elements of this area, intervened in the 80`s, have traces of mass restitution running to one side.

2.2.1 Materials characterization

Considering the data extracted from Guarner González (1987), earth was used in the most comprehensive intervention. This material was collected from quarries in the immediate surroundings, along with gravel from Tinto riverbed, attempting to source the same chalky-red earth with a similar content of clay to that of the original rammed-earth walls. It is clear, however, that in order to improve the quality during successive restorations, the earthen materials were stabilized with lime from quarries and kilns in Huelva that was modified with 10% cement (1). Fragments of ceramics, stones and gravel of different sizes can also be identified in the mixture.

INTERVENTIONS IN NIEBLA CITY WALLS			TYPE OF REPAIRS															
			MATERIALS												EXTERNAL			
			BASE		WALL								TOP					
START DATE OF WORKS	TECHNICAL TEAM	Phase of intervention Element being treated	Reinforcement of base with lean concrete fundation	Reinforcement of base with reinforced concrete fundation	Restitution of variable thickness of disaggregated rammed earth	U-shape metallic anchoring	Reinforcement in corners of towers. Sustitution of stone blocks	Earth renders	Thermography of interphase to assess disaggregation of layers	Lime grout through putlog holes to seal and consolidate interphase	Consolidants and waterproofing	Protection of wall top. 10cm thick layer, metallic mesh reinforcement	Protection of wall top. 25cm thick layer, metallic mesh reinforcement	Water channeling / Rainwater draining	Demolition of dwellings attached to city walls	Removal of irrigation systems close to walls	Removal of trees in garden areas closed to walls
1957	Before second half of 20th century, specific interventions are known at the perimeter of current city walls. Only referenced in archaelogical and historical studies. Always refered to material disaggregation in sectors of the city walls																	
1974 1975	Arq. R. Manzano M. Lopez Vicente	Castle - T Homenaje T7 y T10																
1982 1983	Arq. I. Guarner	Phase 1: T1 a T7 Phase 2: T7 a T14																
1985	Arq. R. Manzano Arq. I. Guarner	Phase 3: T14 a T18 Phase 4: T18 a T20																
1990	Arq. I. Guarner M. Lopez Vicente	Phase 5: T35 a T47 Phase 6: T26 a T31 Phase 8: Castle																
2008	Arq. M. Lopez Vicente	Phase 7: T21 a T26 Emergency T22 a T23																
2010	Arq. M. Lopez Vicente	Phase 2: T10 a T11																

Table 1. Phases of intervention throughout the second half of the 20th and beginning of the 21st centuries (credits: J. Canivell & A. González, 2011)

Although there have been no more than visual inspections, without the ability to count on quantitative test data, it is known that for the execution of the various phases of the work, only organoleptic tests were performed (2) to control the plasticity of the earth and the corresponding percentages of blond-colored sand from the river, as well as fine gravel. It is known that ceramic sherds were not removed from the mix if the amount stayed below 10% in each load (Guarner González, 1987). While analyzing the study areas, almost complete pieces of bricks or stone pieces, exceeding 10 cm/side, were found intermixed in the composition of some lifts of rammed-earth in the lower parts. Furthermore, although the specific composition of the original rammed earth is unknown, a clear color differentiation of the restored wall can be observed. Therefore there is an inconsistency in rammed-earth dosages, which may contribute to the development of certain pathological processes that will be described below.

2.2.2 Metrics characterization

The configuration of the enclosure and, in particular, the distance between towers (from 10 to 12 m), highlights the Caliphate heritage as a construction resource (Qantara Patrimonio Mediterráneo, 2008), although there are sections that increase to more than double this size. In general, the rammed-earth wall's metrics corresponds to the classical Almohad. Thus, the high of the lifts of the original rammed-earth varies between 0.85 and 0.90 m high (from two mamuníes cubits of 47 cm) around the enclosure. Where joints and traces on the rammed-earth walls are visible, the length of a rammed earth box ranges between 1.50 and 2.50 m, being greater in the area of the last emergency intervention. The restored rammed earth does not account for the height (0.90 m) or the sequence of the rammed earth. According to module of lifts (their height) it can be distinguished 10 to 12 layers of 10-15 cm thick per lift. In reference to the restored rammed earth, particularly in the T1-T10 study sector, it was performed a restitution on one side with proper thicknesses

Table 2. Damage characterization of Niebla wall between Towers 1-10 (credits: J. Canivell, 2011)

of more than 0.50 m, although thickness of less than 0.20 m has been recorded, which negativity affects to execution and durability.

2.3 Characterization of pathologies

The characterization of damage is based on an in-situ methodology of visual and organoleptic analysis (Canivell, 2011), and supported by graphic documentation. Due to the constraints of the selected sections, it has only been possible to analyze one side of the rammed-earth masonry, as the other belongs to private plots with restricted access. As described in Table 2, the characterization of damage has been categorized into three groups according to the severity.

In addition, damage is assessed at three levels that are color coded, taking into account the spread of damage and its severity. It should be added that the purpose of this evaluation is to specify corrective measures for the existing damage.

Structural damage: This is linked to processes that affect or could affect the structural stability of the work. There are many forms of this damage; however, only those showing obvious signs of deterioration were considered. Therefore, fissures and cracks were evaluated, whether active or inactive, being in almost all cases of vertical orientation, possibly due to the curing shrinkage of the mass or thermal variations. Collapses refer to the loss of verticality in the wall. In this case there are no collapses of entire sections of the original wall; however, some layers of rammed-earth restored to one side show signs of collapse. As depicted in Table 2, structural damage has had little impact in this sector and, therefore, there was no need to undertake this type of corrective measure.

Materials damage: These include the damage affecting the integrity of the rammed-earth mass. Lack of consistency is a very clear sign in the restored layers of rammed-earth, which disintegrates with a simple touch of the hand. This rammed earth appears to be of irregular compaction, resulting from insufficient control of the work, in light of the inclusions of large stone blocks, fired bricks and even organic materials. In general, erosion is typically caused by external agents (moisture, wind-driven rain, temperature, and fauna). Severe erosion is found in the highest lifts of rammed earth, which is more susceptible to moisture infiltration and the effects of wind. Erosion at the lower parts of the wall is often linked to capillary rise, or the backsplash of water against the wall at the lower lifts. Surface erosion is generally spread and is normally caused by the continuous washing of rainwater. In the sections studied, erosion is aggravated by the accumulation of water in certain obstacles (joints, weep holes), producing cavities. Mass losses, although sometimes confused with erosion, have a different origin. The poor quality of the rammed-earth is the cause of these types of detachments, also aided by other external agents, showing more severity in Sections B, C and F. Finally, a special mention is made of flaking as a singular condition, through which the mass of the wall disintegrates in slab-like shapes, parallel to the façade.

Generally, damage to the integrity of the mass has deteriorated the rammed earth with greater severity in the sections studied, due to the exposure to the southwest (the predominant direction of winds and rains), and the low quality of the restoration rammed earth (particularly between T1 and T7). In certain sections (T7 to T10), the quality of the rammed earth dramatically improves (3), even though its exposure similar.

Superficial damage usually affects only shallow layers of rammed earth and can lead to erosion. The efflorescence that shows up as surface deposit of salts is difficult to identify on rammed-earth masonry and even more so, if it is eroded. However, small deposits have been observed in some stone areas and towers. The uniform soiling is linked to the existence of an aggressive environment with a high proportion of suspended particles, causing a widespread contamination of the wall. Local soiling is caused by the differential water-washing of the wall, causing staining typically at the top of the wall, or at intersections between walls and towers. These dirt crusts are a result of the accumulation of muddy moisture and the development of fungi and lichens, forming thin harder surface layers, which when detached, leave a weakened rammed earth exposed to the outside environment.

Based on this characterization it is possible to determine the current state of conservation of the asset, which, as described below, should be complemented with the study of other risks for damage, aimed at maintaining a good condition of conservation in the future.

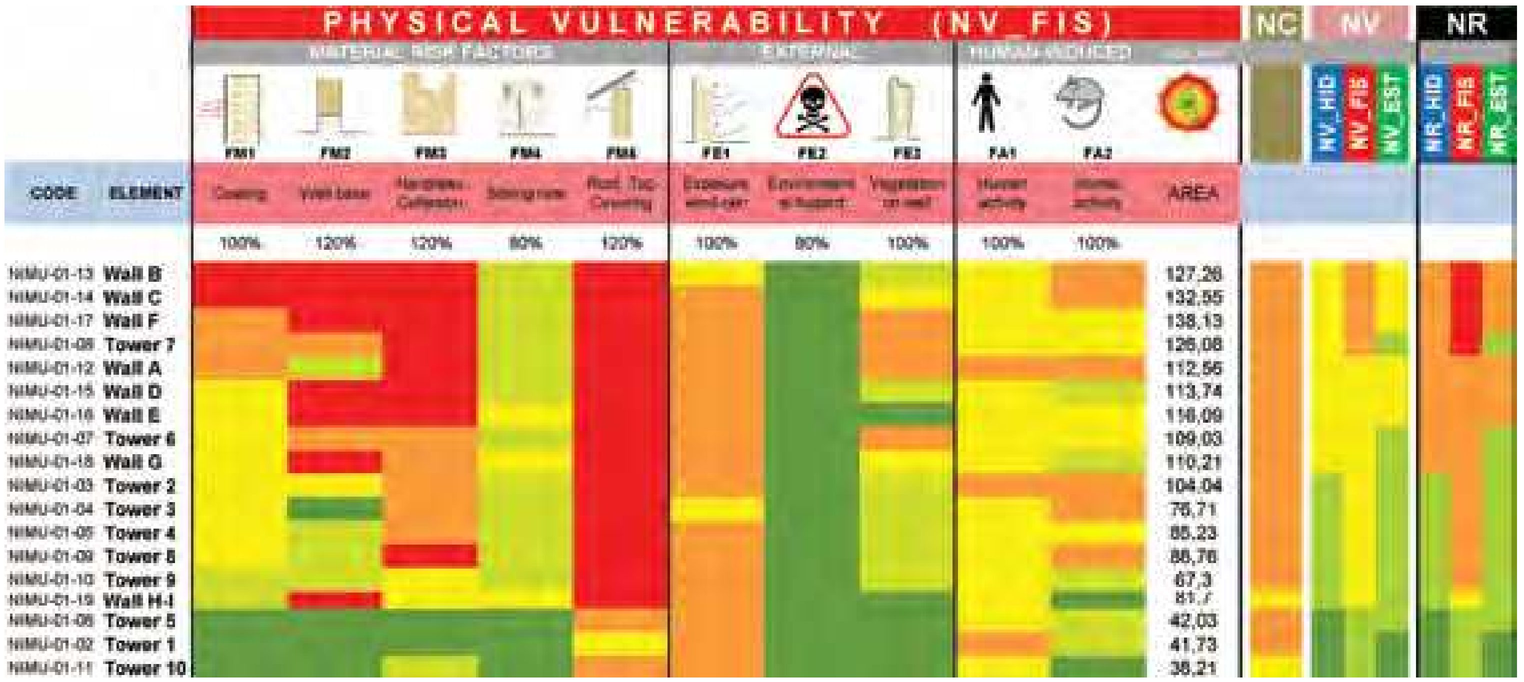

Table 3. Table of risk factors of physical vulnerability to NP (left), NC, NV and NR (credits: J. Canivell, 2011)

2.4 Characterization of Vulnerability and Risk

As damage characterization results in the design of the necessary corrective measures only, given the financial relevance of monumental heritage such as the Niebla walls, it was necessary to expand the evaluation by a characterization of vulnerability, thus facilitating the design and application of protocols and preventive-maintenance measures. To this end, a methodology designed by Canivell (2011) and based on a protocol to the INSHT (4) was applied. Thus, a hierarchy of each of the components of each wall sectors analyzed was achieved, according to an identified state of vulnerability. It is, therefore, essential to divide the construction into components with homogeneous characteristics. This methodology is defined according to the processes described below.

Vulnerabilities of rammed-earth masonry are set first: the hydric, the physical and the structural vulnerabilities, which define pathological processes of uncontrolled water access; erosion, loss of mass and cohesion; and structural stability; respectively. In order to characterize the three vulnerability types, three groups of risk factors were designed, which in turn were classified as external (circumstances outside the masonry), materials-related (in reference to properties or states of the same masonry), or anthropic (external, but with human-activity origins). Like the INSHT system, each factor was evaluated according to its amount of exposure (Level of Exposure: NE), based on a predesigned scale of five levels, from very low to very high northeast exposure.

Nevertheless, it is necessary to note that not all risk factors may have the same weight in defining the state of vulnerability. To this end, evaluations were introduced into the assessment, the so-called Deficiency levels (ND), establishing approximately the probability that a given risk factor is a source of damage. ND accommodates each case study, so the methodology is open and adaptable. By cross-referencing the values of NE and ND, the Levels Probability (NP) are obtained for each risk factor within each of the three vulnerability types. However, although a general reading of the state of the element can be had, as shown in Table 3, there is no value that characterizes a vulnerable state.

With the dual purpose of graphic representation of the NP values and identification of the characterizing value, the use of risk maps was proposed. This is the representation by a radial graph, where each axis represents a value of NP, and depicts a closed traverse. The area of this polygon is used to characterize each state of vulnerability according to a level of vulnerability (NV). Therefore, the greater the area of the polygon, the greater the accumulation of risks to the rammed earth, and hence the greater its vulnerability degree.

However, not all the analyzed elements must have the same treatment or present the same NV. There are a number of external factors (the constructive role of the element, its heritage value, its level of use or maintenance level) that involve different concepts. Evaluating these factors (general anthropic factors) in a similar way to other risk factors leads to their Consequences Level (NC), which define the impact of damage on the analyzed element itself and its users.

Once the three vulnerability types identified by three levels each (NV-HID, NV-FIS and NV-EST) and the consequences (NC) are defined, a true reading of the state of vulnerability can be stated. For this, the pre-defined risk matrices were used, which are instruments typically used in any risk assessment. These define risk levels (NR) for each group of combinations between the values of NV and NC, which is represented in the last three columns of Table 3 (NR-HID, NR-FIS and NR-EST), and in Fig. 2 for the analyzed sector.

Fig. 2 provides evidence of the NR data for each element analyzed. Red represents an accumulation of high levels for risk factors and, therefore, high risk of occurrence and development of pathological processes, producing serious consequences to the asset or its users. The diagrams show how the highest vulnerability corresponds to NR-FIS (erosion, de-cohesion, mass loss), and especially in the fabric and intermittent towers from Towers 1 to 7, which also corresponds to the first phase of intervention (Table 1). In these most vulnerable sections, corrective measures are urgently needed to repair damage, as well as preventive measures to mitigate risks and to ensure greater durability.

This assessment methodology provides an easy and useful tool to prioritize repair actions on a set of components, assigning different levels of intervention (NI) for each NR. For high NR, more urgent preventive measures and stronger corrective measures will be required, thus reducing vulnerability. Also, in the case of high NC, maintenance plans should be implemented or revised.

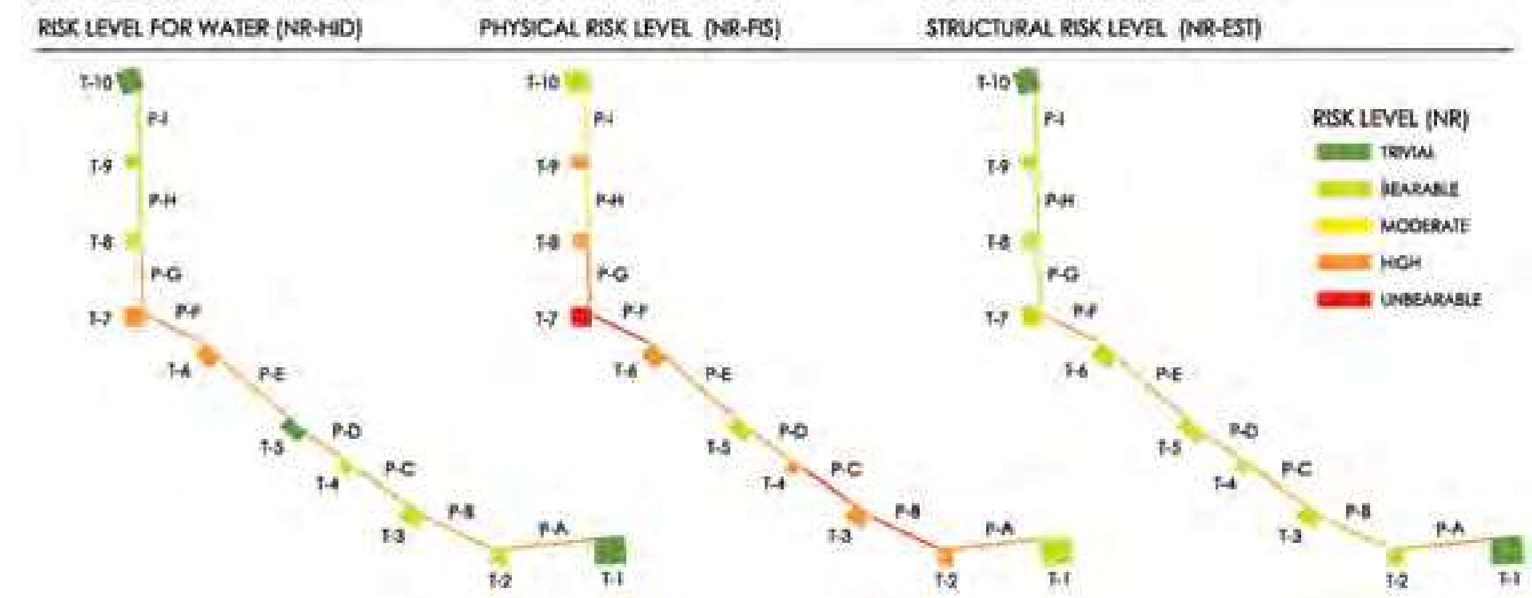

Fig.2 Distribution of the NR for the analyzed wall sections (T1 through T10) (credits: J. Canivell, 2011)

3. DIAGNOSIS AND CONCLUSIONS

The current situation of the Niebla wall, in sectors that have had no interventions in the last decade and also considering the sectors under study as a benchmark, presents vulnerability to erosion. Sections B, C and F are the most affected and sensitive, and also have high NR. These sections coincide with the first phase of restoration of Guarner González (1987). In later stages of the work, the technique and the materials used were improved, evidenced by better vulnerability conditions (sections between Towers 7 and 10). The work of Manzano (1974-75) in Tower 7 has demonstrated poor performance and shows a high NR. The poor condition and vulnerability of some elements is based in a series of associated damages: short mass composition and poor compaction of the restored rammed earth, loss of adhesion for the support, failure of certain construction solutions of stitching, anchoring and coating, leaving the original part most affected and exposed to aggressive agents. In addition, water vulnerability increases as a result of the lack of inspection on the inner surface of the wall, in which uncontrolled accumulation of soils leads to severe water leakage through the wall thickness.

Issuing a more well-founded and comprehensive diagnosis would require the analysis of the internal face of these sections, as well as extending this assessment to other sections of the walled enclosure. Supporting this qualitative assessment with a quantitative one is also recommended, which will provide more accurate information, for example, the type of lime used, particle-size distribution or identification of the mineralogical composition and clay. Thus, the comparison between the original rammed earth and the restored one would determine the suitability of interventions, as well as permit the adaptation and optimization of the materials used to serve as a reference for future action to the wall.

Generally speaking, each intervention has attempted to successively address the mistakes made by the previous intervention, with conservation solutions adapted to the current conditions. Nevertheless, lacking a broad overview over time, specific quantitative data, and comprehensive plan of restoration, the results have been insufficient and inefficient on the medium term. The absence of a control and rigorous maintenance plan, already established by Guarner González (1987), has made these sections more vulnerable, and exposed them to different environmental conditions and climatic variations. Therefore, this study tries to systematize a continuous process of review and control, which should be extended to other sections and generalized for any asset management.

Fig.3 Damage in earthen the fabric of the wall between Towers 6 and 7 in 2009 (credits: A. González, 2009)
Fig.4 Damage in earthen the fabric of the wall between Towers 6 and 7 in 2011 (credits: J. Canivell, 2011)

Notes

(1) According to the special conditions of the Restoration of the Niebla Wall by Ismael Guarner, poor cement (P-150) was used considering to that period's requirements.
(2) Any change in the source of lime required further testing for quality control of the dosage added into the mixture during the work, according to the document's special-conditions requirements.
(3) Following specifications by Guarner, adding lime improves the stabilization of the wall.
(4) The Spanish National Institute for Health and Safety at Work designed a simplified procedure for accident-risk assessment, which has been used as a reference methodology.

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DEVELOPING AN EMERGENCY-CONSERVATION PROGRAM FOR THE CULTURAL HERITAGE OF ABU DHABI, UNITED ARAB EMIRATES

Aqeel Ahmed Aqeel, Amel Chabbi, Hossam Mahdy, Ali Malekabbasi, Benjamin Marcus, Salman Muhammad Ali

Theme 7: Ancient/Historic and Innovative Solutions for Damage Prevention and Performance Improvement
Keywords: Rapid assessment, emergency, conservation, planning

Abstract

Over-shadowed by its rapid growth and new developments, the historic environment of Abu Dhabi is, in fact, rich in cultural heritage that dates back to the 3rd millennium BCE and is comprised of cultural landscapes, archaeological sites, and vernacular buildings built with traditional materials, such as earth or stone. The fragile condition of these buildings and archaeological sites has made immediate action imperative.

The Abu Dhabi Authority for Culture and Heritage launched the first comprehensive program for Emergency Conservation in 2009. The program, intended as a "first response," addresses the urgent conservation needs of these structures by ensuring their safety and stability until further measures can be planned. The program was first developed on a building-based approach; however, it was difficult to prioritize interventions and only six buildings were stabilized in 2009. To better prioritize across multiple buildings and sites, a task-based approach was adopted. A system for rapid assessment, prioritizing and planning intervention tasks, and implementation and reporting was developed (Ziegert, 2010). For each task, the material resources and time needed were estimated. Tasks were then rated, organized and scheduled based on a set of priorities into six-month cycles. The progress of a task was tracked and documented with standardized forms.

The Emergency Conservation Program has thus far been very successful in rapidly tackling a large number of issues among numerous buildings and sites, and ensuring that they are stable before carrying out longer-term conservation. 85% of emergency issues have been addressed since the program's inception with over 36 sites in stable condition. This paper will present the methodology developed for this program and demonstrate how it can be applied in response to emergency situations, such as natural disasters.

1. INTRODUCTION

Over-shadowed by its rapid growth and new developments, the historic environment of Abu Dhabi is, in fact, rich in cultural heritage that dates back to the 3rd millennium BCE and is comprised of cultural landscapes, archaeological sites, and vernacular buildings built with traditional materials, such as earth or stone. The fragile condition of these buildings and archaeological sites has made immediate action imperative.

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2. PLANNING AND PRIORITIZATION

2.1 The development of EC

One of the main challenges facing ADACH was the large number and poor condition of the Emirate's historic resources.

Fig.1 Mohammed Bin Bidowah Al-Darmaki House and Bin Shehail Al-Mottawa Al-Dhahiri House before emergency conservation (credits: Benjamin Marcus © ADACH, 2010)

94 buildings and numerous archaeological sites are listed, many of which were severely deteriorated and represented major safety threats. The urgency of the situation was magnified by the fragility and continuing erosion of the earthen fabric. The EC program was, therefore, launched in 2008 as a comprehensive program to tackle the most pressing needs. Initially, 36 high-priority sites were identified for conservation, based on their structural state and level of decay.

The buildings included in the program are mostly roofless earthen 'ruins'. The palm-wood roof beams and lintels, susceptible to termite infestation and weathering, have collapsed, leaving interiors filled with debris that were causing pressure on the walls. The tops of the adobe walls were eroded from wind and rain, while rising damp and salts in the ground were causing basal erosion. Erosion of the wall base, known as 'coving', quickly leads to structural problems such as cracks, lateral movement and eventual collapse. The sites are typically located in cultivated oases where water damage is prevalent or in underdeveloped areas where they are used as ad-hoc housing for laborers or garbage dumps. At the beginning of the program, nearly all of the 36 sites were unmanaged, or without fencing, signage or visitor control.

The most logical approach when starting the program was to implement conservation through a site-based approach, stabilizing and conserving one building after another. After a conditions assessment was made for each site, a work plan of conservation interventions was prepared and implemented. This made it easier to mobilize resources and, once work was finished, to sign off the site as a completed project.

After the first year, it became apparent that a site-based approach was not as effective as expected, as sites were attended to one at a time while others suffered further decay. The speed of implementation was also a factor in re-evaluating the program, as it required a full year to address only six sites, while urgent issues arose on other sites that were difficult to include in such a fixed program. Additionally, conservation was often hindered by management issues, such as identification of ownership, or occupation of the site by a tenant, the need for archaeological investigation, as well as closing active roads and handling hazardous materials, such as asbestos.

2.2 Task-based planning

In order to effectively address many sites simultaneously, it was thought to look at the conservation task itself as the main element of the program, rather than the site. This allowed the conservation team to deal with issues that occurred commonly across many buildings, such as vegetation and debris removal, structural problems, collapsed lintels, etc. Using this approach, an assessment was made of the remaining 29 buildings in the EC program focusing on the most dangerous conditions. The conservation team and a consulting engineer specialized in earthen construction identified areas most at risk of structural failure and provided recommendations for shoring or supporting with new adobe that would guarantee stability until long-term conservation measures could be carried out. At the same time, conditions that were serious, but did not affect the safety of the building, were also identified. The high-priority tasks were addressed first, while lower-priority tasks were carried out once the site was made safe.

This approach allowed for a more flexible and controlled program, where multiple conservation teams could move from task to task and site to site, completing parallel tasks in a shorter period of time. This was helpful to focus on the most dangerous conditions in the list of sites, grouping the type of task, training specialized workers to address a certain condition, and controlling resources, such as adobe and plaster.

It was agreed to organize the tasks into six-month cycles to better control each cycle, assess the progress of the works, and improve the next cycle based on the experience of the current cycle. The first EC cycle included around 150 tasks for 29 sites grouped by urgency level, task type, site, location and other categories.

2.3 Beyond EC

EC ensured the short-term stability and safety of buildings, but did not address all deterioration conditions or long-term planning issues, such as interpretation, visitation and reuse. Earthen buildings require active maintenance and the EC interventions are being followed by a program of monitoring, mid-term planning, maintenance, and the development of a conservation-management plan (CMP) to guide future conservation activities. Monitoring, which will be explained further in Section 4 of this paper, is critical for gauging the efficacy of conservation interventions, tracking structural movement and detecting maintenance needs. Mid-term conservation activities are intended to address conditions that were not considered emergency, such as site drainage, accumulated debris, termites,

Fig.2 Al-Suroor Southern House after emergency stabilization (credits: Salman Muhammad © ADACH, 2011)
Fig.3 Repair of coving at Mohammed Bin Bidowah Al-Darmaki House (credits: Ali Malekabbasi © ADACH, 2010)

etc. CMPs will be prepared for each building or group of buildings to guide policies for long-term interpretation and use.

3. IMPLEMENTATION

3.1 Conservation techniques

Conservation methods of the EC program are based on both traditional vernacular-construction techniques, as well as modern conservation practice focusing on authenticity and minimum intervention. Conservation mainly addressed structural threats, such as basal erosion, leaning walls, cracks, and deteriorated door and window lintels. Treatments included repairing coving with new adobe, grout injection and crack stitching, rebuilding structurally critical areas of loss, and replacing or supporting lintels. Steel scaffolding was used at most sites to temporarily support unstable walls.

Some of the buildings included in the EC program were restored prior to the establishment of ADACH, and their original fabric is heavily altered. In this case, techniques that replicate vernacular-construction traditions, such as re-rendering with new earth plaster or replacing deteriorated lintels or roof beams with new wood were considered appropriate. Other sites, with a higher degree of material integrity, have been treated with a more archaeological approach. Intervention is kept to a minimum and the focus is on reversible treatments, such as pinning with steel rods or supporting with scaffold.

3.2 Production and analysis of traditional materials

The earthen materials used for EC interventions are sourced and produced locally in Al-Ain area and were selected after a program of laboratory and field-testing. The pure clay is brought to the conservation workshop and mixed with either sand or straw to make adobes or clay plaster/mortar. A large amount of dry adobes and clay plaster/mortar is prepared in the workshop based on estimates of required materials for each cycle. A team of specialized workers carry out and control production of the adobes, as well as other materials needed for EC works, such as 'traditional gypsum', or juss, and sarooj. (Malekabbasi, 2007).

Juss, which is made by burning and grinding local gypsum-bearing stone in a purpose-built beehive shaped kiln, is typically applied to protect parapets and coat interiors of earthen buildings. Sarooj is a fired mixture of clay, straw and animal dung used for centuries in the region to waterproof roof drainage, wells and water channels.

Laboratory analysis was important during the EC program to prepare appropriate conservation materials across a wide variety of building types. Samples from nearly one-third of the EC sites were analyzed using various techniques, such as microscopy, atomic absorption or energy-dispersive X-ray spectroscopy, and X-ray fluorescence or diffraction. Testing was conducted in ADACH's laboratory, through consultants, and in collaboration with local universities. The initial aim of analysis was to characterize historic materials and to confirm the suitability of locally sourced clays for the production of adobes and plasters. Another important goal was to characterize traditional local materials already in use including juss and sarooj.

3.3 Managing site works

Beginning in 2007, a team of two master craftsmen and 18 laborers were selected to execute the works. Many of the workers came to ADACH with experience in the earthen-building tradition of their home countries, such as Iran, Pakistan, India and Bangladesh. Initially, the team was trained in earthen-conservation techniques by using test walls to practice adobe repairs, wall capping, supporting and other protection methods. The training subsequently continued at two historic buildings, Bin Hadi Al-Darmaki House (1) and Al-Jahili Mosque. During this time, the supervising conservators were able to assess the knowledge, skills and quality of all the workers, and assign them to different tasks based on their understanding and abilities. In addition to the master craftsmen, it became apparent that four other workers were highly skilled in conservation. ADACH now has a specialized team of technicians, trained over four years, who are highly qualified in different methods of conservation, restoration and protection of earthen buildings.

Three or more historic sites were usually worked on simultaneously because of the urgency of the EC works. Adobes, clay mortar and scaffold were transferred to conservation sites on a daily basis. Three building conservators supervised the site works during the EC program, each with a team of technicians and laborers. The responsibility of the site supervisor was to plan the task, arrange for tools and materials, and instruct the technicians in the appropriate techniques. Every step of a task was then recorded by daily observations, photographs, and written reports. The workers were also trained to update the site supervisors regarding materials needed or problems encountered with particular interventions.

Fig.4 Abdullah Bin Salem Al-Darmaki House showing steel pinning and shoring (credits: Salman Muhammad © ADACH, 2011)

3.4 Multidisciplinary teamwork

A multidisciplinary team, including other ADACH departments and consultants, is critical to the success of the EC program. The Conservation Department consists of architects, conservators, and a geologist with expertise in earthen building, stone, finishes, materials science, documentation and modern materials. Other specialists involved in the EC program include archaeologists, structural engineers, pest control and hazardous-materials consultants. The conservation department coordinates all coving repairs with an ADACH archaeology team who removes debris per archaeological protocol. Excavations to typically one meter below the debris horizon may reveal hidden damage to the lower walls, original foundation levels, previous repairs, as well as pottery and features that inform the building's history and significance. Rectified-photographic elevations of the excavated openings are then added to the overall documentation of the building.

Structural analyses and calculations were also fundamental in prioritizing and executing EC works. In preparation for each cycle, a consulting engineer specialized in earthen buildings visited every site, identified urgent conditions, and developed traditional and innovative solutions, such as cross-wall pinning, strapping, and shoring. The consultant's solutions relied on materials analysis and static calculations to predict the structural movement of buildings based on the wall heights and the density of the historic adobes.

Termite infestation is a major source of damage at most EC sites. Consulting specialists identified local termite species and specified treatments, such as chemical injection or bated traps. These traps were then used to regularly monitor termite activity. Similarly, asbestos was present at many sites and has been dealt with by training workers in abatement-safety procedures and by monitoring air quality during any repair works.

4. DOCUMENTATION, MONITORING AND DATA MANAGEMENT

4.1 Documentation of buildings and sites

EC sites were documented with an effective combination of tools and software that included a digital-SLR camera, total station/EDM, TheoLT®, PhotoPlan® and Photoshop®. Plans, elevations and rectified images were generated prior to any conservation intervention. In parallel to using these advanced digital techniques, the department also realized the importance of using traditional recording methods. For example, the historic oasis walls in Al-Jimi oasis (2) were recorded with a tape measure, plumb and datum lines. This project was also a good example of recording interventions with panoramic and detailed photography where the irregularities of earthen walls were difficult to capture.

4.2 Monitoring

Monitoring of the buildings before, during and/or after the intervention is an important aspect of the conservation cycle that enables conservators to detect the threat level of certain damage and react accordingly. It was important to first identify the range of building features and intervention types to be monitored, such as inherited building anomalies, permanent building features, short-term intervention methods to support conservation, and long-term intervention methods. This data was compiled into a matrix and paired with the appropriate tools and procedures that ranged from simple gypsum-crack monitors to laser-reflective targets for tracking structural movement and erosion. A flowchart was developed based on this matrix to describe the procedure to follow with regards to visit frequency and level of threats.

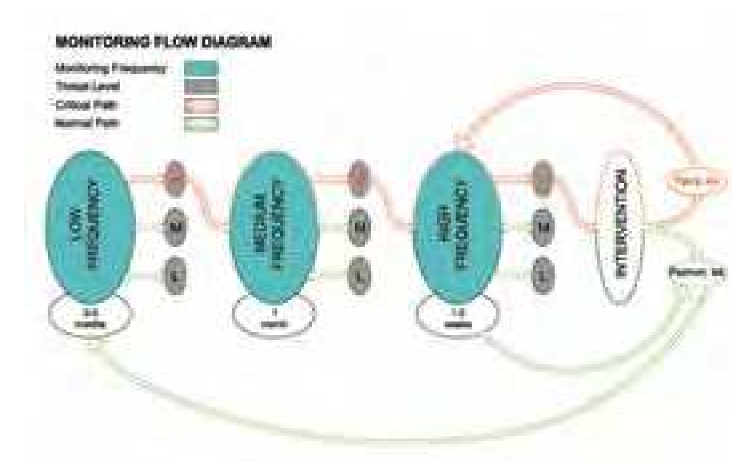

Fig.5 Monitoring flowchart (credits: © ADACH, 2011)

4.3 Reporting system (Tasks Sheets)

The recording methodology for EC is designed to efficiently capture essential conditions-data required for appropriate interventions, accurately estimate resources needed, and mobilize and coordinate the implementation phase. A set of standardized task-recording sheets was designed to record these steps. Firstly, in the Task Identification Form (P1), the conservator describes and analyzes the conservation issue and its causes, as well as proposes prerequisite actions (such as excavations, architectural documentation, or other) and the sequence of steps in the recommended intervention. P1 allows estimating time, equipment and materials. In the second form, Task Progress Report (P2), the conservator summarily tracks the progress of an intervention with regards to quality control, consumption of materials, and any time delays. The progress report can either be organized according to the sequential steps in the execution of a task or, for practicality, can be broken down into phases of execution. In the third form, Task Completion Report (P3), the conservator provides a brief narrative of the implementation of an intervention, summarizes the data pertaining to quality control, material consumption and manpower, and offers recommendations for subsequent actions (such as another intervention, monitoring, or maintenance).

In addition to these forms, issues with buildings were sometimes reported by colleagues not affiliated with the Department of Conservation, such as archaeologists and building managers. It was, therefore, essential that conservators be provided with enough information to understand the gravity of the issue and significance of the area affected before scheduling a site visit to assess conditions and potential treatments. The Task Initialization Form (P0) was, therefore, designed in order to register such requests and allow the team to prioritize actions in the cycle plan.

An Operational Activities form was also developed to register and manage the procurement and production of building materials such clay, sand, straw and adobes.

4.4 Data management

To collect, organize and manage the written, graphic and photographic records produced in the course of all conservation activities, a documentation methodology and comprehensive information-management system were established. The system provides a digital-file structure to organize records pertaining to a particular building throughout the different phases of study, assessment, planning and implementation. The organization of the folders follows the logic of a conservation-management plan. Although EC is generally tackled before a detailed study can be undertaken, it was important to establish an information system that can be populated as resources and time become available, while still providing the proper organization to classify the records produced during the EC program.

5. DISSEMINATION AND PUBLIC AWARENESS

The progress of the EC program has been regularly published through ADACH's monthly bulletin, national newspapers and journals, as well as TV and radio broadcasts. Presence in the media is a means to educate the public about the significance of Abu Dhabi's built heritage and raise awareness on the importance of conservation. The aim is to gain support for the mid-term and long-term preservation of buildings and sites by drawing attention to the urgency of interventions and need for preventive conservation.

The Conservation Department also holds public lectures at local universities and has hosted student groups from local schools to visit conservation sites and practice adobe making. Through ADACH's internship program, the department has trained young Emirati architecture students in the assessment and documentation of historic buildings. An open-door event was held to mark April 18th, the international ICOMOS heritage day, as a pilot for further engagement with the public.

6. VALIDITY AND LIMITATIONS OF THE MODEL

Although the EC program was developed to address the situation in Abu Dhabi Emirate, it can be a relevant model for emergency-conservation needs, such as in cases of natural or man-made disasters. For example, the 1992 earthquake in Egypt was the first major earthquake that hit the country and impacted its built heritage since Ottoman times. Although many highly skilled and experienced professionals were available,

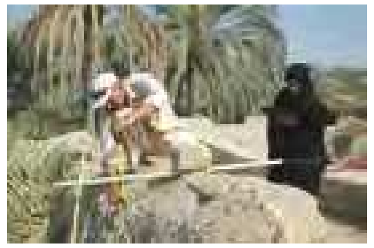

Fig.6 and fig.7 Documentation of Jimi Walls and monitoring of Abdullah Bin Salem Al Darmaki House (credits: Salman Muhammad © ADACH, 2010 - Ali Malekabbasi © ADACH, 2011)

they were not experienced in addressing the urgent need for conserving a large number of buildings at the same time, while no disaster-preparedness plan was in place. In such situations, approaches developed for the EC program can be used as a high-level model and a starting point. They address planning and prioritization, implementation, documentation, monitoring, data management and awareness-raising.

Planning and prioritization are done firstly building by building to understand typical conservation issues, followed by a task-based approach across many buildings. This is a two-way process. Once urgent issues are dealt with, a building-based approach is again used to identify and address mid-term conservation issues.

Implementation is carried out according to one of two approaches according to the authenticity of the fabric and the historic significance of the heritage. For buildings and sites of high significance and authenticity, a policy of minimum intervention is implemented after scientific investigations, studies and diagnosis. While for those that have been extensively reconstructed and are of low historic significance, a traditional master builder's approach to repair is adopted with the aim of conserving the 'tradition' as opposed to the 'fabric'.

The level of precision of documentation and monitoring is defined according to both significance and vulnerability. A regime for managing monitoring tasks across buildings guarantees control of possible deterioration and triggers appropriate actions in good timing.

A data-management system is set and a chain of task records is designed to regulate and record the whole procedure for all tasks. An internship program is designed to train students and young professionals, while dissemination through publications, group visits and public lectures raises awareness and interest in the program.

On a detailed level, approaches and methodology that were developed by the EC program can be relevant for emergency-conservation situations in the Arabian Peninsula, and possibly, the Middle East. However, the limitations of the model should not be undermined by differences in typology of the heritage fabric, construction materials and systems, environment and climate, socioeconomic and socio-cultural contexts.

7. CONCLUSION

ADACH's EC program has been successful in rapidly assessing and stabilizing a large number of threatened earthen buildings. Within the framework of the program, the Conservation Department established a planning system, documentation and monitoring protocol, materials-production workshop and skilled-labor force, and an interdisciplinary team of specialists.

In the future, the EC planning process will allow conservators to evaluate their work through quantifying and monitoring completed interventions. By tracking materials used, type and number of tasks performed, manpower, and the long-term stability of conservation interventions, future cycles can be modified and improved. The EC program is, however, only the beginning of a long process. As the EC cycles progress, less urgent issues are scheduled and priorities shift to longer-term conservation and management challenges, such as sheltering roofless buildings, reuse and/or opening the site to visitation.

The EC planning process is applicable to other regions facing a similar group of at-risk buildings or as a framework for disaster-preparedness planning in heritage areas. As the program was designed for the earthen heritage and conditions of Abu Dhabi, it must be adapted to suit different building materials, climates, and heritage-management contexts.

Notes

(1) See Malekabbasi and Sheehan (2011). Hamad bin Hadi al Darmaki House and the cultural landscape of Hili Oasis, Al Ain, UAE. Submitted for TERRA 2012 (Ref. T4-023).
(2) This opportunity was part of an internship program used to train the young Emirati female students in documentation of old walls with traditional measuring techniques.

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SEISMIC RESISTANCE IN THE CORE OF CARAL, PERU

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Theme 7: Ancient/Historic and Innovative Solutions for Damage Prevention and Performance Improvement
Keywords: Pyramids, stability, seismic resistance, reinforcement

Abstract

The great antiquity of the city of Caral and the level of engineering found in the pyramids leads to the conclusion that its construction technologies influenced the development of the ceremonial architecture of Peru and America. A first realization is that the pyramids were structurally secure due to the stability of their nuclei. The pyramids were stable as stepped platforms, resulting from the burial of previous structures, which was the religious and spiritual conception associated with the structural design. These buildings were treated as living beings that wanted to immortalize themselves with their deities, and once their stage of life came to an end, it was buried to generate yet a greater stepped-pyramid structure.

Burials of the pyramids were carried out with specific materials and technologies developed to achieve the overall stability of the pyramid against seismic events. Platform nuclei were formed through trial and error, with materials of increasing internal friction and greater percentage of voids (angular stones), aimed to increase lateral stability.

The greatest revelation was the use of tension reinforcements. Builders invented bags of vegetal fiber containing stones in a stable equilibrium, which produced a strong earthquake resistant behavior in the cores of the pyramids. These were the forerunners of today's gabion technology. The façades of stone and earth were, for aesthetic purposes, plastered and decorated. They were the mutable skin of the immortal structure.

Additionally, in Caral, the technology of wood, cane, vegetal fibers and earth was developed, known as quincha, which was later re-used in the colonial architecture of Lima, as an earthquake resistant solution following the catastrophic earthquakes of 1687 and 1746. This paper is presented by the structural group of Caral, part of an interdisciplinary team, which describes the details of the research carried out at the pyramid called '*La Galería*', where significant progress in earthquake resistant engineering has been ascertained, developed in Peru over 5,000 years ago.

1. INTRODUCTION

The European outlook for the 'New World' could potentially be misrepresented to its pre-Hispanic Mudéjar history. The meeting of Europe and America did little to save the cultural value and the historical content of the new space found beyond the seas. Native art and building techniques were undervalued.

The discovery and study of historic sites during the past 15 to 20 years, such as Sechin Bajo, Caral, Ventarrón, Chavín de Huántar, Kotosh, Huaca Prieta, which are between 3,500 and 5,000 years old, demonstrate that these are buildings, temples, ceremonial places, pilgrimage centers and cities contemporary with the dynastic works of ancient Egypt. This is, however, a fact that has only recently been revealed, effectively changing the history of Peru and America. These grandiose monuments also transcended the human dimensions and contain secrets of advanced technological knowledge. Specific natural occurrences of this area of the world include the huge seismic activity and the El Niño phenomena. These translated into recurring disasters, exacerbated by the vulnerability of the first buildings that were made with the most accessible materials: earth and stone.

The Caral pyramids were contemporaneous with adobe mastaba, an ancient Egyptian tomb in the time of their first dynasty in 3000 BC, also the time of the first pyramids of large dimension stones. The technology of Caral was so outstanding that despite earthquakes, rains and droughts, Caral maintained the same level of development as in ancient Egypt, where seismic activity is only mild to moderate (Dahy, 2010).

However, the Caral civilization lasted only about 1,000 years. Other natural disasters took their toll, like El Niño, which created periods of rain and prolonged drought that devastated

Fig.1 La Galería Stepped Pyramid, Caral, Peru, constructed of stone and earth around 2700 BCE. Signs of deterioration (credits: J. Vargas, C. Iwaki, A. Rubiños)

agriculture and fisheries with catastrophic events that changed the location of the coast, while in Egypt, 31 dynasties developed their construction technology uninterruptedly.

Consider the following comparison. By the year 2750 BCE (in the second Egyptian dynasty), the first stepped pyramid Saggara, was erected and was built only of carved stone. The increasing size of the stones used (megaliths), representing architectural grandeur, required the use of earthen mortar on masonry joints. Stability was achieved based on the size, weight and friction.

In the mountainous areas of Peru, this process was also similar, except for the elimination of the earthen mortar. It reached the same level of development. However, it did not last only 500 years as in Egypt, but seven times more, i.e. 3,500 years passed between Caral and Tiahuanaco, which also managed to work with megalithic stones for grandiosity without using earthen mortar. This technique of dry stone construction was then transmitted to the Incas, who built monumental megalithic works without earthen mortars in Ollantaytambo, Cusco, Machu Picchu and other places.

The difference in rapid technological development can be explained by the recurrence of natural disasters suffered by the western areas of the South American continent, particularly earthquakes and El Niño. Every great earthquake caused the collapse of the structure, which had already been cumulatively damaged from recurrent earthquakes of lesser severity, which were much more frequent.

The technological advances in construction was made possible by a process of trial and error, but this occurred at a much slower pace than in areas of low seismic activity and natural disasters. Earthquake resistant structural engineering is far more complex than structural engineering for areas without seismic activity. The understanding of this complexity also relates to the criteria and methodology for built heritage conservation. Caral is thought to have been abandoned, as many later Peruvian and American cultures, by a combination of disasters that caused famines and epidemics. In reality, heritage preservation in the world should be divided into two types: seismic areas and non-seismic areas. It could also be divided into areas of natural disasters, and areas without these phenomena. Peru and Western America require heritage conservation criteria different from those universally adopted elsewhere.

Recent research (Hsiang, Meng, & Cane, 2011) statistically supports the possible relationship between social conflicts or civil wars and natural disasters. In the tropics and sub-tropics, El Niño makes certain areas warmer and drier where, statistically, societies affected by famine become violent. Indeed, after the 1789-1793 El Niño, the French Revolution occurred, and after 1983-85 El Niño, “Sendero Luminoso” violence from Ayacucho exploded in Peru. Similar circumstances occurred in Angola, Haiti, Burma and several other countries (Hsiang et al. 2011).

2. THE CITY OF CARAL AND LA GALERIA PYRAMID

The city of Caral was part of one of the six oldest civilizations in the world, being the oldest on the American continent. It originated about 5,000 years ago in central-northern Peru. It was established in the valley of the Supe River, in the province of Barranca, 184 km to the north of Lima. The city was located 24 km from the coast, 350 m above sea level and occupied 66 hectares (Shady, Cáceda, Crispín, Machacuay, Novoa, & Quispe, 2009). Caral was composed of a dozen pyramidal public buildings, from which the Mayor Pyramid Building, the Central and La Galería stand out.

The La Galería pyramid is the third largest structure of the sacred city of Caral. It reaches 18.6 m in height, and has a volume of approximately 30,000 m3. It is believed that this pyramid fulfilled political and administrative functions (Shady et al., 2009). It is representative of the materials and technology used in Caral. The building consists of overlapping platforms bounded by stone and earthen masonry walls, with stairs accessing the different levels.

The platforms were built in different phases. These were initiated by the burial of the structures of the previous phase, and ended with the construction of new perimeter walls and new levels of pavements. The burials were usually composed of organized fillers to improve stability based on earthquake resistance concepts. The external walls were only aimed at fulfilling the function of façades, and not that of containment. This structural configuration is explained later in greater detail.

3. SEISMIC-RESISTANT STRUCTURAL NUCLEI IN LA GALERIA PYRAMID

The age of the sacred city of Caral suggests that the technologies developed in this place were the basis of the technological development in Peru and much of the Americas. Early research shows some common structural criteria with other contemporary ceremonial buildings, such as Sechín Bajo,

Fig.2 Reed *shicras* providing stability to the fill. There are fills with balanced vertical flat edges, which supported the upper overburden and the expansion of the *shicras*’ area (credits: J. Vargas-Neumann)

Las Haldas, as well as later cultures, such as Ventarrón, Kotosh, Chavín de Huántar (which, at the time, was considered the parent civilization), Cupisnique, Moche, Nazca, Tiahuanaco and, finally, the Incas.

One of the most interesting structural concepts is related to the burying of the preceding structures: a spiritual-religious concept combined with technological concepts. The building was considered a living being to be respected once it had fulfilled its life, and was buried instead of being demolished. The result was a pyramidal structure composed of successive structural burials. Earthquakes destabilized these pyramids and forced, through trial and error, the improvement of the materials and technology of their nuclei.

In Caral, it seems that initially cobbles were used to form the nuclei. These stones were sourced from riverbeds; and are characterized as having a very low friction angle and, therefore, high lateral thrust, unfit for the dynamic (seismic) stability of fillers. To gain roughness, the rounded edges of the stones were broken using fire (heat-fractured stones), and the stones were mixed with earth to increase stability. Then, angular-stone quarries, with even more roughness, were used. Another important step was to stem the use of earth in the nucleus, significantly increasing the percentage of voids, which reduced the specific weight of the filling mass and, therefore, the lateral thrusts, which are the ones that determine the stability of the nucleus. At some point, the technology to stabilize the nuclei made an important qualitative leap, a change that even today is astonishing. The inhabitants of the Caral area were farmers and fishermen, they knew cotton, woven fabrics and fishing nets, knew the reeds, cattails and later, sawgrass, a stronger type of reed brought down from the highlands. They created open-weave bags for transporting objects, thereby creating shicras (Asencios, 2009). They found that *shicras* could work as reinforcement for the nuclei of pyramid platforms (Vargas, Iwaki, & Rubiños, 2011).

The fibers and the fiber bags had tensile capacity, better than the fragile materials (lumps of dried earth and stones), which were plentiful and accessible. To combine them together was very innovative, as a bag filled with stones became a structural unit of great virtues. It was easily transportable, and the traction of the fibers controlled the tendency of stones, placed upon each other, to fall apart or roll.

The bags full of stones were used to form the nuclei of the pyramids. These bagged stones did not convey lateral pushes to their neighbors. Therefore, they could create mounds of bagged stones, which had stability on their own and stabilized the nuclei, which improved the structural behavior of the fill, especially under vibrations and forces of lateral inertia during earthquakes. Caral is a precursor of the modern gabion technology.

These bags of vegetable fiber (junco, white grass, etc.) contained a volume of stone and were called *shicras*. These are a constructive element, that is a very advanced concept for its time, which could be efficiently used in modern times for slope stability and control of landslides. The volumes of the *shicras* found can weigh between 15 kgf to 2,000 kgf. The result of their use was the successful construction of assembled piles of mounds or stable pyramids, with optimal earthquake resistant features. The pattern of *shicras* fill was determined. These differ in their disposition, quantity and their interaction with other materials, such as gravel and large stones.

The concept of assembled piles is a precursor of stability concepts in modern times. It is a structural criterion associated with movement control through reinforcement, instead of increasing the resistance of the constituent material, which collapses when earthquakes produce large forces and efforts greater to the resistance of the impacted materials.

Modern building codes use, for different materials, design criteria based on the performance or movement control, rather than design criteria based on resistance (Vargas et al., 2011). This technological leap surpassed that of the contemporary Egyptians. Some Egyptian adobe masonry mastabas have traces of pieces of wood used as local reinforcement (lintels), but no reinforcement distributed throughout the nucleus. In Caral, this was due to the need for the nuclei of the pyramids to be earthquake resistant and not simple fills.

The structural feature of the nuclei caused the walls or the façades not to have a significant structural function. Their purpose was to provide a surface for plastered or painted decorative features, and to define the building. The nuclei withstood earthquakes and the pyramids were stable. The walls were vulnerable, but their collapse did not affect the overall stability of the pyramids.

Research carried out in the field, measured the slenderness of the walls and the volumes of the associated structural nuclei, and it was determined that due to the geometrical and physical characteristics, the walls would not be able to withstand lateral thrust, if there were no *shicras*. The nuclei were stable against earthquakes, but the walls could collapse and be rebuilt (Vargas et al., 2011).

The second type of nucleus structure adds a stone wall of large stones with no mortar, which separated the shicras core and the angular gravel fill. For practical reasons on very long walls, the angular gravel fill, glued to the wall façade, was also bagged in *shicras*. These were, possibly, reconstructions situations, where the facing is remade into a new position to the outside.

The third type of structural nucleus seems to correspond to the earliest periods, before the use of *shicras*. Indeed, the nucleus contains loose angular stones, a solution of high coarseness and low unit weight (an improvement which prevails over the technique of the first fillings with rounded river stones and earth, cut rounded stones and earth, and quarried angular stones and earth). These are found only in the lower parts of the pyramid building. This type of fill was far surpassed by *shicras*.

4. STONE AND EARTHEN-MORTAR FAÇADE WALLS

The walls were not structural elements intended to contain fills and nuclei; rather they were decorative elements of the façade system. The resistance of the pyramids was entrusted to the nuclei and not the walls. It was understood that the nuclei withstood earthquakes, and the walls did not, which could be more easily repaired.

The lower wall resting on the ground was generally composed of large stones (1.00-1.50 m). The joints were filled with small wide stones of about 200-300 mm, known as pachillas. These allowed the insertion of smaller areas of earthen mortar within the joints, which ranged between 20 to 50 mm, thereby more efficiently controlling cracking due to shrinkage of the earthen materials. The height of these walls could be 3.0 m with a thickness of 400 to 700 mm. The largest stones were placed at the corners. The stones were of very different sizes, but the largest stones were chosen for the base. This was intuitive and can be explained by the difficulty of raising the largest stone. The stones for the corners were valuable and re-used with each subsequent expansion. It has been verified that the walls of this style are positioned on natural soil in a layer of 100-150 mm of gravel and earth.

The facing of the upper platforms is typical and the most common. It consists of a relatively homogeneous arrangement of stones of sizes between 300-500 mm. The shapes of the stones, though irregular, tend to be rectangular and their bases horizontal, clearly the result of good carving abilities. Between the stones, there are pachillas of 100-200 mm wide to decrease earthen mortar thickness to 20-50 mm. These were used in the stepped platforms resting on earlier platforms, and not on grade. The height of the existing walls is about 1.60 m, reaching in some areas a maximum height of 2.10 m. The thickness varies between 350-400 mm.

As a variable of these, some very untidy facings are present on upper platforms. These not only include irregular stones (less carving work), but have also lost the horizontal system of courses. It is possible that these variations depend on the

Fig.3 The first type of nucleus structure in La Galería pyramid (credits: J. Vargas-Neumann)

Fig.4 Alternative to the first type of nucleus structure (credits: J. Vargas-Neumann)

working staff, and the ages of the expansions that occurred to the different pyramids of Caral.

The walls were plastered and painted, which shows their function as finishes, as well as the architectural planning. The coatings were of high quality earth and straw to avoid shrinkage cracking. The builders knew how to avoid cracks by mixing earth with coarse sand particles, and controlling cracks with straw to prevent micro-fissures from drying (Vargas, Bariola, Blondet, and Metha, 1984).

5. *QUINCHA* SEISMIC RESISTANCE TECHNIQUE

Another very important technological development that originated in Caral is *quincha*, known in other parts of America as wattle and daub. *Quincha* is a construction technology that uses timber framing, cane or vegetal fibers, coated with earth to build walls, which are then plastered with earth and straw. *Quincha* walls are an elastic structure of narrow thickness and low weight, which has a very efficient earthquake resistant behavior due to its great capacity to dissipate energy caused by earthquakes.

Quincha structures found in the upper platforms of La Galería pyramid incorporated wooden trusses formed by vertical Huarango logs of 150-300-mm diameter, spaced approximately every 400 to 600 mm, along with horizontal elements comprised of bundles of four-six reeds with 25-40 mm diameter, 100-200 mm apart but tied together. These were

a) b)

Fig.5 The oldest example of *quincha* found in America. a) *Quincha* structures; b) Trusses (credits: J. Vargas-Neumann)

secured in place by vegetable fiber ropes. These are covered by earthen plaster placed in two or three layers of 50 mm. The first layer is composed of dark-gray earth that is less clayey. The second and third layers are formed with a yellow earth with a high plasticity and adhesive quality clay. All layers contained organic material (grass or straw). It is still possible to see in some parts that the finish was whitish-color paint.

The location of *quincha* on top of the pyramidal frustum is not accidental. Quincha was of a different material, lighter weight, higher elasticity and flexibility, and of different architectural expression. It had very good seismic behavior and its use must have been predicated by the needs of the spaces formed, for example, the probable existence of lightweight and safe covers, which provide shade and ventilation to environments used for extended periods of time.

6. CONCLUSIONS

The Galería pyramid is a structure of overlapping and staggered platforms, resulting from expansions and successive burials over an extended period of time, possibly around 1,000 years according to archaeologists. This pyramid is fairly representative of the rest of pyramids or mounds built at Caral. There, it is obvious the differences of geometric shapes and probable uses.

It has been shown that the most important structural element was the nucleus structure that provided stability to the pyramid. This stability was based on the use of reinforcement for its traction, which controlled dynamic forces caused by earthquakes. It has been shown that the walls did not meet the most important structural functions (except for their own stability). They role was only to demarcate the building's exterior and to provide a vertical surface that could be plastered, painted, or decorated.

The main reinforcement elements of the structural nuclei were the *shicras*. These controlled deformations and displacements similar to contemporary gabions. However, the shicras have undergone a process of deterioration that has caused the loss of their primal structural characteristics. Earthquakes of later centuries tore down the walls and exposed the *shicras* to weather and ultraviolet rays, reducing their durability and resistance. Even so, the *shicras* and the *quincha* walls are reliable and a robust development of earthquake resistant knowledge at Caral and in the surrounding Supe Valley.

The division of the world into seismic and non-seismic regions has recently raised awareness that there must be a fundamental difference in the structural concepts of conservation, which define intervention processes. This raises the need for new design criteria for heritage recovery, based on earthquake resistant structural performance. It means that movement of elements cracked by earthquakes must be controlled, especially those formed by fragile and vulnerable materials. This means the rational use of reinforcement (capable of resisting tractions) with minimal intervention characteristics, material compatibility, original technology and reversibility. In Peru, there is a movement that seeks to establish criteria or specific principles for seismic activity and the high vulnerability of the materials that make up Peruvian cultural heritage, such as earth, stone set in earthen mortar, quincha, etc. It is based on the principles that consolidation solutions to archaeological sites such as Caral must be sought. It requires training of inter-disciplinary teams to develop and discuss the alternatives for each situation. The sooner these are developed; the sooner decisions and results for preservation will be obtained.

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EARTH AS A STABILIZATION AND CONSOLIDATION ELEMENT FOR BUILT-HERITAGE FOUNDATIONS: TWO CASE STUDIES IN BRAZIL

Silvia Puccioni

Theme 7: Ancient/Historic and Innovative Solutions for Damage Prevention and Performance Improvement
Keywords: Foundations, recovery, tamped earth

Abstract

This paper deals with the use of earthen materials in the consolidation/stabilization of monument foundations from experiments conducted between 2001 and 2004, whose design and implementation were coordinated by the author. For both cases, the author adopted the methodology of her master's thesis, developed from her experience in conservation and restoration of historical Brazilian buildings. The case studies were characterized by characteristic fissure damage at the foundations.

Damage assessment was followed by trials and evaluation,which enabled diagnosis and the design of interventions for the project. The verification of disaggregation and high moisture content of the soil, along with the results of physical characterization tests, substantiated the option for a system of recovery of the structural capacity of the foundations.This occurred through the substitution of the soil with Cyclopean rammed-earth blocks positioned laterally to the foundations, to attain their lateral confinement. This system was compatible with the overall behavior of buildings, whose foundations are direct, continuous and of low depth.

The observation of current state of the two monuments proves that the system adopted was adequate to enhance the structural capacity, since there was no movement or deformation of the masonry. The intervention adopted in the case studies presented in this article preserves the integrity and the authenticity of the original foundation structure of the buildings. Moreover, it also allows its reversibility, as it can be removed without harming the historic building material.

1. INTRODUCTION

This paper presents the application of the methodology that the author developed as part of her master's thesis from the Federal University of Rio de Janeiro. This research was based on the experience of conservation and restoration works on buildings of historical and artistic value in Brazil (1). This paper demonstrates the restoration interventions on two monuments: the Igreja Matriz de Santo Antonio and the Cathedral of Valença, both in Brazil.

2. IGREJA MATRIZ DE SANTO ANTONIO

The Igreja Matriz de Santo Antonio is located in the city of Tiradentes, Minas Gerais, on a hill. In the back, there is an old cemetery. The church was constructed on rammed earth and dates back to the first half of the 18th century. The façade, however, was rebuilt in the second half of that century, using stone masonry with stone ornaments, in accordance to the project of Antônio Francisco Lisboa, also known as Aleijadinho (little cripple), the greatest Brazilian artist of the colonial period. The church is considered one of the most significant monuments of Brazilian Baroque (2).

In 1994, several signs of degradation were detected in the structure of the building, such as, cracks on the sidewalls, on the towers, and, especially in the main façade, where the fissures jeopardized a large swath of stone, on the façade sculpted by Aleijadinho. Also, a large deformation and displacement of the upper-perimeter containment wall was observed.

The IPHAN engineer, head of restoration and structural conservation was asked to solve the problem. Initially, temporary buttressing of the span over the front door was foreseen, to prevent rupture of the central section of the façade, while the repair projects were designed and financial resources required for the execution of the work were secured.

The next step involved documentary research in the archives of Minas Gerais and Rio de Janeiro, in order to obtain a complete history of the physical condition of the monument. Simultaneously, topographic surveys of the entire surface of the church envelope were addressed, and a series of

Fig.1 City of Tiradentes, Minas Gerais in Brazil; on the top right is the Igreja Matriz de Santo Antonio (credits: IPHAN Archive)

mechanical and physical tests performed to better understand the condition and stability of the church. Geotechnical drilling, foundation inspection wells, installation of basal and deformation checkpoints, geotechnical surveys, analysis of non-deformed and deformed soil samples, and measurements of variation in the level of groundwater monitored for three years were completed. Control of the vertical alignment of the perimeter retaining wall was also addressed.

This phase was followed by the analysis and evaluation of the results of all studies conducted so far. It was found that the level of the foundations' base extended to 2.20m below the ground surface. The soil-strength test, SPT type, demonstrated that the soil had low capacity to support medium to high plasticity, with compressibility characteristics up to 5.00m deep. Monitoring of the foundation confirmed the existence of inhomogeneous settlement of the structure. The groundwater level monitoring also determined the existence of a large variation in level associated with the wettest periods, which was exacerbated by the excavations in the cemetery annexed to the church. Investigation of the vertical alignment of the perimeter wall showed a very small height ratio and, therefore, inadequate for ensuring the security of the structure.

Those results supported the diagnosis of the condition of the foundation's stability for the main structure of the church, especially in the area of the towers, where the geotechnical drillings implemented in the area of the foundations indicated that the topsoil had a very low-support capacity. This discovery led to the need for intervention, to improve the behavior of the foundations. Large variations in the groundwater level explain the existence of large gaps due to the undermining of the soil. These variations depend on the infiltration of rainwater, and the fact that the church is built on an area of surface waterdrains and on the slope of the hill. This increases the risk, in terms of the precariousness regarding the capacity of the foundation soil. These facts led to the recommendation of a drainage system throughout the area surrounding the building site, and the recovery of the street drain existing in the back of the church, which was heavily eroded. Excessive deformation of the perimeter containment wall showed failure of transverse inertia to ensure its stability, which led to a proposal for its partial dismantlement and its reconstruction with a suitable geometry, along with an efficient drainage system (Puccioni, 2010).

The proposals for strengthening the foundations of the monument sent to IPHAN by engineers of Minas Gerais highlighted the following: lateral reinforced-concrete bands at the foundations interconnected transversely; reinforced-concrete bands associated with piles that would work by lateral friction; and the implementation of a system of piles inserted directly into the foundation.

As the diagnosis suggested, the main cause of the damage to the structure was related to the low capacity of the surface soil to support the foundation, especially in the area at the front of the monument, which led to another intervention strategy. Whereas the foundation's resistance capacity was unproblematic, the ground around it was not. Therefore, the hypothesis arose of directing the intervention to the lateral soil supporting the foundation and not the foundation itself. The substitution of the lateral soil bordering the two sides of the foundation, by another soil with adequate physical and mechanical characteristics to perform the geotechnical functions necessary to promote stability of the monument was suggested; thereby increasing the resistance to breakdown through shear forces of the foundation soil. This would also reduce to acceptable levels the slow densification process of the foundation soil, while preventing degradation by short- and long-term phenomena.

The developed project consisted of protecting the area of lateral influence of the foundation by associating resistant and low-permeability veneer of rammed earth with an underground drainage system peripheral to the outer area of the monument. The drainage system was intended to eliminate or reduce the variation of groundwater levels, and incorporated surface drainage, which would allow a rapid evacuation of the accumulated water from the grass and paved areas, including the existing street at the back of the church.

Studies for the detailing and specification of the rammed earth veneer began with geotechnical studies performed in the laboratory, using samples of natural soil collected at two points at the level of settlement of the foundations in the region of the towers, in order to verify geotechnical characteristics, including permeability. It was proposed to stabilize the rammed earth veneer with the addition of a small amount of cement to reduce its permeability. Laboratory tests showed that the mixture of natural earth with cement resulted in a material with ideal permeability and resistance characteristics to reintroduce the mass of earth laterally bordering the foundation, indicating the success of the working hypothesis. This solution was linked

Fig.2 Rammed-earth veneer to protect the foundations of the Igreja Matriz De Santo Antonio (credits: Silvia Puccioni, 2000)

to a sewage system, accomplished through drainage channels adjacent to the rammed earth veneer to avoid layered stagnation of the water retained by the curtain.

The implementation of a rammed-earth veneer to protect the foundations was divided into three parts, starting from the part of the right tower, followed by the part of the left tower, and finally the central part of the façade (Puccioni, 1988). This sequence aimed to relegate to the last stage of intervention to the central section, the most sensitive area, being the veneer of Aleijadinho. Thus, the risk of structural movements was avoided during the accomplishment of the work on the façade, as the lateral sections were already stabilized.

The first stage of the work on the front section of the church consisted of dismantling the external and internal floors, whose stones were identified and stored for subsequent re-installation. This stage included the removal of mortars, fillers and other renderings.

The second stage involved the excavation of the two sides of the foundation in alternatingtrenches of 1.00 m length and 1.00 m width, in order to install the rammed earthveneer adjacent to the foundation. The excavation was carried out to the level of settlement of the foundation, and the removed material placed next to the excavation. In a third stage, the voids, gaps and failures of the foundation blocks were in-filled, using variably graduated stones.

Afterwards, the 'shearing tooth' was prepared, consisting of the removal and subsequent reinstallation of larger stones, greater than the interface of the block and rammed earth veneer.

The next phase comprised the immediate rebuilding with rammed earth, compacted in layers up to the height of the original floor. Finally, the rebuilding of external and internal floors, removed in the first stage, was completed.

Along with the improvement of adjacent soil to foundations, an underground drainage system was also designed, encircling the entire structure, in order to direct groundwater away from the perimeter of the church. This project involved the implementation of a deep drainage channel, adjacent to the outer perimeter of the foundations and the rammed-earth veneer, providing a boundary wall for quick drainage of water from groundwater percolation, which might rise to a higher surface level in the area planned for the structure of the church. This could be detrimental to the stability of the foundations, especially in times of heavy precipitation, when the highest and most undesirable levels of groundwater occurred.

3. CATHEDRAL OF NOSSA SENHORA DA GLÓRIA

Given the success of the previously described experience, a similar solution was applied in 2003-2004, on the restoration of the Cathedral of Nossa Senhora da Glória, in the town of Valença, in the State of Rio de Janeiro (Lyra, 2006). The construction of this church began around 1820 and was completed in the second decade of the 20th century. Its construction system was composed of stone masonry bearing walls joined with lime, clay and sand mortar (3).

In this case, the issue involved stabilizing the area of the foundation of the towers that were in precarious condition. The instability of the towers, which had already fallen, was related to the precarious condition of the soil at the foundations, which included disaggregation and high humidity. Another cause was the mismatching base due to the extraction of soil in the second decade of the 20th century, when it was undermined by the construction of a square on the adjacent plot. The restoration of the support of the foundation through the reconstruction of a section was implemented on the sides and fronts of the towers in the adjacent plot, by installing a rammed-earth veneer, and thus restoring the original ground level. With this resolution it was possible to re-stabilize the church without further intervention in the square.

The recovery of the foundations of the churches was performed using the following steps: removal of the floor, digging in alternating trenches with variable widths; in-filling voids, gaps and failures along the foundation blocks; re-pointing of the foundation masonry; linking of elements between the earthen veneer and the existing foundation. Immediately afterwards, infill with cyclopean rammed earth was accomplished. Finally, the original floors removed in the first stage were rebuilt. A system of surface and underground drainage was built as well, in order to maintain a constant level of subsoil moisture.

4. CONCLUSIONS

The use of this methodology for diagnosis, preceding the work itself, was essential for the accurate identification of the causes of deterioration of the monuments. Thus, applying this methodology in the initial phase of the work, including the collection of archival

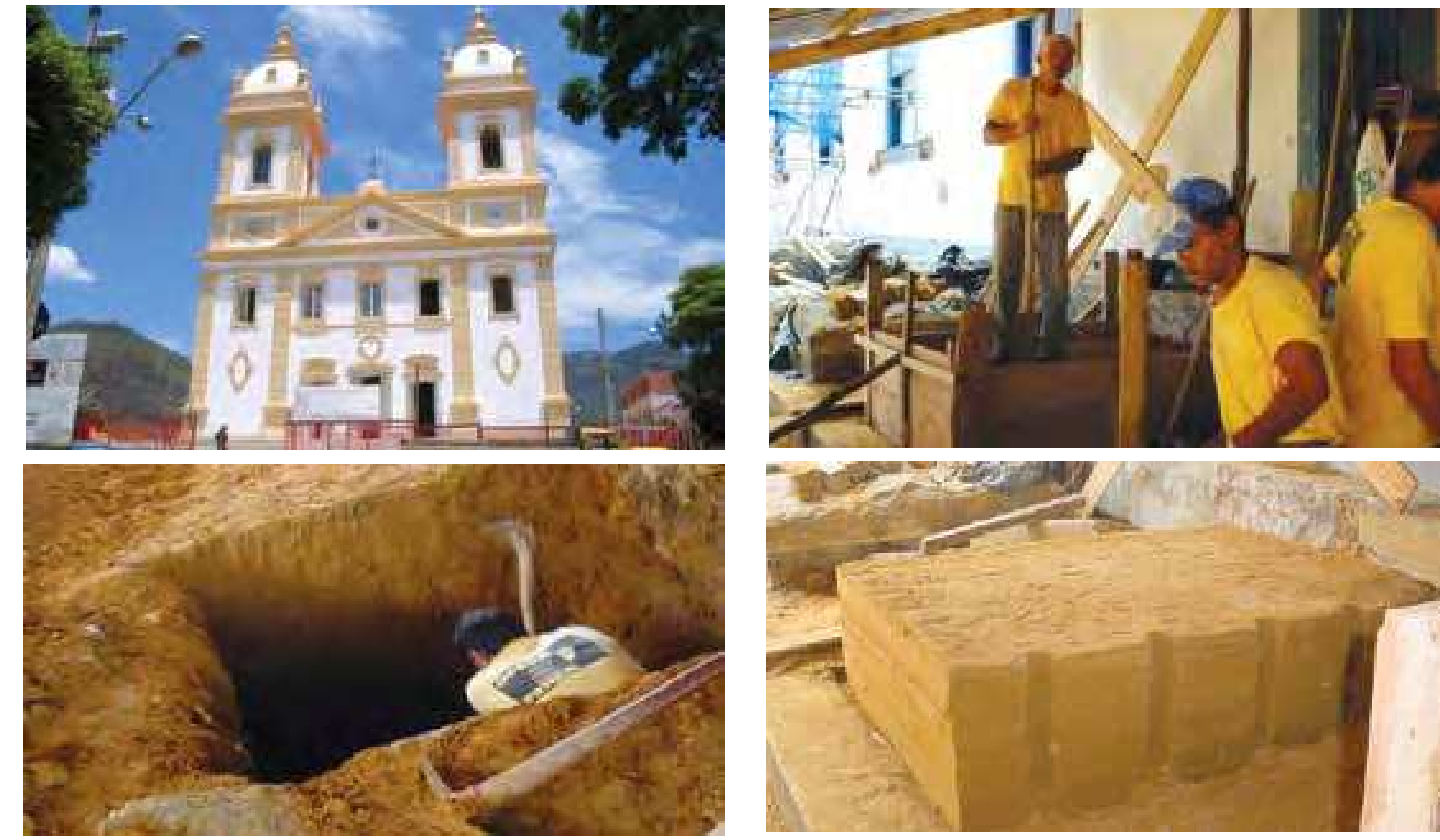

Fig.3 Cathedral of Nossa Senhora da Glória in Valença, Rio de Janeiro, Brazil. Rammed-earth veneer at the bottom of the façade is observable (credits: Silvia Puccioni, 2000)

documents and information about the building, followed by geotechnical tests enabled the realization of an accurate diagnosis. This, in turn, supported the intervention plans. Whereas the foundation was unproblematic in terms of resistance capacity, the ground around it was not. Therefore, the hypothesis for intervention was directed toward lateral soil to support the foundation, as opposed to the foundation itself. In addition, the substitution of the confining lateral soil on two sides of the foundation by another soil with physical and mechanical characteristics adequate for the geotechnical functions performance was proposed.

Eleven years after the implementation of the stabilization at the Igreja Matriz de Santo Antonio de Tiradentes, and seven years after the work on the Cathedral of Nossa Senhora da Glória in Valença, the system of stabilization of foundations with the use of a rammed-earth veneers was found to be suitable to the structural behavior characteristics of foundations in traditional Brazilian buildings, since no new movement or deformation of the masonry has occurred. This recovery system preserves the integrity and authenticity of the original foundation structures of the buildings, and has the characteristics of reversibility, since it can be removed without damaging the building materials that have a relevant historical value.

Notes

(1) The thesis was developed within the Master's of Architecture course developed by the author in 1994-1997 at the Federal University of Rio de Janeiro, Brazil.
(2) The Iglesia Matriz de Santo Antonio was registered in the *Livro do Tombo das Belas Artes of IPHAN*, the Institute for Historical and Artistic Heritage. It was registered as an heritage asset of cultural relevance on November 29, 1949, as N°329.
(3) It is a historical and artistic monument protected by the laws of the State of Rio de Janeiro, through the registration of the historic center of the town of Valença in the Livro de Tombo of INEPAC, the State Institute of Cultural Heritage. It was registered as a heritage asset of cultural relevance in the year 2004.

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STANDARDS FOR THE CONSERVATION AND RECOVERY OF EARTHEN HERITAGE, PERU AND CHILE

Julio Vargas-Neumann

Theme 8: Charters, Standards and Guidelines for Heritage and Construction
Keywords: Standards, earthquake, heritage, conservation

Abstract

This paper presents relevant criteria used in two important official Standards that guide intervention to earthen built heritage in Peru and Chile: 1) the revision of Peruvian Standard NTP E-080 and presentation of Seismic Resistant Conservation Principles for Earthen Heritage; and 2) the Chilean Standard for Structural Intervention in Earthen Heritage Construction. Both cases arise for the first time in either country. In Latin America, these principles or standards cover a huge gap in the regulations for the design of the maintenance and repair of heritage buildings damaged by earthquakes.

A new and indispensable element has been the integration of risk management techniques to disasters, through international declarations and charters for heritage conservation. It foresees the inclusion of social organization in national plans for disaster, as well as the treatment for earthen built heritage, during the three stages: Mitigation Emergency and Recovery. Unlike what was commonly done in the past, it is of paramount importance to stop any attempts at heritage demolition, damaged during the emergency phase of an earthquake.

Therefore, the importance of a pre-demolition or intervention study and the condition of the heritage building is emphasized, to assess the significance of its cultural values and to deeply identify its structural stability. Regulations highlight the vulnerability of earthen material and its tendency to sudden collapse threatening the lives of the occupants or visitors. It also emphasizes the desirability of using criteria based on performance design, which means installing permanent reinforcement to control the movement in damaged heritage structures. However, the use of such reinforcement must meet three conditions: 1) Minimal intervention, to preserve its heritage significance; 2) Compatibility with earthen material, to prevent deterioration due to the reinforcement itself; and finally, 3) Reversibility, to modify or withdraw the reinforcement when better solutions are available.

1. INTRODUCTION

Regulations aim for global sustainability. Regulations work to improve technology and social organization, so that the environment can recover at the same rate that it is affected by human activity. Regulations attempt to develop solutions for durability.

The material advantages of earthen construction are known, such as low pollution, energy savings, low thermal and acoustic conductance, sensory compatibility (visual and touch) with nature and the rural landscape, economy, self-built construction, and easy access to earth as a building material in harmony with the environment. Disadvantages are also known, like the vulnerability of earthen buildings to disasters such as earthquakes or floods, the difficulty of spreading the technology to protect them, and social organization to mitigate the damage and loss of life against these disasters.

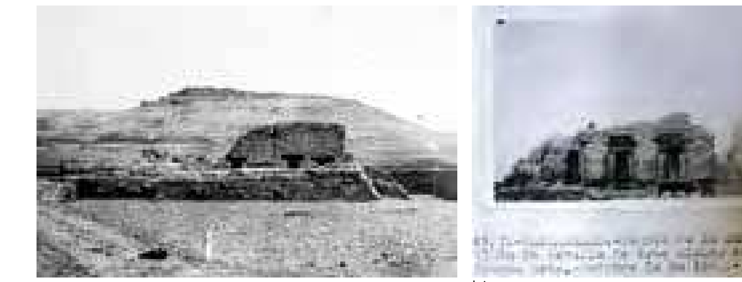
Treatment against natural disasters or risk management has three phases: the emergency, the recovery and the mitigation. These can be associated with short-, medium- and long-term actions, respectively. The last phase is the one that involves prevention and preparedness efforts, wherein society should be organized by all means for the next of these recurring disasters, through regulations.

2. PROTECTION OF EARTHEN CONSTRUCTION IN SEISMIC-PRONE AREAS

Earthquakes are natural disasters that produce loss of life and extensive natural damage, especially in the American costal area of the Pacific Ocean. This area is part of the Circum-Pacific circle, where about 95% of the seismic energy in the world is released as a result of an ongoing process of continental drift associated with the inner make-up of the planet and its dynamic equilibrium.

Some of the countries most affected by these disasters have studied the behavior of earthen construction, either houses or buildings of cultural significance. Experimental studies and post-earthquake observation are the major source of information to mitigate damage from these phenomena and to develop new repair technologies and more stable construction. The study, research and design of the material, existing technologies and their further development are a relevant part of mitigation tasks. Regulations are the technical foundation to build better. Dissemination and technological transfer is an essential, but a rather complex task. Peru was a leader in this area of concern for several decades. Therefore, here are presented the outstanding achievements and regulatory efforts of Peru (ININVI, 1977; MTC, 2000), and more recently, of Chile.

Fig.1 Collapsed houses during the earthquakes of Pisco, Peru, 2007 and Maule, Chile, 2010 (credits: J. Vargas-Neumann, 2007 y 2010)



a) b)

Fig.2 a) Ruins of the Temples of the Moon and Sun (back); and b) Detail (credits: Archive J.C. Tello, 1940)

3. EFFECTS OF EARTHQUAKES ON ADOBE BUILDINGS

The main structural elements of earthen built housing are the walls. Columns, arches, vaults and domes built of earth have collapsed over time due to the action of earthquakes. They are no longer part of the construction typology in American seismic prone areas, but they are found in other areas of the seismic world, and are the causes of fatal accidents.

Earthen structural elements have limitations to seismic safety as the material is heavy, offers little resistance and is fragile. This limits earthen architectural design as well. Peruvian architecture has been influenced by seismic history. The remaining earthen houses from the Colonial era have dense walls, which are very wide with few and small openings.

Increasing soil scarcity in urban areas produces earthen housing with thinner walls and large windows, imitating the architectural models of more resistant materials, such as brick. Nowadays, earthen houses are built very vulnerably.

Roofs of earthen masonry disappeared as a result of earthquakes during the time of the Spanish colony (1532-1821). There are still some remnants in churches. Lighter roofs, along with reed and quincha materials, have replaced them. For ceilings and walls, a type of quincha was developed, which started in the 17th century, and flourished in the Republican period (from 1821 onwards). Quincha is a mixed technique of wood, reed, vegetal fibers and earth, and the oldest traces have been found in Caral, Peru dating to 5,000 years ago (Vargas, Iwaki, & Rubiños, 2011).

The quality of the soil on which the earthen buildings or other vulnerable materials are sited is also a significant factor in their destruction due to earthquakes. Firm soils transmit seismic waves to constructions almost without modification, but soft soils significantly amplify the movement of the foundation soil. This dynamic amplification is a determining factor for the amount of destruction. The Peruvian Standard prohibits earthen buildings on loose, soft, filled and organic soils.

4. EARTHQUAKE DESTRUCTION OF EARTHEN-BUILT HERITAGE

Many testimonies of seismic destruction of earthen archaeological heritage are located throughout the coast and highlands of Peru. A prominent example that has been studied is Pachacamac, especially its Acllawasi Temple, located near Lima. Pachacamac's north-south and east-west roads connected to Qhapac Ñan are shaped by stone walls set with earthen mortar, which have been destroyed by earthquakes since Colonial times. Recently reconstructed, they clearly reveal that the technology of earth and stone masonry set with earthen mortar is inadequate to contain fillers or soil deposits in seismic prone areas.

A good example is the Acllawasi Temple, built by the Incas initially in stone around 1450. It was seriously damaged by earthquakes, and rebuilt with local materials (adobe and wood and reed ceilings) by the same Incas. Photos and drawings from the Julio C. Tello Archive show the remaining vestiges of the temple after the earthquake of 1940, and these account for the inexorable seismic destruction of almost five centuries. Julio C. Tello rebuilt the temple from 1941 until 1945, and four subsequent earthquakes have damaged it again. Today, it is no longer possible to visit the temple for security reasons. The seismic damage of cultural heritage is permanent, cumulative and tends to collapse the structures up to the point where their historical value disappears.

a)

b)

Fig.3 Tests of adobe modules on vibrating table a) Unreinforced module; and b) Reinforced module (credits: Joop den Uyl, file PUCP, 1982)

5. DESIGN CRITERIA FOR EARTHQUAKE-RESISTANT CONSTRUCTION

There are three major design criteria to provide security for earthen buildings:

- Criteria based on resistance;
- Criteria based on stability;
- Criteria based on performance or behavior.

Traditional earthen construction designs have been based on strength and stability. Thick walls are more resistant and stable. The width of walls is, therefore, an important variable. Historical buildings or ruins that have survived earthquakes, although very damaged, are robust, less slender and with small openings. Also, wall density, or the ratio of wall area to covered area in each of the directions of study, is another important variable.

Earthquakes produce dynamic soil movements as sequences of combined and complex waves. Soil movement induces movement in buildings, which, at peak times, are very large, usually quite higher than those supported by the materials. Strong earthquakes crack earthen walls due to their low resistance, and these will gradually become divided into unstable pieces. Based on resistance and stability criteria, too bulky and expensive construction would have to be considered in order to avoid collapse. In general, earthen buildings are insufficient to withstand strong earthquakes and, therefore, are hazardous to life safety.

Modern design criteria for performance consider the most efficient way to control movement and to provide greater security. This consists of the use of reinforcement materials with greater traction. The use of reinforcements must conform to an acquired knowledge, including laboratory experimentation and mechanical testing, as well as the invaluable experience of observation after each earthquake.

The compatibility between the proposed reinforcement and earthen materials is indispensable. Introduced reinforcement, by its hardness, elasticity, texture and strength, helps control the movement of cracked structural elements so as to avoid partial and total collapses without local damage to structural earthen elements. Historic construction requires additional minimum reinforcement, aimed at achieving an intervention

Fig.4 Module reinforced with synthetic mesh or geogrid with total reinforcement and coating of half of the module (credits: File PUCP, 2007)

that impact, as little as possible, the cultural heritage and also respects authenticity. While design criteria for performance is now universally used for all fragile materials in modern construction standards, it should be noted that 5,000 years ago in the culture of Caral, reinforcement was also used for earthen construction, such as plant fibers and the use of mixed earthen technologies combined with wood and reed (Vargas et al., 2011).

6. RESEARCH TO MITIGATE SEISMIC DISASTERS

Since the 1970s, the Engineering Department of the Pontifical Catholic University of Peru (PUCP) has been concerned with the study of the stability of earthen construction in seismic prone areas. The first work was aimed at determining the mechanical properties of adobe masonry walls by static experiments, and the search for efficient reinforcements. In the 1970s, a rotating platform was used to statically test full-scale housing and various reinforcing materials, such as reed, wood and wire (Vargas, 1978; Blondet, 2004). The most efficient reinforcement at this stage was vertical reed meshes, tied to horizontal layers of crushed cane (Vargas, Blondet, Tarque, & Velásquez, 2005).

To better understand the influence of material properties on the resistance of adobe masonry, a project with funding from USAID was developed in 1983 (Vargas, Bariola, Blondet, & Mehta, 1984). The main conclusions were that since the mortar is responsible for the integration of the masonry, clay is the most important component of the soil used to build with earth, as it provides the link between mortar and adobes. Yet clay also shrinks when drying, causing cracks in the mortar. Adding straw or coarse sand to the mortar can control these cracks.

In the 1980s, the first seismic experiments were conducted on adobe house modules using a unidirectional vibrating table (Ottazzi, Yep, Blondet, Villa García, & Ginocchio, 1989). The housing modules used had no ceiling and were tested with and without internal reed reinforcement, in accordance with the

Fig.5 Avoid strengthening with reinforced concrete beams and columns, because they aid in collapse instead of protecting adobe walls, as in this example of the church of San Luis de Canete, damaged during the Pisco earthquake in 2007 (credits: J. Vargas-Neumann, 2007)

National Building Regulation (MTC, 2000).

The main conclusion drawn was that when faced with a severe earthquake, unreinforced structures collapse (Fig.3a). The interior reinforcement of horizontal and vertical reed plus an upper wooden collar beam prevents separation of the walls and maintains some integrity during repeated severe unidirectional earthquakes (Fig.3b), providing the option for future repairs.

Later, another line of research began to develop more efficient reinforcement systems to avoid sudden failures using industrial materials. Synthetic geogrid reinforcing has proven to be very effective. The geogrid must completely cover both sides of the walls and to be fixed to the upper collar beam of the walls.

7. REINFORCED EARTH, A NEW SEISMIC -RESISTANT MATERIAL

As a result of research and post-earthquake observation, it is possible to improve the seismic resistance of earthen constructions, if compatible and traction resistant reinforcements are added. This new material is reinforced earth, which endows structures a large deformation capacity. During an earthquake, although reinforced earth walls present some cracks, they maintain their deformation capability and continue withstanding gravity and seismic loads, safeguarding lives and allowing for their future repair.

8. REQUIREMENT FOR REGULATIONS AND GUIDELINES

To ensure the safety of reinforced earthen work, regulations are required. In the case of heritage buildings, where the cultural value must be preserved, conservation guidelines are also required as it is difficult to establish standards with minimum specifications, which may not be met anyway, because these buildings already existed.

9. SOCIAL EARTHEN-CONSTRUCTION STANDARDS IN PERU

Based on the studies described, since 1977 (Vargas et al., 2005), Peru has a standard for earthen building, which was revised in 1985 and 1999. It is currently under revision again with a new rural and urban vernacular emphasis.

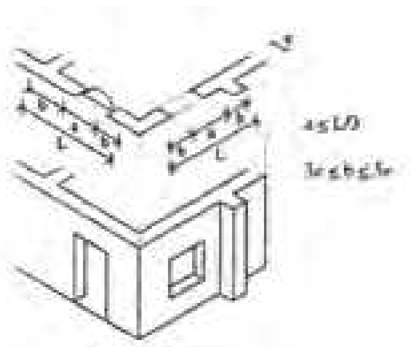


Fig.6 Specifications for wall openings; the relief of the buttresses must be equal to "b" (credits: Norma NTE Adobe, 1999)

The 1985 version was used as the earthen building chapter in Guidelines for Earthquake-Resistant Non-Engineered Construction (IAEE, 1986), which influenced the production of other national standards, such as in India and Nepal. Other countries have also had their regulations inspired directly by the Peruvian Standard (Morocco and Chile). It has influenced also the *Recomendaciones para la Elaboración de Normas Técnicas de Edificaciones de Adobe, Tapial, Ladrillos y Bloques de Suelo-Cemento* from the Habiterra thematic network (CYTED, 1995), including Nicaragua, Ecuador, Brazil and other Latin American countries.

Earthquake Resistant Design (EQRD) standards are legal policies containing technical provisos for structural design of buildings in seismic prone areas. For weak and fragile earthen buildings, the philosophy of EQRD must accept the occurrence of cracking in moderate quakes, while ensuring the protection of the lives of the occupants, and preventing the occurrence of collapse during moderate and strong earthquakes by installing essential reinforcements. The current Peruvian Standard (MTC, 2000) specifies that adobe buildings are to be designed by rational methods based on the principles of mechanics with elastic behavior criteria. However, it also recommends wall reinforcements to improve seismic behavior.

Seismic thrust is represented by a basal lateral force H = SUCP, where C is the percentage of weight to be applied laterally to simulate the seismic force, and depends on the seismic area. In high seismicity areas, C is equal to 0.20. S, the soil factor, is 1.00, if the soil is good (rocky or firm soil), and 1.20 when the soil is intermediate. The use factor, U, is 1.00 for housing and 1.20 for other buildings, such as schools, medical centers, or public buildings. The weight, P, should include the dead load plus 50% of the live load.

Observations of damage from past earthquakes indicate that adobe buildings located on soft soils have significantly greater damage than those located on firm soil. The S coefficient increases to 1.35 for intermediate soil, and construction on soft soil is not proscribed. In the area of greatest seismic activity, the construction of two-story adobe buildings is not endorsed; this is appropriate only in areas of lower seismic hazard. It is recommended that the second floor be built with lighter materials, such as *quincha*, as was also the direction of the Viceroyalty Royal Ordinance after the great earthquake that destroyed Lima and Callao in 1746.

A symmetrical plan is recommended with adequate wall density in two perpendicular directions, small and centered openings. Walls together should be connected together using reinforcements. The foundation must be built with stone masonry. The foundation level must be met by cutting and never by infill.

The *Peruvian Standard* specifies the allowable stresses for adobe masonry. It also specifies that the walls should be well connected. The vertical bracing can be cross walls, buttresses or reinforced concrete columns. The upper collar beams, made of wood or reinforced concrete, are the horizontal reinforcement and must be applied to all walls. However, the current revision to the Standard does not recommend reinforced concrete columns or beams because of their difference in hardness and rigidity with earth.

The walls must comply with certain geometric conditions to ensure good seismic behavior. The maximum length between wall bracing should be 12 times the thickness of the wall, and the openings must be central and small.

Currently, it is known through experimental verification that synthetic meshes are the best reinforcement alternate. This reinforcement was included in the Peruvian norm after the earthquake of 2007, as it has proven to be efficient. Reinforcement requirements depend on the slenderness of the walls. The Standard permits unreinforced construction of slenderness walls less than 6. However, the current review of the Standard recommends reinforcing all earthen walls and limits slenderness to 8 or 10 depending on the seismic area. This is based on laboratory and field experience, which revealed sudden life-threatening flaws for occupants (Vargas, Torrealva, & Blondet, 2007).

10. GUIDELINES FOR HERITAGE BUILDINGS IN CALIFORNIA, USA

In order to understand life-safety issues for occupants of historic buildings of earthen masonry, the Getty Conservation Institute (GCI) with advice from Peru conducted a research program, known as the Getty Seismic Adobe Project (GSAP), which determined recommendations for performance criteria. The types of reinforcement developed in California from 1990 to 1996 (Tolles, Kimbro, & Ginell, 2003) provided some kind of ductility, as well as local and global stability. Slender walls require more aggressive reinforcement solutions and these can become irreversible. The main tools selected were:

- Upper wooden collar beam, as recommended by the Peruvian Standard;
- Horizontal upper and/or lower ties of plastic or steel;
- Vertical ties near the corners and openings of synthetic material;
- Central nuclei of synthetic material in the walls (non-reversible solution).

11. PRINCIPLES FOR SEISMIC RESISTANT CONSERVATION OF EARTHEN-BUILT HERITAGE IN PERU

The Specialized Committee in charge of reviewing and updating the current Standard E-080 Adobe decided to include under the section of existing structures, a chapter for the intervention on buildings of cultural value. This chapter required principles for the preservation of heritage buildings. The proposed principles were unanimously agreed upon, and will soon be part of the National Building Regulations of Peru.

Under the Venice Charter (ICOMOS, 1964), when traditional techniques prove inadequate (e.g. against the cumulative destruction from disasters, such as earthquakes), the consolidation of a monument can be achieved by the use of modern techniques for building conservation, whose effectiveness has been demonstrated by scientific data and experience. The application of these was initially aimed at architectural heritage, but it also extends to aspects of archaeological sites of architectural value, according to the Lausanne Charter (ICOMOS, 1990).

The vulnerability of materials, such as earth, forces conservation compromises, when disasters like earthquakes create vulnerable situations on earthen structures in seismic prone areas. The cycle of damage-restoration-damage associated with earthquakes and earthen heritage has occurred for many centuries. Newly documented during the last century is the starting point for technological change in the prevention of heritage built in seismic prone areas. In Peru, the need to develop adequate principles to preserve heritage was understood. Conservation charters were generated in the West, whereas the principles were generated in the East. These did not consider the fact that the world is geographically divided into seismic and non-seismic areas. Some architectural heritage principles assert urgent protection measures to prevent the imminent collapse of the structures, for example, following the damage caused by an earthquake, as mentioned in the Charter Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage (ICOMOS, 2003). However, today it is considered necessary to act before the occurrence of earthquakes, with a preventive culture, and not acting only in emergency, after the earthquakes have created irreparable damage.

Every intervention should be based on proper studies and assessments, not only on durability against weathering and natural deterioration, but also on the resilience against disasters from seismic activity. Problems should be solved according to local and particular conditions, respecting aesthetic, historic, scientific (physical integrity, materials, technology, stability) and social values of the structure itself or of the historic site. Any proposed intervention should aim to:

- Preserve and prevent deterioration of the building;
- Maintain traditional techniques and materials of special value;
- Ensure the safety of the occupants;
- Keep the intervention to a minimum to ensure authenticity;
- Be technically reversible and compatible with the original material;
- Allow further necessary conservation actions;
- Facilitate future access to information incorporated in the structure.

The decision to use "traditional" or "innovative" techniques should be weighed on a case-by-case basis, always giving preference to techniques that produce as minor an invasive effect as possible, and those that are more compatible with the values of cultural heritage, never forgetting to meet the requirements imposed by the seismic safety and the durability.

Minimum intervention on the fabric of earthen or of earthen-based historic structures is the ideal. Notwithstanding this fact, the minimum intervention aimed at ensuring the preservation of structures damaged by earthquakes may require its partial disassembly and subsequent reassembly, aiming at its proper preservation and the employment of necessary reinforcement. The anastylosis methodologies of intervention can be an option, by using a solution of earthen mortars or addition of liquid earth (sieved earth) as an integrative material, seeking the maximum use of the original earth or similar earth. As for additives, the use of chemicals or industrial binders should be avoided. These have no real evidence of durability, or may, in time, have a behavior that will generate discontinuities or subsequent deterioration.

To better understand these principles, defined as minimal intervention, is the set of actions necessary to prevent further deterioration to a historic building, such as reversible reinforcement, temporary or permanent, which can be substituted by a better solution without causing significant damage to the historic structure at a later date. Compatible reinforcement, even in advanced stages of deterioration of the fabric, helps controlling the movement of the original structure, without further damage.

12. CONCLUSION

Chilean engineers developed advanced building regulations for all materials except for earthen construction. The weakness of the material and the amount of life lost from earthquakes in vulnerable earthen houses and churches were certainties that advised against promoting any further construction with earthen materials. However, Chilean families were raised in adobe or quincha houses, and many of the ancient buildings built of those materials now constitute valuable cultural heritage.

The earthquake of February 2010, which hit mainly the central part of the country, destroyed much of this heritage. The community reacted looking for the legal means to obtain permits and licenses to repair and rebuild its lost cultural value. The Institute of Construction organized a Commission for Heritage Construction, which created a Committee for the Chilean Standard of Structural Intervention in Earthen

Building Heritage, in order to develop the first legislation that would allow a legal conduit for the reconstruction of damaged heritage. The absence of earthen seismic resistant construction experience, research, builders and masons skilled to perform the great task of restoring historic churches, manor houses, museums and public buildings built of this material resulted in the decision of using the experience developed in Peru.

The inclusion of Peruvian engineering by the Committee of the Standard allowed the quick development of a legislative draft, which was submitted to the Ministry of Housing and Urban Development (MINVU). After a period of discussion, MINVU collected observations and issued the official version. The document clarifies that it is not aimed at promoting new buildings, but rather the reconstruction of the existing earthen heritage. Adobe, rammed-earth, *quincha*, and stone masonry with earthen mortar are the techniques covered in the document.

Characteristic values of the allowable stresses for adobe masonry are encompassed, as well as the design, by analysis methods and traditional calculation. These include reinforcement recommendations with materials resistant to traction and compatible with the earthen material, such as the synthetic mesh developed at the Pontifical Catholic University of Peru. The main chapters of the Standard are intervention, structural and economic criteria, structural design (design philosophy); diagnosis of the monument; registry of the building (description); analysis and verification of the design and the geometry; mechanical properties of the material, design and calculation basis; structural intervention plan, restoration, reinforcement system, implementation and maintenance.

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PREVENTIVE CONSERVATION: A CONCEPT SUITED TO THE CONSERVATION OF EARTHEN-ARCHITECTURAL HERITAGE?

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Theme 8: Charters, Standards and Guidelines for Heritage and Construction
Keywords: traditional practices, risk, management

Abstract

The concept of preventive conservation (PC) is relatively old, as the term was already in use as early as the end of the 19th century. As the definition implies, the theory of preventive conservation was developed mainly in the context of work on movable heritage. Yet the concept appears to be equally applicable to built heritage, and more specifically to earthen-architectural heritage whose basic raw material is usually fragile by nature and in some circumstances, can decay relatively fast.

Though earthen architecture is varied, one of its characteristics is that for each typology, there is always a specific way of ensuring durability or minimizing the risk of damage. This is achieved by implementing a variety of measures that depend on the physical, economic and social context of the site. What is interesting is that all of these measures are aimed at protecting and extending the life expectancy of the structures in question, thus linking them to the concept of preventive conservation.

This leads to the conclusion that preventive conservation is by its very nature a concept well adapted to earthen structures. Taking into account climate change, which brings about unusual situations, reinforces the suitability of the concept, which allows us to anticipate natural disaster.

This paper examines the suitability and limits of applying the concept of PC in the conservation of earthen architecture through theoretical analysis and practical examples. It concludes with recommendations for its adoption, taking into account intrinsic specificities, and both the tangible and intangible values of the heritage being considered for conservation.

1. INTRODUCTION

The concept of preventive conservation is relatively old, having been in use as early as the 19th century. Yet it has not been widely utilized by practitioners. It was only in recent times, after the acceptance of the failure of the more commonly used methods of 'remedial conservation' that the concept reappeared in the 1970s, gained ground in the 1980s, and acquired recognition as a specific discipline in the early 1990s.

The concept was widely disseminated, mainly through the efforts of ICCROM (International Centre for the Study of the Preservation and Restoration of Cultural Property ICCROM (de Guichen, 1999) posited that preventive conservation should be defined as follows: *"The full range of actions designed to safeguard or increase the life expectancy of a collection or an object."*

As this definition implies, the theory of preventive conservation was mainly developed in the context of work on cultural material, primarily by ICCROM, but also by other organizations, such as the Association of Art, Archaeology Restorers with University Education (ARAAFU) or the International Institute for the Conservation of Historic and Artistic Works (IIC).

However, at the beginning of the 1990s, North American professionals enlarged the field of application to historic buildings and housing artifacts, by adopting the New Orleans Charter (APTI/AIC, 1990-1993). This initiative did not move further, though the concept of 'risk management', which is nowadays quite widely considered, is similar, but in general is limited to disasters.

By the mid 1990s, a partnership with ICCROM (1) led CRAterre to explore the possibility of applying the concept of preventive conservation to the conservation of the Palais Royaux d'Abomey in Bénin. The results of this experience being quite promising, CRAterre decided to continue this exploration. This was the start of a series of field activities throughout the world in which preventive conservation was considered as a priority for the definition of conservation strategies and, further, for their implementation. The following is the result of this exploration, and the current state of our reflection on this question.


Fig.1 and fig.2 Preventive measures at the Royal Palaces of Abomey, 1996, Prema Project, ICCROM, CRAterre, DPC Benin (credits: Thierry Joffroy, 1996)

2. ADAPTATION OF PREVENTIVE CONSERVATION TO THE PRESERVATION OF EARTHEN-ARCHITECTURAL HERITAGE

When we started to consider preventive conservation, we quickly agreed with the idea that the concept could be applied to built heritage. However, if the problems of conservation and destructive phenomena were similar, it was also clear that the environmental factors, the scale of the work and the budgets involved were different and more complex. But adaptation was possible, and the old adage "*prevention is better than to cure*" is probably hard to question. The financial savings that this could bring was also evident, and this was a very important consideration for CRAterre, which works in the field of low-cost housing. The concept was also quite well expressed by what became a motto in the framework of the GAIA project (2): "*Maximum understanding, minimum intervention*" (A. Alva).

In trying to adapt the definition of preventive conservation to immovable cultural heritage, it was quite natural to just complete the existing so that it could apply at the same time to both immovable and movable heritage. Thus, the definition was extended as follows: "*Preventive conservation is the full range of actions designed to safeguard (or increase the life expectancy of) cultural heritage, artifacts or built structures*".

Looking at the specificity of immovable heritage, and more specifically, its related environmental and scale limitations (as compared to museum objects), we formulated an additional concept: "*ensuring that the risk of damage is reduced to a minimum*". The fragile nature of earth as a construction material is a factor that makes preventive conservation even more suitable. In certain circumstances, the destruction of structures built with earth develops quite fast. Hence, the importance of anticipating damage risks, and in many instances, the need to be able to intervene quickly so that the process can be arrested before pathologies develop to an irreversible stage.

An observation or review of the various traditions used for building earthen structures makes it clear that durability is often aspired to and that it is achieved by implementing a whole variety of measures. These are often complementary with specific choices/uses that are adapted to the specificities of the physical, economic and social context of the site. What is interesting to note, however, is that all these measures are aimed at protecting and extending the life expectancy of the structures in question. Thus many of those can be associated with preventive-conservation measures, which leads on to the conclusion that preventive conservation is by its very nature a concept well adapted to earthen structures.

Such traditional measures include:

- The use of architectural shapes that generate minimal damage;
- The carrying out of regular maintenance work on a larger or smaller scale;
- The protection of earthen structures by other, more resistant, materials;
- The physical-chemical stabilization of earth with natural products that improves its physical properties.

It is, therefore, logical to assume that in order for preventive conservation to be successfully implemented at a specific heritage property, it is appropriate to first and foremost:

- Gain awareness of the range of these traditional measures in order to be able to identify those that are/have been used in the construction of the relevant structure(s);
- Have a good understanding of the circumstances and processes of degradation;
- Evaluate the validity of these solutions for the heritage in question;
- Look at the range of other possible preventive measures, including those that might be required in order to adapt to climatic change, and with a specific outlook to 'living' heritage;
- Envisage the consequences of their implementation;
- Look for the adaptations needed to ensure integration, taking into account the evolution(s) of the cultural, social and economic environment.

In this respect, it is important not to lose sight of the fact that in certain cases, the durability of the structures has not traditionally been the main objective. We need to recognize that in some cases, on the contrary, this relative durability linked with the possibility of recycling the raw materials presents endless opportunities for adapting or modifying structures, if not rebuilding them from scratch.

This, therefore, allows the user to adapt his immediate environment as he pleases, as his needs and wishes evolve. These instances of traditions very much caught up in a process of evaluation raise what are specific conservation questions, because to a large extent the authenticity of these structures lies in this ongoing evolution. In some cultural areas, earth structures have gradually been reinforced, covered or partly replaced by other more resistant materials, just as a natural development process.

In the same line it is important to recall here that conservation is to be value-oriented and that in addition to technical considerations, the values and the elements carrying them need to be well identified. In the field of earthen-architectural conservation, the issue of patina and its significance often leads to dilemma when taking conservation decisions.

Fig.3 Traditional rendering of the Askia tomb by the overall population of the city, Gao, Mali (credits: Aldiouma Yattara, 2014)

3. IMPLEMENTATION OF PREVENTIVE CONSERVATION

The following presents a proposal for an intervention methodology constructed around 10 steps and points to be considered towards the application of the principles of preventive conservation to an earthen architectural heritage. The technical approach described does not exclude a participatory approach. On the contrary, working with stakeholders and sharing decisions with them is most of the time a plus towards an effective and successful implementation of preventive conservation. Some recommendations:

A) Examination of the site:

- Documentary research;
- Supplementary documentation of the building(s);
- Study of the physical, social and cultural context;
- Identification of the parties involved – individuals and interest groups.

B) Identification of causes of damage (diagnosis):

- Examination of the building in the light of its function (in connection with the way its durability is assured);
- Gathering of information (previous studies, works already completed);
- Repair of the 'disease' (effects of damage);
- Identification of definite causes (circumstances and processes);
- Identification of probable causes, and those still requiring verification.

C) Classification of causes according to risk level:

- Damage;
- Progression of damage (active or passive);
- Risk of damaging effects following one after the other ('domino' effect);
- Elaboration of a risk hierarchy;
- Risk prioritization.

D) Urgent measures:

A first series of urgent measures can be implemented. These can include:

- Provisional repairs, consolidation, stabilization;
- 'Permanent' (see point G below) repair;
- Specific treatment (against insects, animals…);
- Others.

Some of the above-listed measures may require a research-development phase before application, so as to ensure that the result is as close as possible to what is expected.

Fig.4 Traditional preventive measure of snow removal from a wall and wall base in Khiva, Uzbekistan (credits: Thierry Joffroy, 2003)

E) Implementation of regular inspection (monitoring):

- At least once a year and,
- In the wake of specific events (exceptionally heavy rain, storms, fires).

These inspections must cover most of the activities described in points 1 and 2 above. The assessments submitted will facilitate the elaboration of an annual conservation plan.

F) Regular maintenance:

It is desirable that maintenance should be the focus of a practical memorandum stipulating not merely what actions need to be taken but also within which time span, as well as the personnel, financial resources and equipment necessary.

It shall include activities of various types, such as:

- Tidying up and de-weeding the territory surrounding the earthen architectural heritage;
- Repairing and maintaining surface drainage;
- Treating roof timbers;
- Re-plastering.

Regular maintenance can also include ongoing work to eliminate secondary risks, which were not covered by the initial plan for urgent measures.

G) Repair:

Despite well-advanced efforts to avoid all damage, repairs of varying magnitude (preventive conservation) can prove necessary as a result of:

- Accidents or vandalism;
- Certain materials wearing out;
- Or in order to make a structure suitable for use again (rehabilitation).

In such cases it would be appropriate to proceed with repairs of a temporary or permanent nature (at the same time the concept 'permanent' should be used cautiously, since no materials last forever). 'Permanent' repairs, of course, cannot be undertaken unless sufficient documentation (tangible and intangible, movable and immovable) is available to make it possible to proceed with due respect to the authenticity of the site. If doubts remain, repairs can still be carried out, as long as it is made clear where the repairs start and the original structure ends. In the case of earthen structures, it can prove difficult to mark that demarcation. It is, therefore, necessary to keep a thorough record of the intervention.

Recent research has made it possible to perfect or apply technical solutions, which can prolong the life of earthen materials considerably. It is, however, appropriate to thoroughly evaluate:

- Their effectiveness in relation to the type(s) of earth available;
- The cost of the envisaged repairs;
- How easy they are to implement;
- If the authentic nature of the site is being respected.

In many instances, research will be necessary to ensure that the treatment suggested is giving the expected results (physical, aesthetic properties).

H) Developing or nurturing expertise:

Preserving skills is essential in order to ensure that work will be carried out with due respect for the authenticity of the building(s). Initially, documentation relating to expertise should involve the following:

- Identification, selection and recruitment of skilled personnel;
- Research into documentation on the relevant expertise;
- Research and experiments, if the relevant expertise has been lost or new solutions are planned.

If traditional channels for the transmission of the relevant expertise appear undermined, it would be appropriate to take steps to revive it by:

- Practical training (in the case of a large number of traditions);
- On-site training;
- Specialist training;
- Academic training.

Promotion and market research in connection with expertise are also a solution, which has to be considered, since facilitating practical experience and making it an integral part of modern life represents a major guarantee for the survival of expertise.

I) Natural resources

In some cases, the conservation of heritage and of the practices traditionally linked to it depends on the availability of the natural resources. These could include:

- The earth itself: this may involve several qualities and, therefore, several quarries;
- Vegetal infusions, such as trees, plants that are used as additives;
- Animal infusions like hair, dung.

Regarding the work itself, water is often very much required. Taking this into account, it is also important to verify that these resources can be available, both on the short and long term. For example, in some cases, the protection of a quarry can be paramount to ensure that the right building material is available. The improvement of access to water can also be a very important factor facilitating the continuation of some of the traditional conservation practices of regular rendering of historic structures. Besides that, the protection, and when necessary, the regeneration of tree species that are used for lintels, roofs, and beams can also be a paramount factor for ensuring that proper conservation work is implemented.

Fig.5 Test walls at Loropeni, Burkina Faso, WMF project (credits: David Gandreau, 2004)

Fig.6 Preventive measure with sacrificial capping, Fayaz Tepa, UNESCO-Japan-Fund-in-Trust project, Uzbekistan (credits: Thierry Joffroy, 2003)

J) Equipment:

Many of the proposed interventions presented above can only be implemented if specific equipment is available. In some cases, the acquisition of modern equipment (mixer, crane) can be a good alternative for diminishing the load of work, and might be required when social practices have diminished. Equipment that can be useful includes:

- The means for regular inspections, such as transport, cameras;
- Equipment required for condition surveys, like ladders, templates;
- Site-work equipment, such as transport, tools;
- Equipment for research and experimentation, like laboratory, templates, experimentation facilities;
- Organization of the documentation, such as hardware and software, files, shelves.

4. SPECIFITIES WITH REGARD TO ARCHAEOLOGICAL SITES

Archaeological sites have several specificities:

- They are prone to plunder and to the impact of public works;
- They do not have their traditional protection and so are often very much unstable, though, generally, they have deteriorated into a relatively stable shape (Tepa); when excavated for research, their relatively stable shape is changed and often renders the structures prone to quick decay.

These considerations lead to the necessity to:

- Ensure that impact studies are undertaken before large public works are planned;
- Ensure that sensitive sites are protected/guarded;
- Ensure that conservation measures are planned together with the excavations, with the possible use of temporary shelters, backfilling, and/or work that ensures stability and renders possible the visibility of the revealed artifacts/structures.

This last proposal is paramount, because poorly conducted excavations or those abandoned can lead to rising damp at the base of structures; poorly regulated surface drainage is extremely dangerous for earthen structures, and can result in complete destruction of the discovered structure.

5. FINANCE AND MANAGEMENT

Even though preventive conservation is an economical way of conserving heritage, it can only be put into practice if regular financial resources are available to enable the implementation of the full range of the proposed measures. In fact, it is still difficult to make a complete separation between the concept of preventive conservation from the broader one of 'heritage management', which involves legal, administrative and institutional issues, the exploitation and promotion of the site, permanent and/or temporary staff, operational partnerships, as well as technical and financial resource considerations.

In this context, all efforts (activities) undertaken in connection with the development of the site can be regarded as preventive conservation, as soon as they are aimed directly or indirectly at generating resources and thus at making possible the provision of regular financial support, at a level adequate to ensure that the site concerned is monitored and regularly maintained. Paradoxically, this could extend as far as partial reconstruction (naturally based on thorough documentation) provided that it enables visitors and decision-makers to appreciate the site better. At some point, there is an intervention at the site, those who pay for it are often interested to 'see the difference'. That might need to be addressed, at least partially. At the same time, such cases must remain the exception, knowing as we do that there are numerous other ways for promoting a site effectively, like guidebooks, publications, maps, panorama plinths, exhibitions, organization of cultural events.

Considering that all these actions can prove to be effective and useful in relation to high-quality conservation of the site, it is desirable to consider a preventive-conservation approach as part of the site's management plan. It is appropriate to remember the cultural significance and the attractive features of a site to be conserved, and that these are crucial for a correct identification of the conservation aims, the activities and measures adapted to the conservation of the site in question and their prioritization. Finally, over and above the elaboration of such a plan, only a dynamic vision of the future is effective. It is, therefore, appropriate to periodically revise the plan so as to adapt decisions and objectives in light of research being carried out and results obtained. If the site evolves, the interest in it will also rise. One also needs to take into account the evolution of the site's physical, social and cultural context.

6. CONCLUSION

As long as preventive measures are very common in the traditions of building and living in earthen buildings, preventive conservation appears to be naturally suited to the conservation of earthen architectural heritage. In our changing world, and more specifically, with regard to climatic changes, such a preventive approach also appears to be very compatible, as it can easily include the risks linked to it (risk management). In the context of a possible long-running economic crisis, its capacity to lead to low-cost solutions is also a very strong advantage.

This paper has proposed a methodological approach for its implementation and provides a list of points that probably needs to be considered when trying to apply it. Through the reflections presented herein, one can realize that preventive conservation cannot be implemented without putting it into context of a larger management scope, which obviously also implies the involvement of stakeholders and, to a certain extent, sharing decisions with them.

Furthermore, we also need to realize that in its basic concept, preventive conservation may lead us to freeze heritage in the state in which we found it. But as developed herein, the very nature of this heritage might evolve and freezing it might not be the right way to respect its authenticity. In the same vein, especially when dealing with living heritage (historic centers, cultural landscapes), it is also important to take into account the other recommendations that have recently been established by the conservation community (e.g. the Vienna Memorandum) that opens the reflection on the need for changes (acceptable changes) to ensure that living in heritage remains possible, a primordial condition for its conservation.

Preventive conservation cannot be applied strictly in every situation, but it is a very useful concept for all those who wish to conserve earthen architecture but have limited means available to them. It also often leads to decisions that had naturally come to those who built and, later on, maintained these heritage structures, ensuring the authenticity of the interventions.

Notes

(1) A partnership between ICCROM and CRAterre was established in the framework of the PREMA program (Prevention in Museums in Africa) at the occasion of a major field project at the Royal Palaces of Abomey, Bénin, a World Heritage Site.
(2) The GAIA project was a joint initiative by ICCROM and CRAterre developed between 1988 and 1998, which included advocacy, research and training activities.

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INTERNATIONAL HERITAGE CONSERVATION PRINCIPLES IN EARTHQUAKE ZONES, JAPAN

Kanefusa Masuda, Olga Keiko Mendoza Shimada

Theme 8: Charters, Standards and Guidelines for Conservation of Heritage and Construction
Keywords: Lima Declaration 2010, Venice Charter 1964, Nara Document 1994, World Heritage

Abstract

The Lima Declaration, adopted at the "International Symposium on Disaster Risk Management of Cultural Heritage; Sustainable Conservation of Urban Cultural Heritage in Seismic Zones" on December 3, 2010, says at its beginning that "*World is divided into seismic and non seismic areas. Earthquakes occur mainly along two big circles: The Circum-Pacific where more than 95% of seismic energy is dissipated and the Eurasian circle. Following the International Conservation Charters and conservation policies, now we address the cumulative damage to cultural heritage associated with severe earthquakes prone areas.*"

Japan and Peru are both located on the Circum-Pacific Seismic Zones, and also have rich cultural heritage, including many UNESCO World Heritage cultural sites. The structures of these heritage are mainly constructed with earthen, stone or wooden material, all ecological and natural materials, easy to reuse again for the reconstruction works after the earthquake disasters. For their sustainable protection and safety for human life, we need to constantly take care for the structures and be prepared for the next earthquake disasters based on management plans. Heritage values after reconstruction deeply depends on craftsmanship, one of the four tests of authenticity in the evaluation of World Heritage sites. Our heritage values are thus deeply related with intangible values, like techniques and community traditions.

The Venice Charter in 1964 and the Nara Document on Authenticity in 1994, both guiding principles for the World Heritage system, and both adopted in seismic countries like Italy and Japan, do not have enough tools necessary for sustainable protection against earthquakes. We need careful understanding of existing conservation principles, but if they are not enough, we have to examine a new principle to solve this problem. This paper intends to clarify the above points, introducing recent disaster experiences in Japan, especially the case of East Japan Great Earthquake in 2011 and Kobe Earthquake in 1995.

1. INTRODUCTION

East Japan Great Earthquake, which occurred at 14:46 on the afternoon of March 11, 2011, with a magnitude 9.0, caused great tsunami disasters along the northeast coast of Japan. There was almost 19,000 victims from the tsunami, with the visual images of the devastation dramatically broadcasted through TV news to all over the world. The people in the affected areas are now slowly rehabilitating near their old towns and villages, and they have huge works to reconstruct their own houses in a safer way and also to re-start their industry, with the help of central and local governments and many volunteers. But they also need the recovery of communities and cultural traditions, through the reconstruction of tangible and intangible cultural heritage for their own sustainability.

This paper intends firstly, to introduce Japanese experiences in the recovery restoration of Western-style historic buildings after the Kobe earthquake disaster in Japan on 1995, and then to investigate the fact that so many World Heritage sites are

Fig.1 Recent big earthquake disasters in East and South Asia (credits: Mendoza Shimada, 2011)

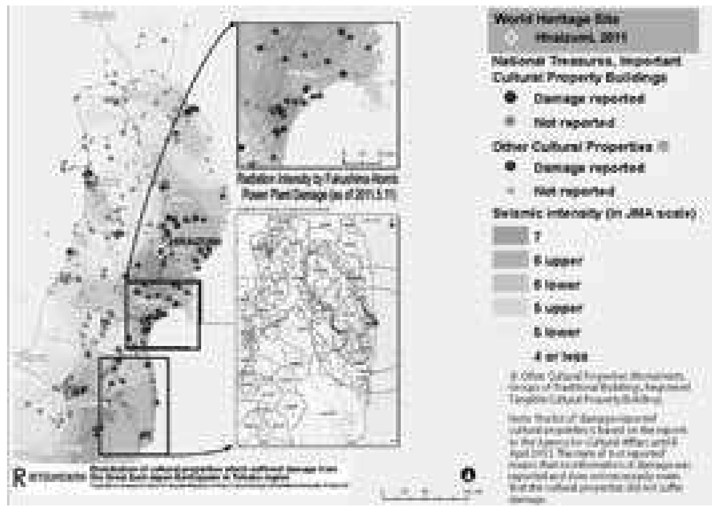


Fig.2 The distribution of cultural heritage damaged by the East Japan Great Earthquake (credits: Ritsumeikan University, modified by Mendoza Shimada and Masuda, 2011)

Fig.3 Kobe 15th Mansion (protected heritage) destroyed by Kobe Earrthquake, M.7.3, January 17, 1995 caused liquefaction of the ground (credits: K.Masuda 1995)

located in the earthquake zones of the world, and finally, to propose a re-thinking of the international conservation doctrinal texts for the sustainable protection of heritage values of fragile but ecological structural materials like wood and adobe.

2. SEISMIC DISASTER AND CULTURAL HERITAGE RECONSTRUCTION IN ASIA

2.1 Earthquake disaster and cultural heritage in Asia

In these decades, Eastern and Southern Asia region have experienced many big earthquake disasters and many cultural resources, including several World Heritage sites, were affected. In China, for example, Dujiangyan, inscribed in 2000, was badly damaged by the earthquake in 2008. The Old Town of Lijiang was listed in 1997, immediately after a big earthquake damage in 1996. The town has been impacted five times from earthquakes in the 20th century, including 1933, 1951, 1961, 1977, and 1996. Periodic reconstruction here is a long cultural tradition (ICOMOS-Japan, 2011).

2.2 East Japan Great Earthquake in 2011

In the case of the East Japan Great Earthquake in 2011, a Japanese World Heritage-nomination site, Hiraizumi, situated in the central inland part of the affected area, was inscribed on the list just after the disaster in the same year. There was not any severe damage at the main wooden gilt pavilion building built in the 12th century in Hiraizumi, but the World Heritage Committee could have been influenced indirectly by the severe Tsunami image in the region. There are several National Treasure buildings in the high seismic intensity area, but their damage was not so great, because they are located in places that traditional knowledge indicates as safer.

Another more serious problem is the radioactivity influence spread by the nuclear-power plants' accident in Fukushima, caused by the attack of the Tsunami of 11-meter high wave. Many populations are prohibited from entering the high-radioactivity area. Not only did they lose their hometowns, but also their own community memories and heritage. As the half-time period of Cesium 137 radioactivity is over 30 years, people cannot come back to their homeland anymore until the next generation. No one can take care of the fragile wooden heritage in the area for such a long time, and the heritage may lose its meaning as memory for the local people. The most serious damage is to humans, especially in young children. Cultural heritage cannot be inherited here for the future. Earthquake can be a trigger to cause the next various serious disasters.

2.3 Kobe earthquake disaster in 1995

The Kobe earthquake occured at 5:46 in the early morning of January 17, 1995, with a magnitude of 7.3 that killed some 6,600 people (ICOMOS-Japan, 2011). The magnitude is smaller than that of the East Japan Earthquake in 2011, but the epicenter or the seismic fault was just under the large city of Kobe, and the fault break happened at a shallow depth in the ground. Many wooden houses and modern concrete structures were destroyed and many people were killed while they while sleeping. Modern structures, like other types of buildings, as well as highways and railways, were also badly destroyed.

3. DAMAGE OF WESTERN-STYLE BUILDINGS AFTER THE KOBE EARTHQUAKE

3.1 Damage and reconstruction of the 15th mansion in Kobe foreign settlement

Kobe city started its modern history as a habortown open to foreign countries in the middle of 19th century. A foreign-settlement area was prepared by the Japanese government near the harbor, and many Western-style office buildings were constructed by different foreign marchants or traders. Those foreigners built their residences on the backside of the hill area called Kitano town, from which they could look down their ships in the harbor, as well as the settlement area. The settlement system was cancelled at the end of 19th century, but these foreign western style buidings became an important cultural character of modern Kobe city.

Kobe city suffered an air-bombing attack in 1945 during the Second World War, and a large area of its downtown burnt down. Most of the collapsed buidings during the 1995 earthquake were those built quickly after the World War II fire, and the structural quality was not enough to protect inhabitants against the earthquake and its after fires. But many Western-style wooden buildings fortunately survived these disasters, and are contributing to the historical character of Kobe city.

The 15th Mansion was constructed in the foreign settlement in 1881 as the US Consulate office and it was built in American east-coast style, with timber-frame structure and brick wall. In 1989, it was designated as an Important Cultural Property building by the central government. The owner was a private company, and constructed a new high-rise office tower next to the historic protected building. As it is located in the central downtown area, the building had been used as a Chinese popular restaurant.

Fortunately, the collapse of 15th Mansion did not kill nor injure anybody, because the earthquake occurred in the very early morning. But if it had happened at lunchtime, for example, some 50 people might have been killed by the collapse of this historic structure. If anyone was killed in this building, the government would not have been able to escape from its responsibility. During the Kobe earthquake, hundreds of historic protected buildings were damaged, but none caused death or injury. Several historic buildings collapsed as a result of this strong earthquake; however, 15th Mansion was the one most severely damaged. The central government started immediately to make the recovery plan of cultural heritage, and the reconstruction of 15th Mansion became a symbol of the cultural heritage recovery projects.

The reconstruction of 15th Mansion had to keep the authentic value of the original design, material, craftsmanship and setting, but also to achieve enough structural safety to be used as a popular restaurant. The only possible way was to combine several new structural reinforcements, utilizing firstly, base-seismic isolation below basement floor, secondly, replacing the dangerous brick chimney with reinforced-concrete pillars on the new basement, and lastly, inserting steel frames supported by the new chimney pillars into the roof space for capping the heavy brick-wall top so that it will not break down during the next earthquake of the same level. As the result, in this reconstruction, 75% of the old wooden material was reused and installed in its original position, respecting the authenticity of building fabric.

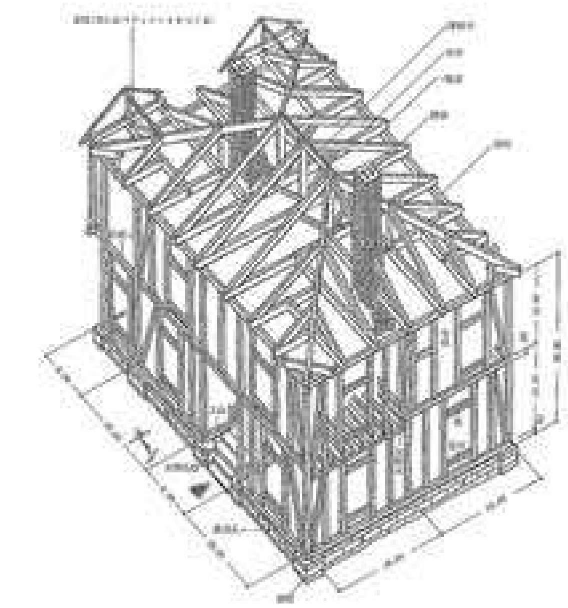


Fig. 4 The original wooden-timber structure and chimney, all typical of US east coast non-seismic region, was restored. (credits: K. Masuda & O. Mendoza, 2011, edited from the conservation report 1998)

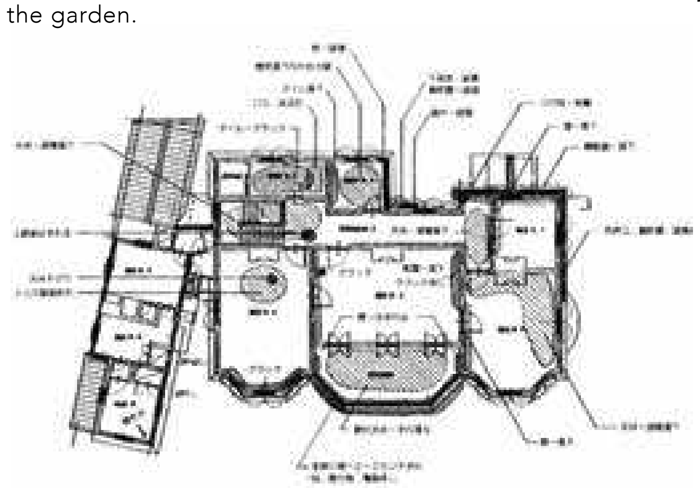
3.2 Damage and restoration of western-style houses after the Kobe earthquake

Another big recovery project was in the Kitano foreign-residential area, which is protected as a townscape conservation district by the central government since 1980. In a rather small area of 9.3 ha, 65 protected buildings are listed, and many of them were partially damaged by the earthquake, especially at their heavy brick chimneys.

These houses were built before the 1920s, when brick structures became forbidden in Japan. The free-standing upper part of the chimney on the roof, with a weight of almost 1 ton, is considered a dangerous structure for earthquakes, when most of them are shaken, then fall down, destroying the roof, ceilings and floors all the way to the ground, making big holes at every level. Several brick chimneys came down beside the bed where house owners were sleeping, like a kind of air bombing.

But the building structures in this district were generally safe, because the main wooden-structural frames were built by Japanese traditional carpenters, and the walls were strong enough to resist an earthquake force with plaster on wooden

a) The Former Hunter House (A), 1903 and its fallen chimney in the garden.



b) The Former Hansel House (B), up & left, constructed in 1986, was destroyed by free-standing heavy brick chimneys falling down at many rooms.

c) The Kobe-townscape conservation district, with many Western-style rich houses, was also damaged by Kobe Earthquake 1995.

Fig.5 Earthquake Damage and Reconstruction of Kobe 15th Mansion (credits: Masuda & Mendonza Shimada, edited from the Conservation Reports of Kobe Kitano District)

lathing. This is a type of Colonial-style building structure, and came to Japan after Colonialists had experienced several seismic-prone countries, like India, Indonesia, and the Philippines.

3.3 Seismic safety as a conservation priority in seismic-zone countries

What is the difference between the damage and their repair work of the 15th Mansion and the Colonial-style residential houses? They are similar as foreign Western-style buildings with structural timber frames. The main difference is the wall structure, heavy brick versus light plaster on lathing, or where the technology came from – a non-seismic region or a seismic zone. The brick chimney and fireplace in the Colonial-style house were added in cold Japan, as the latitude is far north, like the US East Coast or England. They were not used in southern hot countries, but they are dangerous in seismic Japan. The seismic safety is the priority here even in cultural heritage conservation.

4. WORLD CULTURAL HERITAGE IN THE EARTHQUAKE ZONES

4.1 Regional distribution of world heritage sites in the earthquake zones

World Heritage sites are increasing every year, but the characteristics of this distribution map and 2008 chart are similar even now. 27% of cultural heritage is within 200 km from past main epicenters. In the earthquake zones, including the Southern European region, about half the sites are within 200 km. But it is true that earthquake zones are a relatively very small area on the earth, and many ICOMOS leading countries, like France, UK and Germany are located outside of the dangerous zone where post disaster reconstruction is cultural tradition. The world is divided into seismic and non-seismic areas. Here we need a bridge between the two areas to build a worldwide risk-preparedness policy, based on the conservation principles.

5. CONCLUSION: NEED FOR A NEW INTERNATIONAL CONSERVATION PRINCIPLE FOR THE SUSTAINABLE PROTECTION IN EARTHQUAKE ZONES

5.1 Existing conservation principles are not effective in earthquake zones

The Venice Charter (ICOMOS, 1964) and Nara Document on Authenticity (ICOMOS,1994) are both main doctrinal texts within the World Heritage system and both adopted in seismic countries, but neither have enough tools necessary for the sustainable protection in earthquake zones. There is a need to carefully understand existing conservation principles, but if they are not enough, a new principle has to be examined to solve this problem. We are always between two earthquakes, past and future. Periodic recovery is essential and to ensure life safety conservation techniques have to be found.

5.2 Rethinking keywords from the Venice Charter related to earthquake zones

The Venice Charter is a basic doctrine. We can find many keywords, which need rethinking from the view of sustainable protection in earthquake zones as illustrated in Table 2. Reconstruction, for example, is forbidden, but is essential in earthquake zones after disasters. The disaster-affected place is not an ancient archaeological site, and communities and people need heritage reconstruction for their own collective memory and their sustainability. In the rethinking process, we will find many valuable concepts or frameworks in the existing doctrinal texts for a new risk-management doctrine concept. The rethinking viewpoints in Table 2 are some examples as a first step. Fragile building materials, like wood and adobe, are popular because for easy recovery in earthquake zones. This means our heritage sustainability is deeply dependent on traditional craftsmanship and its supporting social system; intangible values based on community.

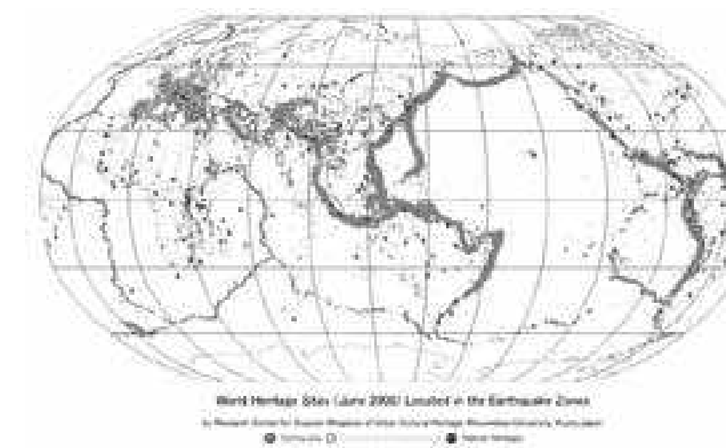


Fig.6 Map of UNESCO World Heritage sites located in earthquake zones (credits: UNESCO-WHC)

Region/ Distance from the epicenters	0-100 km	100-200 km	within 200 km		far than 200 km		total	
Cultural /Mix	100	91	191	27%	513	73%	704	
Australia/ New Zealand		1	1	14%	6	86%	7	
Caribbean	2	3	5	45%	6	55%	11	
Central America	10	10	20	59%	14	41%	34	N°5
Central Asia	2		2	22%	7	78%	9	
Eastern Africa	2	1	3	14%	18	86%	21	
Eastern Asia	10	11	21	42%	29	58%	50	N°3
Eastern Europe		1	1	2%	56	98%	57	
European Russia			0	0%	14	100%	14	
Melanesia	1	1	2	100%		0%	2	
Middle Africa		1	1	100%		0%	1	
Northern Africa	3	4	7	21%	27	79%	34	
Northern America	1		1	7%	13	93%	14	
Northern Europe	1		1	2%	49	98%	50	
South America	8	16	24	57%	18	43%	42	N°2
Southeastern Asia	6	1	7	39%	11	61%	18	
Southern Africa			0	0%	7	100%	7	
Southern Asia	6	8	14	29%	34	71%	48	
Southern Europe	35	23	58	45%	70	55%	128	N°1
Western Africa			0	0%	16	100%	16	
Western Asia	13	8	21	40%	31	60%	52	N°3
Western Europe		2	2	2%	87	98%	89	
Natural	36	18	54	31%	120	69%	174	
total	136	109	245	28%	633	72%	878	

Table 1. The regional distribution of World Heritage sites located in earthquake zones (World Heritage sites; total 878 sites as of June of 2008)

Keywords in English (used place in the Venice Charter text, 1964)		New rethinking view points on heritage conservation in earthquake zones
Concepts & Heritages	Authenticity (Preamble, P)	The Nara Document 1994, diversity
	Historical evidence (Article 3, A)	History coexisting with earthquake
	Living witness (P)	Witness of earthquake disasters
	Message from the past (P)	Earthquake-disaster history
	Own culture and traditions (P)	Culture coexisting with earthquake
	Principle (P)	Principle prepared for disaster
	Traditional techniques (A10)	Techniques prepared for disaster
	Modest Works of the Past (A1)	Sustainable living heritage
	Monument (P, A2, 4, 5, 6, 7, 9, 11, 14, 15)	Periodic earthquake recovery
	Urban or Rural Setting (A1)	Sustainable living heritage
Conservation Actions	Anastylosis (A15)	Earthquake disaster and recovery
	Conservation (A2, 4, 5, 6, 10, 14, 15)	In history, coexisting with disaster
	Restoration (P, A2, 9, 11, 12, 14, 16)	Periodic earthquake recovery
	Consolidation (A10, 16)	Periodic earthquake recovery
	Construction (A6, 10)	Conservation work for the next quake
	Indispensable extra work (A9)	Periodic earthquake recovery
	Modification (A6)	Consolidation for the next quake
	Reconstruction work (A15)	Sustainable living heritage
	Replacement of missing part (A12)	Periodic earthquake recovery
	Replacement of missing part (A12)	Consolidation for the next quake
	Use of any modern technique (A10)	Periodic earthquake recovery

Table 2. A proposal of rethinking the meaning of key words in the Venice Charter in 1964, respecting the disaster-recovery history of heritage located in earthquake zones (credits: Masuda and Mendoza Shimada, 2011)

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HARNESSING POLITICAL AND TRADE STRUCTURES TO ACHIEVE STANDARDS FOR EARTHEN BUILDING IN SOUTHERN AFRICA AND BEYOND

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Theme 8: Charters, Standards and Guidelines for Heritage and Construction
Keywords: Standards, acceptability, low carbon, emissions

Abstract

Following the adoption of the Code of Practice for Rammed Earth Structures by the Standards Association of Zimbabwe, it was decided to harmonize Standard by two regional blocs. Both COMESA (1) (19 countries) and SADC (2) (15 countries) agreed to do so but in practice, SADC was chosen to move the process forward. Four years on and the group is working with 10 of the 15 countries and have brought the process to the final voting stage for harmonization. On acceptance, people in 15 countries will for the first time be able to build earthen structures in urban areas under standards published by their own country.

It seems that using the existing trade and political structures of regions is easier than single countries, and that earthen construction has to learn the language of international-trade agreements. It was decided to look at changing the restrictive building codes and building regulations through the language of global-standards systems; concepts such as Technical Barriers to Trade (TBT's) may prove easier instruments to change than previous work with organizations already in the field of construction and materials.

However, this approach requires that members of states and of regions take up their position as stakeholders and use the existing apparatus to change the regulatory scenario, which has prevailed up till now. In this way, the acceptance of earth can be changed, as a useful economic tool, a viable construction material, a mean to increase employment and of reducing harmful greenhouse gases, from one of negative perceptions to one of positive adoption.

Much of the groundwork has been laid out, not just by people working with earthen architecture but also by international institutions, such as the International Organization for Standards that needs to be engaged.

1. INTRODUCTION

Rammed Earth Consulting CIC, an independent earthen-building company in the UK, and the School of Architecture at the University of Pretoria have been collaborating on the SADCSTAN (3) harmonization process for the Zimbabwe National Code of Practice for Rammed Earth Structures since 2008. In the Southern African region, there is still an extant knowledge base of earthen building in rural environments and urban peripheries, but apart from Zimbabwe, planning and legal systems in built-up urban areas of the SADC region legally prevent people from using any earthen-building technology, in this way not only preventing tenure and access to financing of built property, but also any chance of effective inter-generational transfer of vicarious knowledge and skills of a range of earthen construction.

From different perspectives, the authors have come to a shared realization of the urgency to create the legal environment for the use of rammed-earth technology, on the one hand as a conservation strategy to provide a supportive-future context for a range of tenuous indigenous-knowledge systems relating to all forms of earthen construction to survive and be transmitted into the future, and on the other hand as a strategy to allow these technologies to play their part in a global strategy towards achieving urban densities using low-carbon emission construction methods. At present, the main thrust of these strategies is directed towards the regulatory environment in earthen construction. This paper demonstrates the complexities of achieving the legal right to build, live and work in earth in urban areas.

2. BACKGROUND

Following the adoption of the Code of Practice for Rammed Earth Structures by the Standards Association of Zimbabwe (SAZ, 2001) (Keable, 2011), there was a six-year hiatus in activity in that region. But after the publication of the UK Rammed Earth, Design and Construction Guidelines (Walker, Keable, Martin, & Maniatidis, 2005), a dialogue started with the Standards Association of Zimbabwe (SAZ) to harmonize the rammed-earth standard through the regional blocs. Both COMESA (19 countries) and SADC (15 countries) agreed to do so. For a number of reasons, SADC was chosen to move the process forward.

Reasons for choosing SADC include lack of funding, building consensus takes time, travel and money. Firstly, SADC was founded as a political organization, whereas COMESA began as a loosely formed trade body. Secondly, and perhaps counter intuitively, the more political SADC have moved trade, standards and the removal of barriers to trade faster and more effectively than have COMESA. Finally, SADC includes South Africa, which as one of the three economic powers of the continent, which was perceived as being the most likely to join the process and, thereby, to wield a great influence over the other two, namely Egypt, and later on Nigeria.

Four years on and the group is working with 10 of the 15 countries, Botswana, Malawi, Mauritius, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe. For the moment, the process has passed five of six voting stages for harmonization.

On acceptance, people in 15 countries will for the first time be able to build earthen structures in urban areas under standards published by their own country. The legitimacy that this brings will, inter alia, allow schools to be built using earth for the first time, as any school is classified as an urban area.

3. STANDARDIZATION

The technical process of harmonization has changed over the period, since the work has been developed with SADCSTAN, which has brought both threats and opportunities. On the threat side, there is the fact that systems have changed and transparency is low. So discovering the status of any particular project to harmonize a standard may take weeks, or even months. The timing of this information may prove to be crucial, as work items may be dropped due to technicalities before the relevant stakeholders have any idea that there is a problem.

The only way to mitigate these kinds of issues is by building networks within the national standards bodies, by keeping communicating with them, and this may mean travel around the region to ensure that information is current. One of the reasons that projects may be dropped and another threat to the process is funding for and with SADCSTAN. After having enjoyed good funding from the EU over a number of years, this has now been severely scaled back, a situation apparently unforeseen by SADC members. As a result, a number of projects were dropped in early 2011 for having taken 'too long'. Our document was one of them, it had been agreed to four years ago, but the country secretariat dealing with the project, Botswana, did not issue the document to the other member states for 18 months. These kinds of blockages have only been removed by active participation on our part as national stakeholders to the process.

On the positive side, the opportunities have also increased if the harmonization is successful. It is now agreed that, once harmonized, all standards immediately take precedence over all previously existing standards (this does not apply in this case as there are not any) but that they also take immediate effect, so that all member states will be obliged to publish and abide by the new standard. There is also what is known as the tripartite agreement between SADC, COMESA and EAT, which should greatly reduce the time a harmonization process takes in any of the other two regional blocs once one of the three has successfully harmonized a standard.

The above machinations and interventions may seem like academic trivialities, but if these small interventions and machinations are not continuously managed and reinforced towards an accepted regional-regulatory standard, both the global-heritage community's good work on protecting earthen-building knowledge and skills and the scientific community's good work on advancing earthen-building technology will come to naught – without standards for earthen construction at the national, continental or global levels, it will continue to languish outside of common usage for most.

The rate of urbanization in Africa is the highest in the world – at the same time formal systems of housing and infrastructure provision are failing, resulting in a growing reliance of informal methods of providing these (Ogbu, 2009; Bakker, 2009). Most rural immigrants to the city currently still possess knowledge of earthen building, but a next generation may have lost this. The almost exclusive use of cement and concrete for buildings in African cities is growing exponentially and is vigorously promoted by the large global-cement companies from both the West and the East, but Africa will have to bear the costs of the long-term environmental impacts and un-sustainability of these short-term gain initiatives.

4. PRODUCTS AND PROCESSES

The growth of standards and building regulations has been rapid and global over the same period that commercial-construction products have increased from being a relative rarity to a global norm (Yahya, Agevi, Lowe, Mugova, Musandu-Nyamayaro, and Schilderman, 2001). The use of cement has been brought from a product to a norm for a variety of reasons. The production of cement, as with much of industry, is capital intensive, and so many governments around the world, seeing it as a strategic good, have also been major shareholders in the production process. This coupling of state and commerce has led to a rapid adoption of building regulations, which proscribe the size and strength of all built elements from foundations to lintels, homes to factories, schools and clinics. In many cases, the absence of a common code and standard was the driver of the process and is understandable. Additionally, cement is now recognized as responsible for around 10% of global human CO_2 emissions while still remaining the preeminent state regulated and prescribed material (Keable, 2010). However, with the rapid growth of products in construction, the process has led to many building types, which follow process rather than to use a product have fallen out of the regulated arena.

The link between products and standards is multi-facetted. There is a political dimension to this: governments wanting to control where and how building development takes place, where one group of people live relative to another group, the types of materials to be used and the flow of revenues that result. But companies also have a big say in the standardization of their products, and they bear the cost of doing so. In the case of processes, which may have been in existence for hundreds or even thousands of years, there is not necessarily a sponsor ensuring that the particular process or practice has a space in which to operate in a modern market. Companies are also increasingly targeting schools of architecture through the medium of design competitions to focus on standardized-building products, especially steel and cement, which in turn has a diminishing effect on the richness of syllabi and the eventual approach to architecture and construction, as well as the quality of the bio-physical environment and socio-cultural environments.

This, is a major challenge to the earthen building and conservation community, to provide that vital role of sponsor advocate to practices, which have ancient provenance but which have been left out of (very often) Colonial practice, and have failed to find a voice in the post-Colonial era and a critical role in ensuring greater environmental quality for future generations and helping to arrest climate change.

5. NEXT STEPS

The authors have stressed the importance of efforts to conserve knowledge and skills in earthen construction, as well as continuous research and experimentation with traditional and new earthen-focused technologies and additive materials, but have also demonstrated the extreme urgency for achieving a supportive-regulatory environment and harmonization.

In this endeavor for the SADC region, there are several next stages in the process once harmonization is achieved in the 15 countries comprising SADC. Of course, there is a big job to be done in the wider dissemination of the new national standard in each of the countries concerned. In some, this will have natural advocates, people and organizations already in the fields of construction and conservation that are aware of this technology. Countries like South Africa, Namibia and Mozambique have vocal opposing lobbies that have to be countered. In other countries where dissent from prescribed norms has been thoroughly quashed – such as Malawi – the job has fewer local advocates and may take time to root. And other situations – such as Angola, so long gripped by war and poverty, and where building control was very low on the list of government activities but now prosperous once more – the task is immense.

But there is also an ongoing regional dimension to this work. Clearly, rammed-earth is but one of a family of technologies, which have been overlooked by successive generations since the introduction of product-based norms. In the past few years, the normative growth in earthen construction has grown rapidly from a very low base. The adoption last year of a non-prescriptive ASTM in the USA covering all forms of earthen construction implicitly or explicitly is a major step forward. Many countries in the SADC region for instance have MOUs with ASTM and could form technical committees to adopt this code. It is recognized that for many people, the idea of a standard for earthen building is strange enough, but the need for two is absurd. But, however, that may be once a single earthen-building standard is in place in any country, it will be much harder to prevent the next one and the next one.

As stated above, COMESA already agreed to the rammed-earth standard and it should be somewhat more straightforward to do so once SADC has completed the process. Other organizations, such as the West African bloc ECOWAS, may also then follow suit. ARSO, the African regional-standards organization, likewise may have a part to play.

6. PROCESS

The interesting thing about standards is that they require the participation of stakeholders. This is what gives them their legitimacy. This legitimacy may be largely national, as in the case with Zimbabwe, or may also include international cooperation. The working group peer-reviewed the ASTM standard, as did many others in the global community.

This process has to be understood and engaged with, by the international earthen-architecture community. The language of technical barriers to trade, of harmonization, and the resources to engage with the process need to be embraced. There is a dynamic in the organization of local knowledge and advocacy and the input of international learning and experience, which could be both powerful and swift. At present, technical committees tend to be engineering and technocratic in form and substance. Ministries and corporations, who can afford to stack the committees, end up being the arbitrary arbiters of technologies of which they know little or nothing. But when local knowledge groups in the professions, built-environment related tertiary-educational institutions, NGOs, communities, construction and conservation groups are mobilized to seek a presence on these committees, the effect can be startling.

If Terra is to have a lasting effect, it would be in the promotion, advocacy, global management and oversight of this process.

7. CONCLUSION

In order to begin the long job of building acceptance for earthen structures in Africa, it will be necessary to address standards and regulation issues. This means both writing and adopting guides and norms for earthen building, but also redrafting norms written for materials like cement, norms that have mysteriously come to apply to all other materials.

This is a process that takes time. It is a process which is not well understood and which is changing fast in the African context. Regional agreements mean single-country codes can now be harmonized by many countries, and enjoy immediate force in law. When the standards are generated in the region rather than parachuted in from elsewhere, there may be particular interest and willingness to uptake.

This process has been largely unfunded and a labor of dedication, but it is critical that through pressure from those working in this field, its significance should be better understood by funders, and that the current emphasis on research is strategically shifted to standards dissemination until that goal is reached.

Because earthen building is still proscribed in towns and cities, and millions still have no choice but to live in shacks from found materials because standardized materials like cement are completely unaffordable, and because professionals in the built environment are not educated to see earthen construction as acceptable or viable, it is imperative that the legal tools are put in place to allow millions, the dignity to legally procure decent, affordable, environmentally sound and sustainable earthen schools, clinics, commercial buildings and homes for the first time.

Notes

(1) COMESA: Common Market for Eastern and Southern Africa.
(2) SADC: Southern African Development Community.
(3) SADCSTAN: Southern African Development Community Cooperation through Standardisation.

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PROTERRA IBERIAN-AMERICAN NETWORK: HISTORY, INVENTORY AND PERSPECTIVES

Marco Antônio Penido de Rezende, Célia Neves, Luis Fernando Guerrero

Theme 9: Education, Training and Outreach
Keywords: Network, Iberian-American, technological development, technology transfer

Abstract

The PROTERRA Iberian-American Network is a collaborative organization established in order to investigate, preserve and disseminate earthen architecture and its construction technology. It brings together over 100 professionals from 21 countries of the region in various research areas, such as teaching, design, construction, training and dissemination. The Network has published nine printed books, 20 CD-ROM and other electronic publications, and has promoted more than 60 courses and workshops, and over 30 conferences and seminars, among which 12 Iberian-American Seminars of Architecture and Earthen Construction (SIACOT) were accomplished under its direct auspices. Currently, the Network has a significant role in research and dissemination of earthen architecture and construction throughout the Iberian-American region, both from the point of view of conservation, as well as construction technology, and new architecture.

The origins of this organization began in October 2001, as an Iberian-American research project, supported by CYTED (Ciencia y Tecnologia para el Desarrollo), which led to interesting and unusual contributions to the discipline, particularly those that resulted in the creation of the Network at the end of the Proterra project, in February 2006. Since then, without any formal funding, the Network continues developing various activities from the initiative of its members, and has even increased the number of courses and seminars in relation to previous years, when working within a funded rese arch project.

The dynamism and interesting past of the Network led to the development of a study conducted in 2010 at the University of Oregon, USA. This paper presents part of the results of that study, which discusses the different activities accomplished by the Network, and incorporates also the oral history and actions of one of its members, as well as the first and the second Coordinators of the Network.

1. INTRODUCTION

Sustainable development and cyber space are perhaps the two most obvious features of the 21st century. Both are used by the PROTERRA Iberian-American Network, created to promote and raise awareness about earthen architecture and its construction, especially within the countries of the region. It started in 2001 with just seven members as a temporary four-year program. Known as the Research Project, it rapidly expanded with the association of other professionals involved in the subject. At the end of the project, the challenge of continuity was assumed by the Network, based mainly on common interest and volunteer work of its members. The story of PROTERRA, documented through papers authored by its Coordinators (Neves, 2006; Neves, 2010; Neves and Guerrero, 2010), as well as reports and newsletters, motivated the development of a post-doctoral level study, which sought to synthesize and analyze the activities carried out over time since the initial Research Project to its current networking activity.

2. PROTERRA IBERIAN-AMERICAN NETWORK

The current PROTERRA Network was named after the project that instigated it in the scope of the XIV Subprogram of Social Housing-HABYTED of the Science and Technology Program for Development-CYTED (www.cyted.org). The project Proterra began in October 2001 and was concluded in February 2006. As an "*international and multilateral technical cooperation project*" (Neves, 2006), it sought the transfer of scientific and technological results of earthen architecture and its construction to productive sectors and social policies of Iberian-American countries.

According to Neves and Guerrero (2009), its main forms of action included:

- Information and specialized distribution of the technology of earthen architecture and its construction;
- Exchange of information and experiences;
- Technical support to applied research projects;
- Capacity building and technology transfer at different levels;

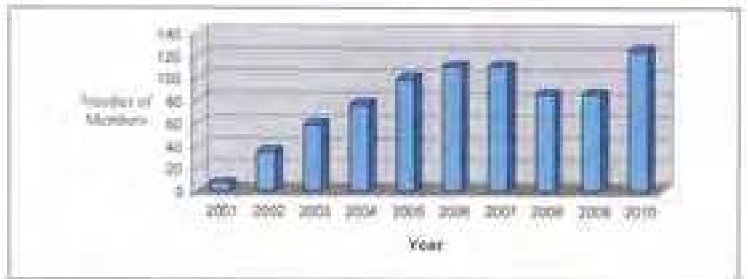

Table 1. Evolution of PROTERRA Network membership (1) (credits: Rezende, 2011)

• Databases and several publications;
• Advisory and consulting services.

With the imminent completion of the project, at its last meeting held in Monsaraz, Portugal, in October 2005, it was decided to create the Network despite the lack of financial support from the CYTED Program, or any other agent of international funding. It was possible to continue various activities because there was already an international team of professionals interested in promoting the improvement and dissemination of the technology of earthen architecture and its construction.

To this end, regulations were established defining the nature and objectives of the Network, its thematic areas, operational structure, conditions for its management and association. According to its statutes, it is defined as "an international network of integration and technical and scientific cooperation in the Iberian-American field, which operates in the development of earthen architecture and its construction" (Neves, 2006).

Any discussion and agreements on the regulations for creating the Network were accomplished over the Internet, taking advantage of the listserv created in October 2003, and adopted as the official form of communication and development for many of the Network's activities. Proterra Project refers to the period during the sponsorship by CYTED (from 2001 to 2006), and PROTERRA Iberian-American Network refers to the next stage (from 2006 to present).

3. PROTERRA TEAM

From its outset, PROTERRA sought to add new members for specific aims, especially those of gathering active professionals in different and geographically distant areas, able to promote the development and technological transfer. This created a discussion environment of knowledge sharing, as a way to identify opportunities for the development of joint activities.

Although the object of PROTERRA was aimed at the use of earth in contemporary construction, since its launch, PROTERRA also integrated activities and professionals dedicated to the preservation of heritage, in order to understand the strong connection between the knowledge produced for the restoration of buildings and the actual construction of housing. The technological basis developed in this field has

Fig.1 PROTERRA Project activity in Colombia: Construtierra 2006 (credits: Luis Fernando Guerrero)

been essential for rescuing and maintaining the tradition and the memory of this constructive knowledge. Moreover, the research conducted and the solutions put forward for heritage restoration have also provided effective solutions for construction systems currently in use.

This trait began to distinguish PROTERRA from other similar projects, which are usually closed groups to facilitate and coordinate the various works to be executed. But in this project, membership was closed to interested persons, regardless of their academic level and training profile. The project had criteria for admission of members established by its supporter CYTED with four categories of members that differed by location (country), experience and performance. These included effective members, collaborators, observers and 'friendly-institutions' representatives. Currently, the Network no longer uses these categories, except the reference to friendly-institution, which relates with associated institutions.

The operational experts within the field of study were enrolled as full members; specialists with little or no action within the field of study, but with activities related to earthen architecture and construction, as well as experts from a broad Iberian-America were enrolled as collaborating members. University undergraduate and graduate students were included as observer members. The friendly institution category was created to integrate institutions that did not always have specific action on the issue, whether or not of Iberian-American origin, but which supported, participated and followed the project. Each institution could designate up to three representatives as members of PROTERRA. All members enjoyed the same rights, notwithstanding their group, with the exception of financial support for the implementation of project activities, and the participation at Assemblies, which were privileges restrict to active members.

Table 1 presents the evolution of PROTERRA' s team, whose number of members was gradually increased from the beginning of the project, ranging from 80 to 120 since the establishment of the Network in 2006.

PROTERRA' s team always maintained its unusual nature due to good participation from academics, researchers and other professionals dedicated to design and execution of the work, and activities relating to technology transfer. Neves (2006) argues that at the end of the project in February 2006, PROTERRA had more than 100 participants from 18 Iberian-American countries with the following profile: 42% have their main professional activity at universities; 16% at research institutions; 18% at NGOs, and 24% in architecture offices and other public or private enterprises primarily focused on social housing construction programs.

The reduction of the number of members observed in the year 2008 is due to the assessment by the coordination of integrating just the members that were more active responding back to the activities of PROTERRA. By 2010, the PROTERRA team expanded with the entry of other interested colleagues. In several meetings the 'ideal' size for a smooth functioning of the PROTERRA Iberian-American Network was discussed. The consensus points to a number of around 100 members. In parallel, PROTERRA has always stimulated the creation of national or thematic networks, which associate with it and with each other, allowing the expansion of the number of people united by a common goal, in addition to facilitating the discussion of specific problems of a regional nature, and to disseminate and to exchange experiences in the international arena.

It is important to refer that Proterra project (2001-2006) was coordinated by Célia Neves, from Brazil, who also launched and coordinated the PROTERRA network from 2006 to 2008. The second coordinator was Luis Fernando Guerrero Baca, from Mexico (2008-2011). The third coordinator was Mariana Correia, from Portugal (2011-2014) (5).

4. ACTIVITIES OF PROTERRA NETWORK

Table 2 summarizes the main activities developed by PROTERRA since its beginning.

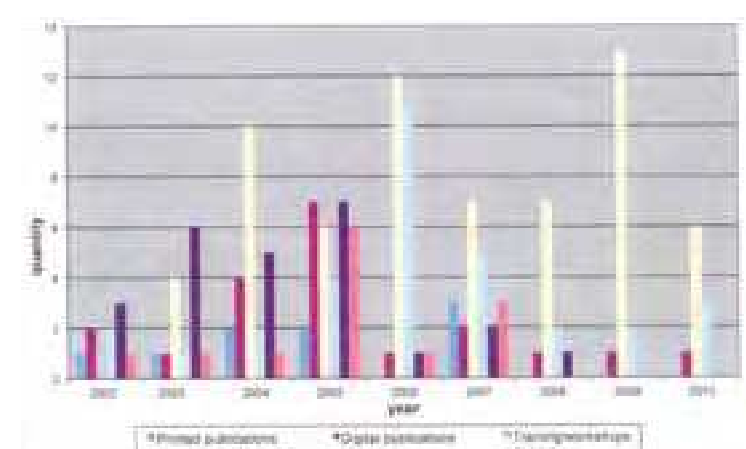

Table 2. Main activities developed by the PROTERRA Network (2) (credits: Rezende, 2011)

While a research project, the activities were scheduled at an annual meeting according to the working capacity of the team and following the basic guidelines of its supporter, CYTED. The activities were recorded in annual reports submitted to CYTED and CNPq (3), the Brazilian participant of the CYTED body. As a network, PROTERRA plans its activities in an annual meeting, or through collective electronic mailing to the listserv. Implementation, however, depends on the funding obtained by its members for various financial institutions. The activities are duly registered in the newsletter published quarterly.

Regarding the survey presented in Table 2, the activities were organized into six categories with some adjustments, such as demonstration projects and other activities in support of earthen building. These were accounted for in the category of 'training and workshops'. Other activities, such as companies, institutions and governments agencies, were not accounted for, as well as meetings and work directed towards standardizing earthen buildings in different countries, protection against earthquakes and other natural phenomena, development of collective research that led to the glossary of technical terms for earthen architecture and an inter-laboratory program.

Regulations for the use of earthen materials were always one of the essential activities of PROTERRA. After its inception, PROTERRA published recommendations for the development of technical building standards with mixed techniques (4) of earthen construction (Hays and Matuk, 2003). In 2005, with the support of PROTERRA, the Autonomous University of Tamaulipas organized the 1st International Congress-Workshop for Standardization of Earthen Architecture to show the progress in knowledge and activities established for the development of "*earthen standards*" (Congreso, 2005). Other actions had occurred, and are still occurring, in order to create the scientific basis for these regulations. In 2007, PROTERRA launched an international inter-laboratory program aimed at standardizing laboratory tests related to soil characterization and the qualification of products used in various construction systems. At the end of 2008, the inter-laboratory study was completed to test the compressive strength of adobe (Neves and Faria, 2008).

From the results obtained, a PROTERRA procedure is being proposed for testing the compressive strength of adobe. In addition, it also seeks to advance in the inter-laboratory program, by establishing the procedure for testing small adobe walls, in order to evaluate the behavior of adobe masonry and to test procedures for CEB (compressed earth block).

A focus of great interest to countries located in the mountain ranges of the Andes and Mexico corresponds to the behavior of earthen constructions during earthquakes. PROTERRA always sought to contribute to the identification of technical solutions to prevent disasters resulting from this natural phenomenon. It supported the implementation of SismoAdobe2005, organized by the Pontifical Catholic University of Peru in 2005, which brought together 359 people from 26 countries, presenting research and construction solutions adopted in certain regions that can be utilized in other regions mainly for the benefit of low-

Fig.2 Workshop at the 11th SIACOT in Tampico, Mexico, Sept. 2011
Fig.3 Workshop at the 14th SIACOT in San Salvador, El Salvador, Nov. 2014
(credits: Luis Fernando Guerrero)

income communities, which are generally the most affected by these events.

At one of the first meetings of the project, the difficulty of communication between the countries of Spanish and Portuguese languages, each with of its own technical terms, was identified. As a result, a decision was made to organize a database of common technical terms in various Iberian-American countries with the possibility of being expanded in the future to other languages. PROTERRA members documented and recorded regional technical terms of the past and present; Gallaecia Higher Education School [ESG-Escola Superior Gallaecia] from Portugal edited the information, generating the Specific Terminology of Earthen Architecture and Construction (available at: www.redproterra.org). The ESG also launched and managed PROTERRA website, since 2007.

Another activity that was not specifically identified, but was adapted above all others, was the transfer of technology. Since its inception, PROTERRA valued actions corresponding to these types of activities. In its general assembly in 2004, transfer knowledge was codified through the identification of training activities and dissemination, and looking for more efficient ways to transfer knowledge (Correia and Neves, 2008).

By analyzing Table 2, it is possible to see that 2005, although almost the last year of the project, was one of the most active. It is evident that the following years were also quite productive, albeit with fewer types of activities and the prevalence of training and workshops. These events have a practical nature and the participants learned the basics of earthen construction or restoration. Typically, PROTERRA conducts workshops in conjunction with SIACOT, occasionally with different audiences: graduate students and people from communities participate with much enthusiasm.

Further analysis of Table 2 shows that a reasonable number of exhibitions occurred between 2002 and 2007. In order to disseminate to universities the research being conducted, as well as the work of Iberian-American professionals, members of PROTERRA prepared illustrated panels presenting their work with short explanatory texts. These were recorded on a CD, and printed in several countries. At each exhibition, panels depicting local experiences were added, usually prepared by people who were not members of PROTERRA, thus enriching the heritage of each country. As these traveling exhibitions were easy to transport and assemble, this method of diffusion proved extremely effective and reached a wide audience.

Publications are one of the priorities of PROTERRA. After completing the project, due to printing costs, digital publications were preferred, distributed on CD or placed on websites. Papers presented at conferences and other academic events were released on CD and, whenever possible, also printed. In order to have an adequate bibliography of training activities, Proterra Project published in 2005 Soil Selection and Control Methods for Earthen Construction-Field Practices, which was the result of work involving five specialists members of PROTERRA (Neves, Faria, Rotandaro, Cevallos, and Hoffmann, 2009a). In 2009, this document was revised and also published in Spanish (Neves, Faria, Rotandaro, Cevallos, and Hoffmann, 2009b). In 2011, PROTERRA published Earthen Building Techniques in Portuguese and Spanish (Neves and Faria, 2011a, 2011b), and PROTERRA Workshops. Instructions for the Organization in Spanish (Neves and Faria, 2011c), for the purpose of collaborating on the practical activities of capacity-building events. These documents are all available at www.redproterra.org.

The conferences recorded in Table 2, which correspond to the events promoted by PROTERRA, were excellent opportunities for dissemination, and occurred mostly during the period between 2002 and 2007. Currently, PROTERRA has participated more effectively in events, not only with presentations at conferences, but as an organization capable of conveying the state of the art of earthen architecture and construction in Iberian-America. In October 2010, PROTERRA was invited to form a panel at the annual meeting of the Association for Preservation Technology International (APTI) in Denver, United States.

The performance of the Network relative to the project showed a significant increase in activities, training and workshops, 2009 being an exemplary year with 13 events. Other activities that have also increased are the hosting of conferences and events. In this case, a high concentration of events occurred in the years 2006 and 2007.

Editorial activities, especially printed ones, had a significant reduction. With the completion of the project, there were no more resources for the publication and distribution of printed materials. However, PROTERRA understands that there is a lack of publications on this topic in the Iberian-American region, and that efforts should be concentrated to develop more publications, especially digital ones, as they are easier to finance and distribute.

Exhibition activities were also quite small. Despite its relevance for the dissemination of earthen architecture and construction, exhibitions were not defined as a priority, and since 2008 even less so, although one may occur on occasion.

All things considered, with the completion of the project, there was an increase in training activities, workshops and events, which has been very positive contribution to a greater diffusion of earthen architecture in Iberian-America. However, there was a reduction in the number of publications and exhibitions. Although lack of funding may partly justify the reduced number of printed publications, it appears to partly be a result of the management of

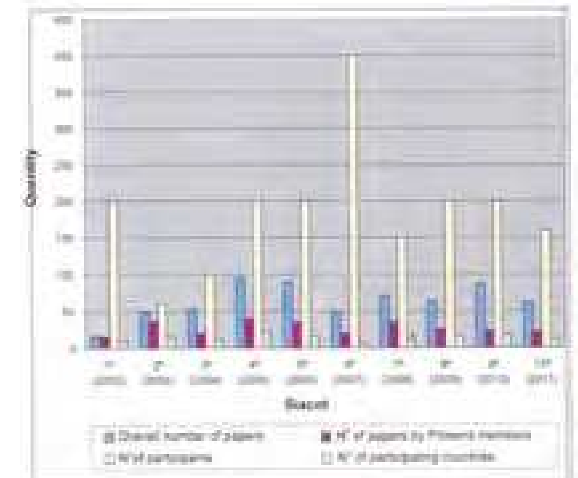

Table 3. Number of participants, papers and countries at the SIACOT seminars (credits: Rezende, 2011)

the Network itself. It is important to clarify, as noted by Camarinha-Mattos (2004) and Dorogovtset (2010), that when the Network's management is identified as the probable cause, shortcomings in coordination are not being pointed out, a characteristic attitude and action of all members involved.

5. IBERIAN-AMERICAN SEMINAR OF EARTHEN ARCHITECTURE AND CONSTRUCTION – SIACOT

The first event to occur focused on the possibility of developing a community oriented activity in the region, bringing together its members in the first annual meeting in Salvador, Brazil in September 2002. The 25 Proterra project members from 11 countries that were present had much to contribute to the dissemination of earthen architecture and construction within the community, as well as to non-specialists. Thus began SIACOT, an event created with the aim of promoting interaction between academia and the production sector, including professionals from the most diverse areas of activity and society in general, to show the state of the art of earthen architecture and its construction in Iberian-American countries. The number of participants, of countries represented and papers published, edited by Neves (2006 and 2010) and Rezende (2008), are summarized in Table 2 (5).

In the period of the Proterra project, the SIACOT was associated with the annual general meeting, whose expenses were funded by CYTED, the program sponsor. However, due to the strategy adopted to increase the number of members of Proterra, there were not enough financial resources to fully assume the travel expenses of all, to participate in the assembly and, consequently, in the corresponding SIACOT. The procedures adopted were to encourage Proterra members to find their own institutional financial aid, and to request various contributions from the organizing institutions to serve the largest number of members possible.

The criteria for granting financial support to the coordinator's staff members was defined in a clear and transparent way. Without the financial resources of specific sponsors, each member had to find their own support, and whenever possible, the organizing institutions facilitate the participation of the Proterra members in the SIACOT, by assuming some of their expenses.

Table 3 indicates a sharp increase in the number of papers, averaging 50 to 80 items per event, as well as an increase of authors, who are not members of PROTERRA, demonstrating the success of the events as a place for disseminating achievements and research, especially in Iberian-American countries. Thus, SIACOT, by virtue of the large number of papers published annually, has become an important portal for dissemination of earthen architecture and it construction.

In addition to presentations of academic papers, other parallel hands-on activities occur during SIACOT, particularly workshops. These activities also contribute to dissemination and training, creating a healthy environment of awareness, knowledge and other information sharing among participants, and facilitating the development of joint projects, as well as friendships.

6. CONCLUSIONS

According to Neves and Guerrero (2010), the activities of the Proterra project remain an axis of strategic development for the medium- and long-term work of the PROTERRA Iberian-American Network, which can be grouped into four lines of action, developed either individually or collectively.

The first concerns the issue of research, whose knowledge generation is produced by the Network members from different fields. This ranges from earth characterization, development and performance of building systems, structural analysis, environmental impact studies, relationship between architecture and health, history and construction archeology, studies and conservation of heritage structures, among many others. The results are presented at different events, and publications are disseminated at national and international levels. However, SIACOT, which is held annually, is the ideal place for this purpose. The raison d'être of this international event is precisely the presentation and collective discussion of research progress and experiences in different fields of knowledge of earthen architecture and its construction.

The second line of action refers to formal education. Although examples of earthen construction can be found on five continents, paradoxically, universities are unequipped for this branch of science. The evolution of related disciplines occurs in a disjointed manner. Currently, the PROTERRA Iberian-American Network looks to integrate institutional actions like those of the Chaire UNESCO Architectures de Terre, among others, aiming at collaborating within the structure of teaching/learning suitable for the discipline of earthen architecture and construction among the universities operating in this area.

Another activity that receives much attention within the Network is the training of human resources through practical workshops. Self-builders participate in these, including people in general, community members, students, professionals and teachers, among others. This process is very effective because it facilitates the transmission and assimilation of construction techniques, either

Fig.4 Workshop on painting with natural colors, at the 15ºSIACOT in Cuenca, Ecuador, Nov.2015 (credits: Luis Fernando Guerrero)

through the experience acquired by direct contact with the materials and tools during practice, or as a collective work, in addition to the technical assistance offered by instructors.

The plans developed for this line of action showed the need to systematize procedures to facilitate the organization of workshops and to ensure the pedagogical aspects of this form of capacity building, regardless of the local agent or organizer of the event. Therefore, there is an effort towards developing PROTERRA documents for trainers and workshop organizers, as well as attendees. Thus, pertinent procedures to different types of workshops can be created, establishing methods for planning and the corresponding activities in order to avoid unpredictable circumstances.

Despite the enormous efforts in publishing earthen architecture and its construction, the number of publications devoted specifically to this issue remains low when compared to the available documents in other fields of expertise. In reality, there is a potentially high demand for this type of documentary resources, particularly focused on regional realities and written in Spanish and Portuguese, which has not been properly addressed.

The need to establish a management process is recognized for the convergence between supply and demand for resources to support the publication of books and journals associated with appropriate distribution and marketing schemes. Electronic publications of this type have a much broader scope than printed editions, and allow for substantial savings of time and material resources. These publications rely on a scientific committee, which evaluates and ensures the scientific rigor of the texts that help enrich the level of knowledge in the field of earthen architecture and its construction.

Finally, 10 years after the formation of a group of people involved with earthen architecture and its construction, and its final integration as the PROTERRA Iberian-American Network, there has been a notable advance in most of the goals outlined from the start. The structure of collective work was consolidated, a healthy exchange of experiences among professionals was created, and the impact and development of actions related to teaching, research and dissemination was evaluated.

Despite the excellent performance of earthen architecture construction from the point of view of sustainable development, there are yet challenges to face for its effective approach. Through the work of PROTERRA, the image is expected to change so that earthen architecture's economic and ecological qualities are properly recognized and valued.

Notes

(1) There is no record of the number of members in the years 2007 and 2009; therefore, in these years, in Table 1, is repeat the number of the previous year.
(2) In Table 2, 2002 corresponds to the period between October 2001 and September 2002; 2003 corresponds to the period between October 2002 and December 2003; and other years are for the period from January to December of each year.
(3) CNPq - National Council for Scientific and Technological Development.
(4) Mixed techniques correspond to the building systems in which a material is used as a supporting element, usually wood, and earth as filler. It has several names, such as bahareque, quincha, pau a pique, and taipa de mão, among others.
(5) Note added during the proceedings publication: The forth mandate is coordinated by Hugo Pereira, from Chile (2014-2017) with the support of a Coordination Council composed by the three previous coordinators.
(6) Other relevant data from SIACOT is a follows:

SIACOT	Date	Place	Organization
1º	September 2002	Salvador, Brazil	Polytechnic School of the Federal University of Bahia, State University of Feira de Santana and Center for Research and Development
2º	September 2003	Madrid, Spain	Higher Technical School of Madrid. Research Center for Traditional Architecture
3º	September 2004	San Miguel de Tucumán, Argentina	Faculty of Architecture and Urban Planning of the National University of Tucuman; Regional Research Center of Earthen Architecture
4º	October 2005	Monsaraz, Portugal	Escola Superior Gallaecia, Foundation Convent of Orada, Centre of the Earth Association
5º	June 2006	Mendoza, Argentina	Environmental Institute of Social and Human Sciences; Regional Research Center of Earthen Architecture
6º	September 2007	Tampico, Mexico	Autonomous University of Taumalipas
7º	November 2008	São Luís, Brazil	State University of Maranhão; TerraBrasil Network
8º	June 2009	San Miguel de Tucumán, Argentina	Faculty of Architecture and Urban Planning of the National University of Tucuman; Regional Research Center of Earthen Architecture
9º	February 2010	Coimbra, Portugal	Archaeological Studies Centers of Coimbra and Porto; University of Coimbra, Escola Superior Gallaecia, Centre of the Earth Association
10º	November 2010	Montevideo, Uruguay	Regional North Faculty of Architecture of Salto

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TERRA EDUCATION 2010 INTERNATIONAL SEMINAR: EDUCATION FOR EARTHEN ARCHITECTURE

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Luis Fernando Guerrero, Hugo Houben, and contributions from all workshop participants[1]

Theme 9: Education, Dissemination and Outreach
Keywords: Didactics and pedagogy, priorities and strategy

Abstract

In the year 2010, from May 24th to May 29th, the National Superior School of Architecture of Grenoble (ENSAG), France, with the CRAterre-ENSAG Research Unit and the UNESCO Chair Earthen Architecture, organized an international seminar on education for earthen architecture. More than 40 university lecturers, researchers and experts in education, coming from Europe, Africa, America, Asia, representing the interface of numerous international, regional and national specialized networks (such as PROTERRA, UNESCO Chair, Cedterra, DachverbandLehm e.V, ASterre, TerraKorea), universities and faculties of architecture or engineering, research units, training centers, and NGOs, were invited. During six days, they shared their experiences, debated the state of the art in the field, and developed a joint reflection. This allowed envisioning the future development of higher education and research (didactics and pedagogy, PhD programs), and vocational training and actions aiming at promoting awareness for the general public regarding earthen architecture, its conservation and its contribution to sustainable development. Based on 22 presentations, prepared by 96 contributors, this collective reflection was then developed within four thematic workshops, as follows:

Workshop 1: Reviewing the types of higher-education and vocational-training curricula available, educational tools and learning methods;

Workshop 2: Strategic directions for research and doctoral programs: what research priorities to develop in order to meet the expectations and needs of society?

Workshop 3: Methods of evaluation and validation of skills learned; certification of professional qualifications;

Workshop 4: Difficulties, gaps and blockages/instances, and acceleration of education-development actions and specialized training in earthen construction and architecture.

1. INTRODUCTION

In October 2001, the First UNESCO Chair - TERRA Consortium International Workshop on the subject of "Earthen architecture education in the world: Current status and future action" took place in Grenoble. The results of this first meeting confirmed the existence of a dynamic network of international higher education and vocational-training structures in the field of earthen construction and architecture, while revealing the achievements obtained through great effort, hard work and dedication on the part of individuals and institutions involved. These results also contributed towards building a foundation of ideas by specifying essential recommendations and conclusions for a better integration of earthen-architecture education as part of institutionalized curricula. The idea is that the people trained may better fulfill a social role as future trainers and professionals, and as local sustainable-development 'facilitators'. At that time, it was developed a clear awareness of the need to promote earthen architecture in connection with core social issues: the fight against poverty, access to decent housing and the improvement of living conditions, the boosting of local economies and the valorization of local resources, knowledge and expertise, as well as the preservation of cultural heritage and the natural environment. Almost 10 years later, how far have we come individually or together? How have we addressed, through the prism of our field of action, increasingly strong social issues? What are the new occurrences that seem to amplify the presence of an earthen-architecture movement internationally? How are reexamined the needs for more in-depth education practices and the impact of research, both fundamental and applied, dealing with the design and construction of architectural projects? What skills and possibilities for action are we building? How do we handle the shifts and developments required to make a qualitative leap, without which the future could, in many respects, be threatened? These are questions that challenge our attitudes as teachers, trainers, researchers, and professionals in the field.

2. A BROAD PARTICIPATION AND INTERNATIONAL REPRESENTATION

The TerraEducation 2010 seminar, brought together 41 participants from 23 countries, in Africa, America, Asia and Europe:

- Africa: Angola, Cameroon, Morocco, Nigeria, South Africa, the Democratic Republic of the Congo, and Uganda;
- America: Argentina, Brazil, Chile, Colombia, El Salvador, México, Peru, United States of America, and Uruguay;
- Asia: Bangladesh, India, and the Republic of Korea;
- Europe: France, Germany, Italy, and Portugal.

Workshop participants represented a wide range of institutions: international organizations, public universities and faculties or departments of architecture, planning and/ or engineering; private institutions; architecture, engineering or archaeology research centers and laboratories; vocational training centers; NGOs, private foundations, professional associations and representatives of international, regional and national networks.

2.1 The seminar: background and objectives in brief

The goal of the seminar was to better evaluate the strengths and weaknesses of the actions developed in recent years while facilitating sharing and collective thinking. Through these objectives, the seminar aimed to develop the following contributions:

- Allow an analysis of experiences in earthen-architecture education at all levels;
- Consider the evolution of teaching methods for a better transmission of knowledge;
- Reflect on a frame of reference of the skills involved in earthen construction and architecture, and on the ways of assessing these skills;
- Assess the impact of research on teaching, including doctoral research in the field;
- Contribute to the establishment of an international platform of excellence in education for earthen architecture;
- Define a common vision of the international development of education in the field.

2.2 Activities and working methods

The first two days were devoted to the presentations of participants into six themes:

1. Curricula/higher-education programs;
2. Curricula/professional-training programs;
3. Education and doctoral research (PhD);
4. Didactics;
5. Outreach in schools and for the general public;
6. Skills references and validation systems.

On the third day, the participants visited the Grands Ateliers de l'Isle d'Abeau, where they attended the activities organized by students from the post-master DSA-Terre and the Master "Eco-habitat and building cultures" of ENSAG, as part of the eighth annual festival "Grains d'Isère". The fourth and fifth days were dedicated to group work, within the four workshops mentioned above. At the end of the fifth day the results of the workshop were presented during a plenary session.

3. REPORT OF THE SEMINAR-WORKSHOP

3.1 Evolution of societal issues and responsibility of educational institutions

The present era is marked by a distinct shift in societal needs, which demands both global and targeted solutions, to cite a few such problems:

- The dramatic expansion of poverty, a growing low-income population, social injustice in access to employment affecting many nations, and the consequent difficulty in accessing decent housing, which is exacerbated by urban growth and the shift of the poorer population towards the urban outskirts;
- Lack of access to primary, secondary and tertiary schooling for children from the poorest families, augmented by a weakening public sector: the privatization of educational institutions further exacerbates social injustices;
- Accelerated degradation of natural environments and alarming decline of non-renewable resources and energy, and their correlated pollution and climate-change problems;
- Loss of built heritage and age-old building traditions with the frenzied growing production and use of building materials with high environmental impact;
- The international financial crisis: loan inflation, real-estate crash, stock-market crisis, public and national debt, economic crisis and falling investments.

In this context of strong pressure on today's society, alternative responses with the potential and ability to answer social, environmental and economic needs must be pursued. Earthen architecture has a crucial role to play in terms of access to housing for the poor, the development of local economies, and for long-term sustainable development (environmental and energy alternatives). However, much must be done to upgrade the raw earth-building culture, its evolution and adaptation to the current needs and demands of modernity, constructive and architectural quality, and energy efficiency, all in a global context that is increasingly exposed to strict normative framework. In terms of architectural and vocational training for earthen architecture, a huge gap in competencies and professional skills must be filled in order to develop business, social and

Fig.1 Group visit at the *Domaine de la Terre* and the *Grands Ateliers*, Villefontaine, North Isere (credits: Hubert Guillaud, 2010)

economic recognition. As such, educational institutions have a heavy responsibility to meet the challenge of specialized education to transmit their learning. This responsibility, in the field of earthen architecture, is broken down into several levels identified by the seminar TerraEducation 2010:

1. The global-paradigm shift and its local applications;
2. Institutional legitimacy of the education systems in the field;
3. Developing and strengthening networks;
4. Development of fundamental research, basic R&D, and action research;
5. Integration of specialized education in public policy;
6. The development of professionalism in the field;
7. Amplification of technical training;
8. Communication;
9. Community support.

3.2 The paradigm shift

If it is declared today that society has 'the right to use earth', it seems more appropriate to say that it has 'the right to housing and a healthy environment'. It is a change in the scale of what we perceive as our just dues that the paradigm shift imposes, that is to say, to 'think' of earthen architecture through the prism of a broader vision because it is no longer just a material, earth, or even 'earth architecture' but much more. What is in question is society, the peoples of the world, how to put our various building cultures (knowledge and skills) to good use, and the social and economic benefits we can draw from that. However, in many cases, the training let alone the diversity of different contexts. The 'global' reduces the characters of the 'local'. A radical change is needed and the entire pedagogical engineering must be revised to address this paradigm shift.

3.3 Institutional legitimacy of the education system

Despite a real willingness on the part of numerous educational institutions, these institutions do not enjoy adequate recognition, and their role is not yet perceived as being legitimate, thus hindering the development of earthen architecture and construction, which now offers great potential for responding to the needs of society.

- Earthen architecture is part of the cultural, social, economic and environmental identity for a large part of the world population;
- Earthen architecture is a means to provide solutions for social vulnerability, environmental sustainability and access to social housing, better management of economic growth, more social justice, and self-determination of peoples.

The international networks should be more inciting and proactive to ensure that lessons are developed in universities and training centers by promoting the establishment of cooperative agreements focused on this goal with the institutional members of the network. The universities do not adequately fulfill their influential role to lobby public decision-makers and the private sector, while they have every legitimate reason to do so, this mission being part of their institutional mandate. It is, therefore, necessary to strengthen their influence with policymakers, teachers and researchers, professionals, and more widely, extend it to civil society.

They could hold a leadership position in these areas through:

- The setting up of systems for evaluating the quality of construction and architectural projects;
- Validation of best practices for interventions in the material domain (built environment, heritage), as well as immaterial (crafts, arts, cultural identities);
- Contributing to the visibility of achievements of excellence that would strengthen the credibility of earthen architecture with civil society;
- The fulfillment of a civic solidarity through the development of collaborative and participatory projects with professionals and civilian communities.

3.4 Developing and strengthening networks

Even if a large coordination effort has been undertaken over the past decade, especially in terms of sharing and dissemination of information, it is, therefore, necessary to:

- Strengthen existing networks, making them more active, share the information more effectively (dissemination of reports);
- Clearly identify the members, their status, and provide them with greater visibility;
- Take advantage of existing networks to find ways to raise funds;
- Organize seminars to assess the progress being made; for this, evaluation indicators must be defined.

There is also a lack of dissemination and implementation of new knowledge and educational tools and materials. This lack can be partly remedied by better information sharing within the network (intranet), by broadcasting at least a brief description of new tools and teaching materials that are produced.

3.5 For a better integration of education policies

Obviously, there is a significant gap in public policy and implementation of legislative frameworks on earthen architecture. This deficiency contributes significantly to:

- A lack of recognition and awareness of the societal value of earthen architecture among professionals, and more broadly in civil society;
- The biased weighting of high environmental-impact building systems;
- A lack of funding for the development of more substantial earthen architecture.

The move towards a better integration of earthen architecture in public policy directly concerns the universities and their full institutional legitimacy in education. They can better fulfill this mission by:

- Creating a shared platform to develop a real political agenda within the universities themselves, and in relation to policymakers, government bodies, NGOs, the public and private professionals, and representatives of civil society (associations, communities);
- Producing and sharing case studies that enhance the analysis of financial and wider socioeconomic benefits of projects completed;
- Producing and sharing of life-cycle analysis for environmental models;
- Adapting model indicators.

3.6 The place and role of research

Research in the field of earthen architecture focuses on three major problems:

- The lack of clearly defined relations between scientific research, the transmission of knowledge, and the varied realities of techniques applied in the field;
- The lack of sharing available research results to a larger audience;
- The need to develop more useful research, in tune with the real needs of society.

Obviously, while continuing to develop fundamental research on matter and material, it would be better to develop further experimentations for innovation, R&D and applied research, particularly in the context of pilot projects that directly involve professional stakeholders and beneficiaries. This contextualized and targeted research should also be used more in the development of teaching methods and teaching materials, which can be more shared out. There is also a huge lack of coordination of scientific research at an international level with a redundancy of efforts contributing to the waste of human and financial resources. Networks should play a more active role to reduce this waste and to establish a more visible coordination.

Doctoral research (PhD) is not structured enough, facing a set of priority issues, among which the following may be addressed:

- Analysis of the financial and economic benefits of earthen architecture;
- Analysis of case studies of architectural projects involving the use of earth and other actual building materials (hybrid-building systems);
- Studies on the traditional earthen architecture and building cultures;
- Evaluation of conservation and restoration actions for historical buildings;
- Studies on crafts and craftsmen's productions, their inventory, documentation and evaluation.

Publications on earthen architecture are mainly carried out by professional experts and are intended for that category of people. The paradigm shift mentioned above requires a heightened level of interdisciplinary approach for new studies, researches and projects.

3.7 A necessary development of professionalism

A lack of academic recognition of the value of earthen-architecture education is perceived. Strategies should be found and applied in order to:

- Better present the work carried out in universities to local populations;
- Facilitate collaborations between universities, their faculties and departments;
- Facilitate cooperation between different professional bodies.

Similarly, a lack of specific competences related to earthen architecture is noted in the academic field and among 'pseudo experts'. It is very important to legitimatize the few institutions that perform quality work on the basis of an evaluation and of clearly defined indicators. Professionalism involves in addition to a vocational training, using adapted didactics and teaching materials suited for students. It seems particularly appropriate to:

- Identify, evaluate and share within the network (intranet) at least the titles, together with a brief description, of all didactic materials produced by the international academic community (while clearly addressing the issue of copyrights);
- Produce educational materials on the basis of accessible knowledge to all teachers, regardless of the contexts of use;
- Produce synthetic documents for students that are adaptable to different contexts (translated).

The development of earthen architecture also suffers from a lack of integration between professional and academic knowledge, as each is expressed through different languages. Educational research can play a decisive role to facilitate a better integration of both types of knowledge and produce educational resources better suited to both contexts. There is a clear imbalance between top-down and bottom-up approaches. A change in attitude is needed to better focus on a bottom-up approach of teaching methods and professional-training programs, aimed at architects mainly, who shall become the 'facilitators' of the development of earthen

Fig.2 Workshop 4: the group worked on strategic directions for research and PhDs (credits: Hubert Guillaud, 2010)
Fig. 3 the group worked on difficulties, gaps and blockages (credits: Hubert Guillaud, 2010)

architecture, providing support to communities. There is a lack of integration of interdisciplinary approaches in the teaching of earthen architecture and training programs that tend to be focused on the technical aspects of building only, barely taking into account the complexity and the many dimensions of the concept of habitat (holistic approach). All these lack areas imply the necessity to develop learning on the following subjects:

- Improvement of social housing;
- Building cultures, cultures of living, and customs;
- Reuse of existing buildings (historic or recent) to mitigate the necessity for building new structures;
- Earthen-architecture cultural heritage, tangible and intangible;
- Project management;
- Professional ethics;
- Interdisciplinary approaches,
- Crafts skills and business skills.

3.8 Developing technical and artisan-training programs

It must be noted that artisans and small-scale contractors are the main actors involved in the development of earthen architecture, and that their capacities in the field of earthen construction are still poorly recognized. This situation may change by:

- Developing educational programs that involve craftsmen more directly;
- Certifying the skills of craftsmen.
- Likewise, artisans suffer from a lack of viable markets in which to position themselves. To change this situation, several possibilities have been identified:
- To develop craft skills and support their implementation;
- To better identify and analyze actual and potential markets;
- To promote projects that demonstrate craft and contractors skills: pilot projects and architectural references to facilitate a better integration of earthen architecture in development programs.

The loss and degradation of knowledge and traditional skills today poses a serious problem that contributes to hindering the development of earthen architecture. It is necessary:

- To develop training materials, specifically adapted to the training of artisans;
- To better study the production processes of local crafts through their inventory, documentation and qualitative assessment.

3.9 Developing communication efforts

The sector that invests in the field of earthen construction and architecture, whether academic or professional, is not sufficiently recognized. New strategies must be deployed to develop task forces acting at the interface between universities and governments, exerting a greater influence.

There are too few publications highlighting the diversity of earthen architecture and building cultures of the world, aimed at the general public. Besides, the launch of a high-ranking, interdisciplinary review is absolutely a key to direct proper significance to the subject area. It is also necessary to publish articles on earthen architecture in journals of other disciplines, in order to call attention to the relevancy of researching in earthen architecture and construction. Also, it is important to use and develop different media facilitating communication: exhibitions, videos, documentaries and films, radio programs, etc. Because our academic field is linked to a broad set of goals and objectives, it becomes absolutely necessary to extend our communication to policymakers, researchers, professionals and society, in general.

The articles and other documents that are produced to support this effort of communication must be written with a vocabulary that is adapted to targeted audiences, away from the canons of scientific writing, without being too general and banal.

3.10 Getting to know local and regional developments

Our academic field is not responding enough to the expectations and needs of communities. Universities need to better fulfill their social mission by facilitating the access to knowledge and creating knowledge-transfer opportunities aimed at those who should be the primary beneficiaries. To further develop this goal, it would be important to:

- Develop and support actions aimed at the most vulnerable populations;
- Value and promote crafts skills, contractors skills, and good practices;
- Promote and organize professional technical-training programs within communities.

4. CONCLUSION: EARTHEN ARCHITECTURE AT THE HEART OF A ‘POLITICAL AGENDA’

The work carried out during the TerraEducation 2010 workshop (AAVV, 2010; Guillaud, 2011) revealed a set of strategies that would contribute to remove the blockage, knots and resistance that are opposed to the development of specialized-education programs. It also pointed out the opportunities that educators, scientists and professionals, who are invested in the field, can use in order to gain access to new levels of recognition, visibility and efficiency in action. This international seminar contributed towards reinforcing and reactivating a network of skilled players, already active in national, regional or international groups.

The challenges ahead are both significant and substantial. However, the current expectations and needs of society, and the fundamental questioning of a model of industrial and socioeconomic development whose effects are obviously damaging, are a favorable ground to the development of earthen construction and architecture. The international political agenda of many nations has begun to take note of the paradigm shift and, in this context, the future of earthen architecture seems more and more open to provide relevant answers through the three pillars of sustainable development with culture and governance. In this respect, due to their institutional legitimacy in education and research, universities have an important and decisive role to play.

Major efforts remain to be made towards the development of sharing information and working tools (didactic materials) to enhance the communication of activity results for a better coordination of human and material investments in research; more demonstrations of architectural quality and habitat projects; and local development involving a wider range of stakeholders, fully integrating the civil society.

Universities should develop and consolidate their links, partnerships, cooperation and collaboration agreements, not only among institutions – and through an interdisciplinary approach – but also among lecturers, researchers and students, as it has been noted. It should also encounter other stakeholders, such as policymakers, integrating different groups of skilled professionals, communities, self-builders and the general public.

More than ever before, great efforts must be devoted to the development and implementation of missions of solidarity and citizenship in universities. TerraEducation 2010 has helped to clarify this fact, as well as the need to disperse the least amount of energy, to reinforce networking and to reduce isolation and separation.

There is a ‘political agenda’ for earthen architecture today that universities, training centers, NGOs, professionals, associations and the civil society must bear full responsibility for, by joining efforts for a better federation of human and material resources.

Notes

(1) Workshop 1: Isa Abdul, Umar Abdullahi, Romain Anger, Claudia Cancino, Kathleen Dardes, David Gandreau, Philippe Garnier, Hugo Houben, Thierry Murat, Islam Shariful, Horst Schroeder, Francisco Javier Soria López.

Workshop 2: Gerhard Bosman, Mariana Correia, Marcelo Cortes Alvarez, Minchol Cho, Laetitia Fontaine, Mauricio Ganduglia, Luis Fernando Guerrero Baca, Hubert Guillaud, Eduardo Salmar Nogueira e Taveira, Jenny Vargas.

Workshop 3: Robert Bidime’Nouga, Lydie Didier, Alexandre Douline, Rosario Etchebarne, Uta Herz, Serge Maïni (Satprem), Adolphe Mayogi, Jean-Marc Mei, Michel Mourier, Elena Ochoa Mendoza.

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CASARÃO DO CHÁ RESTORATION AND RESCUE OF A JAPANESE WATTLE-AND-DAUB BUILDING TECHNIQUE IN BRAZIL

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Theme 9: Education, Training and Outreach.
Keywords: Japanese wattle-and-daub, restoration, building process

Abstract

The technique of building with earth in Japan, especially wattle and daub, is one of the most advanced in the world. For more than a millennium, both the technique and the materials have been improving, adapting to the nature of the locale, including earthquakes, weathering, and temperature differences, among others. Such is the cultural consolidation of this technique that by referring to Japanese wall, wattle and daub is directly inferred. In Brazil, wattle and daub (*pau-a-pique*) is used in several regions; its implementation was present in buildings in rural areas, in coffee plantations and in colonial architecture. Despite this, the technique is currently undervalued.

The house of tea (*Casarão do Chá*) was built in 1941 of wattle-and-daub and eucalyptus-log structure. It is the first Japanese building declared architectural heritage in Brazil, and is currently being restored. The aim of this work is to confront the differences and similarities between the construction technique of the *Casarão do Chá* walls in relation to the Japanese technique; analyzing the techniques and materials used that replaced the Oriental materials. As a research method, it was necessary to save the original process that was used in this building, from the study of the Japanese plot as theoretical framework. Also the materials and construction methods were analyzed, permitting verification of adaptations to the set of procedures for conducting the restoration work. This work not only promotes the improvement of the Brazilian technique, it also creates an identity for the society with the declared heritage assets.

1. INTRODUCTION

Casarão do Chá (house of tea) was built in 1942, by Kazuo Hanaoka, a carpenter whose initial purpose was to develop a tea factory. The world was facing a period of war and exports of products from Asian countries had suffered a series of sanctions, which became attractive for some agro-industrial sectors in Brazil (Handa, 1987). At that time, the agronomist Furihata was the representative of the enterprise in Brazil called Katakura Gomei Gaisha, which had appointed Kazuo Hanaoka for the construction of the tea factory in the district of Cocuera, in the eastern rural area of the city of Mogi das Cruzes. The first migrants settled there in the 1920s, which was a time of great agricultural development for the Japanese colony. Many families went to this region in search of land for farming. After the arrival of the first immigrants, who initially came as workers for the coffee culture, the area of Barrio de Cocuera was basically composed of smallholders working in the cultivation of land with various products, such as vegetables, fruits and root vegetables (Saito, 1961).

For the construction of *Casarão do Chá*, the master carpenter had locally sourced materials, such as some varieties of eucalyptus for use in the main structures, rounded wood of smaller diameters for secondary structures, and bamboo to build the framework, which would be filled with earth mixed with straw. The roof used French-type ceramic tile, which relied on small beams of eucalyptus logs.

From its launch, the factory operated for 24 years. It was called Tokio Tea Factory [*Fábrica de Chá Tókio*], and all its production was directed towards the international market. The inner space arrangement was based on tea production, from the arrival of raw materials, dehydration, rolling, fermentation, drying, and packaging to the shipment of the goods.

2. *CASARÃO DO CHÁ* AND THE FACTORY SPACE

Casarão do Chá was built on two levels; the plan of the first floor was 35.50 m x 15.40 m, enclosing an area of 547.70 m²; and the second floor with its pink mahogany flooring had an area of 250.00 m². The upper floor was intended for the wilting of tea leaves, which was the first stage of the manufacturing process. Long net-like fabrics were extended in several layers, so that the collected leaves aired until humidity was reduced to 65% (Almeida, 1957). This first phase could last from one to three days, depending on local weather conditions. After this stage, the leaves were sent to the first-floor level through tissue pipelines to continue with other operations, such as pressing for breaking the cell wall, sorting, fermentation (1), drying, roasting, storage and packaging (2).

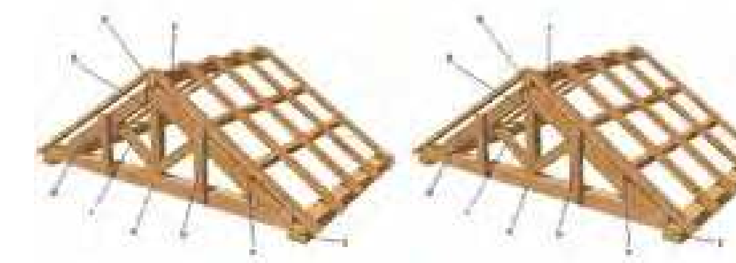
Fig.1 *Casarão do Chá*, Mogi de las Cruzes, Brazil (credits: Eduardo Gamboa, 2007)

The construction system adopted is similar to the Japanese traditional construction system. However, it differs in the structure of the roof, which used Western-style trusses. A system of beams and pillars is utilized in Japan to structure the walls, and horizontal and vertical elements (*hari, tsuka Bashira*) (3) make up the roof structure. The principle of using diagonal bracing elements is not part of the traditional Japanese construction system. According to Matsuura (4), vertical and horizontal elements in the structure, allow the construction's malleability.

Timber preparation encompassed the cut of eucalyptus parts, which were then submerged in a lake next to the building, following a leaching process contributing to the preservation of wood. Larger size and difficult to transport timbers were covered with a wet tissue, taking due care to keep it constantly wet for four weeks (5). The bark was manually removed using care to avoid marking the wood, and then the pieces that made up the entrance porch and other special elements were polished (Kuniyoshi and Pires, 1984). Once the wooden structure and the roof were assembled, the walls were made of the Japanese wattle-and-daub technique with a bamboo framework.

The origin of Japanese architecture comes from China and Korea, from which construction techniques were introduced in the Middle Ages during the period when Japan was isolated from the rest of the world. At this time, the technique was perfected through alterations in the original layout, with a more complex bracing system, which was also optimized during this period. The curving of the eaves was subtly adapted to the Japanese taste.

The peculiarity of the construction of *Casarão do Chá* is the fact that the carpenter, Kazuo Hanaoka (6), used un-dimensioned wood, utilizing the trunk and its branches in structural and



a) b)

Fig.2 a) Japanese roofing structure – Nijubari Koyagumi; b) Western roofing structure - truss (credits: Mokuzoujikugumihou, Wikipedia.jp, 2011)

aesthetic composition. This is the case of the main entrance pillars, where the branches from the main trunk aids in the support of the wooden beam that distributes the weight of the roof on the wall, permitting a roof cantilever of approximately 2.30 m from the column. The segment functions as a bracket, and at the same time it is elegant and its curvature assists in the façade's composition. In a similar way, other parts of the building also adopt this principle.

The use of wood in its natural state, as applied in *Casarão do Chá*, is also known in Japanese architecture. However, the plan of both tearooms, Chashitu and Sukiya (7), that comprise the teahouse, have somewhat limited space. The abundant use of these elements in the construction of *Casarão do Chá* is owed to the company administrator, Katakura, who allowed carpenter Hanaoka to freely use these elements. Hanaoka developed several spontaneous and creative works, for example the railing to the upper level, the division of compartments, and some roof structures. Moreover, the carpenter also included some elements of the traditional Japanese architecture, such as Irimoya, karahafu, and oogidaruki (8), resulting in a building composed of Eastern and Western elements and techniques.

3. WATTLE-AND-DAUB IN JAPAN

Despite having the basic materials, such as wood, earth and straw, Japanese wattle-and-daub structures differ from the wattle-and-daub method typically used in Brazil. Some of these differences relate to the structure of the framework, preparation of earth, and method of its application. Optimization of the Japanese technique developed over millennia, reaching its apex in relation to the dominant idea that it was a healthier, more sophisticated and comfortable wall, known as Tsuchikabe (9). This concept is the opposite of the image that the Brazilian population generally attributes to this technique.

Several tools were designed during the evolution of the Japanese technique, especially in the Middle Ages. In turn, experience with various materials developed based on earth, straw and other plant fibers, such as mitsumata (10) and the asa (11), as well as the use of resins from marine algae, virgin lime, and the combination of these elements in varied dosages, due to the peculiarities of each region.

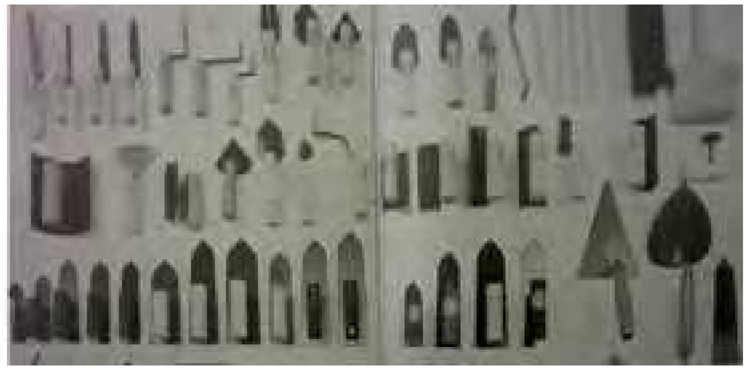


Fig.3 Llanas, trowels and other tools for building a wall (credits: Yamada, 2007)

The various properties of soil that serve as a basis for the preparation of earthen plaster and mortar, were already formulated through experience for use on walls, in order to resist the climatic conditions of each region. For example, in the region of Kochi (12), wattle-and-daub walls were finished in Tosashikkui (13), a milk-colored treatment characteristic of the region. It is applied to the last layers of wattle-and-daub walls. This provides weatherproofing, as well as, resistant to temperature variations and strong winds. The composition of the material for this finish was based on lime mixed with very fine plant fibers that prevent micro-cracking, giving greater stability to the applied material. Different types of adhesives were also added, such as those that were based on algae, which helped to improve the walls' resistance to temperature variations, also ensuring its durability and waterproofing over time (Yamada, 2007).

4. THE JAPANESE WATTLE-AND-DAUB OF *CASARÃO DO CHÁ*

The wattle-and-daub used in *Casarão do Chá* is quite simple if compared with the more sophisticated techniques used in Japan, and there are a number of technical and material adjustments used. However, the structural principles were preserved: the load distribution of the wall is given, not only at its base, but also in the setting of the entire peripheral structure.

In *Casarão do Chá*, the original material used in the structure's frame was solid wood and not bamboo, though the framework was of bamboo, split into strips of about 3 cm, which were largely tied with annealed wire. The substitution of solid wood for bamboo was the result of the abundance of this material in the working environment. The split bamboo is the original form, which was also used in the restoration. The earth applied on the framework was carried out in four stages: a) arakabe (gross wall); b) nakanuri (intermediate rendering); c) uwanuri (plastering); and d) shiague (finishing) (14). These stages occur as the previous stage is consolidated, and it starts with the application of the first layer on one side of the wall. The preparation of the earth for the gross wall is made at least three months before its application. The clayey soil is submerged in water for at least two days. This procedure hydrates the earth and stabilizes the organic matter and microorganisms that are present in the soil.

After this stage, chopped straw of about 10-cm long is placed. In the original wall, a straw called Sapê was used (15), whereas in the refurbishment, rice straw was utilized, which is the material most commonly used in Japan. This selection of vegetal fiber is due to the fact that Sapê was not available in the region, since it is collected in the autumn. According to the local population interviewed, the earth preparation was carried out in the spring. The ancient inhabitants of the region are important carriers of knowledge to augment the selection of materials, and the correct period for their collection, as they know the appropriate moon, as well as the seasons favorable for planting and cutting of trees. Despite the fact that several of these concepts became legends, knowledge was based on their own personal experience, as well as the experience of the population, in general.

The mixture of straw with earth was gradually prepared for three months. The chopped straw was distributed over the earth and compressed homogeneously to mix well with the earth. The amount of straw varies greatly, depending on the type of earth. According to some data, both from Japanese literary sources and the experience of professionals in the area, for every 1 m^3 of earth, between 15 kg and 60 kg of straw is added. During this three month period, the mixture of straw and earth goes through a fermentation process, altering the color of the earth because of the decomposition of the straw, as well as biological and chemical processes that increase the binding capacity of the earth by improving its plasticity and ultimate strength, enabling its ease of application on the wall.

In addition to discoloration, the odor is quite strong and the temperature rises during fermentation. These indicators are observed when the mixing process is manually accomplished. Therefore, there is no single standard that defines the proportions of the various materials in the mixture. According to information obtained by specialists on the subject (16), verification is based on experience and know-how, as the base material itself, earth, differs from one place to another. The differences in the percentage of clay, silt, sand, and organic matter, among other intrinsic soil characteristics, is what determines the ideal dosage of the different elements, in order to develop a wall with a good level of performance.

After preparing the earth, the first application is made from the inside out, so that the inside layer dries quickly, taking around 15 days. After that, the outer layer is applied. Some of the variables to be taken into account for the application and drying are: a) individual method of the person performing the 'seasoning of the earth'; b) wet or dry weather periods, because in dry periods the wall cures faster; and c) the orientation of the building in relation to the incidence of sun, wind and rain, as for example in the application of layers during the rainy season causing delays, where the application of the next layer cannot be performed for months. On the other hand, constant sun and strong wind exposure can accelerate the dehydration of the earth, causing significant cracks and curvature of dry earth.

When the first earthen layer is applied on both sides and its dehydration and curing environment is favorable, the wall acquires strength and endurance. Fixing the earth of the first application to the bamboo is accomplished with excess earth squeezing out on the opposite side of the application. These irregular earthen protrusions become mechanical keys that assist in the cohesion of the different materials. Cracks appearing from drying shrinkage vary from a few millimeters up to 1.3 cm; these are relatively high if compared to Japanese examples (17). A high percentage of clay in the earth used at *Casarão do Chá* resulted in an increase in the strength of the wall. However, cracking also increased, demonstrating that the relationship of the grain-size distribution of the earth must also be taken into account.

The principle of application by layers is specifically to ensure resistance of the first layer, which provides the structure for the wattle-and-daub wall. Gradually, the following layers are less resistant and, therefore, more stable. Clayey earth is mixed with sand and lime, and chopped straw can gradually be used up to the second layer, with lengths ranging from 5 mm to 12 mm, to assist in the deformation of the cracks caused by the first layer. The straw mixed while preparing the earth of this layer should be chopped into smaller pieces, about 2 cm to 3 cm. The third layer is applied after the drying of the previous one. It is, therefore, necessary to hydrate the substrate for the application of the next layer, as application on a dry surface may cause an accelerated dehydration resulting in cracks and/or good adhesion between layers may not occur. As the more stable materials are gradually applied, the wall is prepared to receive the next layer. The sequence of increasingly less thick layers is applied externally. In Japan, this process can include up to nine layers depending on the desired finishing.

Retraction manifests itself differently, depending on the thickness of the applied earth to the outside of the wall. The surface with the smaller cracks corresponds to the lesser thickness of the layer applied over the surface of the column, which is inside the wall. To allow a better adhesion to the surface of the column, sisal ropes are placed vertically and secured with nails. The distance between the ropes is about 3.3 cm (18) and approximately 70cm between the nails.

In the case of the walls of *Casarão do Chá*, and because it is a building erected for tea production, there was no need for a more sophisticated finish. However, it was necessary to create a white wall without porosity for reasons of cleanliness and maintenance.

5. THE FRAMEWORK OF THE WALL

The wall framework is the base on which the earth is placed. The closure of the openings between the studs is performed in two stages. The first is the construction of frame that is structured with bamboo logs with an approximately 4-cm diameter, in a pattern of about 40 cm x 40 cm distance. The bamboo is tied with straps to form the framework. Bamboo straps are tied onto both sides: vertically on the inboard side and horizontally in the outboard side. There is actually no criterion defined with respect to the direction of the bamboo straps (19). However, in the case of the refurbishment of *Casarão do Chá*, the logic used was as follows: by applying the earth on the inboard side, the surplus that extrudes to the outboard side could be better embedded and supported if the bamboo straps were placed horizontally.

a) b)

Fig.4a) Shrinkage fissures resulting from drying of the first earthen layer; Fig.4b) Appearance of the inboard side (credits: Akemi Hijioka, 2010)

Three types of bamboos (20) were used in *Casarão do Chá*. The bamboo is selected based on function (choice of diameter) and age. The driest period for cutting bamboo influences its durability, minimizing the attack of termites and other xylophages. Bamboo of around 5 cm in diameter was divided into six longitudinal portions, obtaining strips of 2.5 cm to 3 cm width. Length varies depending on the span. In the case of *Casarão do Chá*, the three types used included 600 units of the first type of bamboo, 600 units of the second type, and 500 units of the third type, totaling 1,700 pieces of varying lengths.

The original walls built in 1942 were largely in good condition. However, the deterioration of the wooden structure of the building led to the decision for the removal of the wall. For the structure of the frame, buxom wood of various species was used, secured with bamboo straps and tied with annealed wire. In parts, the frame structure was destroyed by attack of xylophages but the earth was still intact, creating small tunnels inside the wall. The wall panels were in good condition. However, all wood structural elements, such as columns and beams were affected. So, although the earthen wall had not been harmed, it was necessary to remove it to change the columns and beams.

The frame structure is embedded in the peripheral structure through 2.5 cm ties made at the columns and the beams. Thus, besides a proper connection, the wall load is also distributed along the periphery of the structure. This also allows the removal of the walls in a practical way, because the dovetail (cuts on wood) makes it possible to remove the panels without interfering with the structure of the building.

6. CONCLUSION

The use of earth and wood is a principle of traditional Japanese architecture. Great temples and palaces have lasted for centuries, such as the building, Horyuji, which is 1,300 years old.

The *Casarão do Chá* is a building that imparts some of the principles of traditional Japanese architecture. It does not embody a simple transfer of technology, but it has implications for the understanding of the know-how manifested in every detail of its construction.

Knowledge was transformed into know-how through adjustments, alterations and adaptations to the new environment and new materials; and all of these changes are embodied in the building. The renewal allowed the deconstruction of the construction process that brought to light technical and historical information to be analyzed for the preservation of the building over time.

The optimized evolution of the technique occurred gradually and was consolidated in Japanese culture as a noble material, healthy, safe and refined. Contrary to the concept established in the East, wattle-and-daub in Brazil, for most people, is associated with insecurity, poverty, poor health, and improvisation, among other negative connotations.

By reviving the technique of Japanese wattle-and-daub applied in *Casarão do Chá*, it is possible to explore the current application of this technique, effective for use in the construction of more sustainable housing, and that contributes to change the negative concept still associated with it. This restoration experience also raised several questions that are in the process of being addressed, through data collection and systematization.

Notes

(1) This phase is described in most operations as fermentation; however, it is actually oxidation.
(2) Vicente Unzer Alemeida from the School of Sociology and Politics of São Paulo describes the tea-manufacturing phases in a study on the occupations of Ribeira Valley.
(3) Hari refers to the horizontal element, and tsuka or tsukabashira to the vertical piece of the roof structure.
(4) Shoji Matsuura in Miyadaiku Sennnen's "Te to Waza" analyzes the construction elements of wood in relation to flexibility from their positions and functions. He also claims that excessive rigidity resulting from the locking system is against the nature of the exertion demanded, and to which the building is subjected.
(5) Kuniyoshi, C. and Pires, W. in Casarão do Chá, an interview with the carpenter's family, recounts the sequence to prepare the wood for use in construction.
(6) Master Carpenter, from the Province of Nagano. He arrived in Brazil in 1929 as an emigrant invited by the company administrator Katakura Gomei Kaisha, Furihata.
(7) The Sukiya (数奇屋)-style house adopts some principles of the art of the tea ceremony or ikebana.
(8) Designations on the drawings of the Japanese roof.
(9) Tsuchikabe (土壁) is composed of the ideogram for earth and wall, meaning a wall with earth relating to various techniques, including bahareque with bamboo attachments, as well as rammed earth.
(10) Vegetal bush (Edgeworthia chrysantha) used as a raw material in papermaking, composed of malleable and resistant, fine fibers. There are records that Mitsumata was used since the 16th century, and in some literature, even earlier.
(11) Vegetal bush (Cannabis) used since ancient times by Japanese agricultural culture. Its fiber was used in the manufacture of fabrics, ropes and utensils, as well as its seed, which was used for oil production.
(12) A province located on the island of Shikoku in the Pacific Ocean. Strong winds blow from the sea.
(13) Tosashikkui is the name of the finishing technique. Tosa is the ancient name of the province of Kochi, and Shikkui is the final lime-based finish layers.
(14) This sequence is commonly used in the implementation of Japanese wattle-and-daub; the initial three layers are typical of Japanese bahareque walls. Generally, the difference is in the final layer of the finish.
(15) A plant of the grass family (Imperata brasiliensis) whose leaves and stems are widely used for roofing of rustic houses.
(16) Communication with Professor Nakao, from the Tajima Technical University in the province of Hyogo, who through the model specialist, Prof. Seiji Yoneda, sent information about the process of preparing the earth for Japanese wattle-and-daub walls.
(17) The Japanese examples suffer minor rebound only. Cracks in the first layer vary no more than 0.5 cm (5 mm), according to information from the previous source.
(18) A measurement corresponding to 1 Sun (寸), the Japanese unit of measure, and the canon adopted for all measurements in Casarão do Chá.
(19) Information obtained from literature research, and from meetings with Japanese specialists on the topic, such as Sakan (a professional specialized in walls) and Prof. Nakao, Tajima Technical University.
(20) The first type was peasant bamboo, then Hachiku bamboo (Japanese species of compact fibers with good strength and workability), and finally the ones of smaller diameter used as fishing poles. These three types of bamboo form the supporting structure.

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CORNERSTONES COMMUNITY PARTNERHIPS (USA) ASSISTS COMMUNITIES IN PRESERVING THEIR EARTHEN ARCHITECTURAL HERITAGE

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Theme 9: Education, Dissemination and Outreach
Keywords: Training, community, partnerships, volunteerism

Abstract

In 2011, Cornerstones Community Partnerships celebrated 25 years of outreach: disseminating information and educating Southwest communities about the regional heritage of earthen architecture. Cornerstones began when a conditions survey of over 300 adobe churches, missions, and moradas took place, resulting in the 1986 formation of Churches: Symbols of Community, whose mission was to strengthen communities by assisting in their preservation of historic buildings and cultural traditions. In 1994, Churches became Cornerstones Community Partnerships, a non-profit corporation.

Initially, work focused in northern New Mexico, home to a unique patrimony of vernacular-earthen architecture; Cornerstones has now built a national and international reputation for the creative use of historic preservation as a tool for community revitalization, the affirmation of cultural values, and the training of youth in traditional-building skills and sustainable-construction methods.

The largest aspect of this work has been the dissemination of skills and methodologies used for centuries to maintain and perpetuate earthen architecture. Cornerstones' goal has been to educate communities and others about the benefits of traditional building, while also taking into account the very real situations of each work site and community. To this end, different strategies are employed concerning community volunteerism and outcomes. These strategies have also pushed Cornerstones' staff to develop new outreach materials and partnerships. An examination of past and present projects (Pajarito, Socorro, San Miguel, and Santo Domingo) demonstrates these processes of education, strategies, and developments, and the paper concludes with a commentary about the future.

1. INTRODUCTION

In 2011, Cornerstones Community Partnerships celebrated 25 years of outreach: disseminating information and educating Southwest communities about the regional heritage of earthen architecture. Cornerstones has assisted over 260 communities in their preservation efforts on over 300 structures. In reviewing this achievement, we are reviewing our past and planning the future, celebrating successes, focusing on challenges, and continuing to learn.

2. THE FIRST 25 YEARS

Cornerstones began during the 1980s, when a statewide assessment of over 300 adobe churches, missions, and moradas took place, resulting in the 1986 formation of Churches: Symbols of Community, whose mission was to strengthen communities by assisting in preservation of their historic buildings and cultural traditions. In 1994, Churches became Cornerstones Community Partnerships, a non-profit corporation. Initially, work focused in northern New Mexico, home to a unique legacy of vernacular-earthen architecture, but has extended throughout the southwest and into Mexico.

2.1 Community support and cultural revitalization

Communities in the Southwest are particularly rooted in traditions and customs relating to all aspects of life. In Pueblos, feast days bring back family members from all over the country to dance, cook and eat together, and renew family bonds. In small villages, the annual clearing of the acequias (irrigation ditches) for spring and summer farming and the renewal of adobe plaster on the community church have helped keep communities together. Sadly, due to the passage of time, demographics affecting community and the onset of 'modern practices', many of these rich traditions and skills have weakened or have been forgotten. As a result, when historic buildings need repair, there may be no one with the knowledge to accurately assess and repair damage; and there may be no one strong or young enough to begin and complete the necessary work. Cornerstones has sought to fill this gap. Cornerstones was formed, not just because historical buildings needed repair, but also because the communities often needed assistance in re-learning the traditional skills required to maintain these buildings. Many of these centuries-old structures symbolize the rich heritage of the original builders. Traditions of community cooperation in maintaining the buildings have been passed down for generations. Therefore, continuing the process of preservation preserves cultural heritage.

2.2 Placelessness

In a world where placelessness, a term coined by geographer Edward Relph, is the rule and not the exception, Cornerstones' work influences a community's sense of itself – or indeed sometimes helps to create a community. Relph described placelessness as "*the casual eradication of distinctive places and the making of standardized landscapes that results from an insensitivity to the significance of place*" (Relph, 1976, Preface). The most blatant example of placelessness might be a MacDonald's restaurant – which is the same in Chicago as it is in Paris and as it is in Hong Kong. However, historic preservation of cultural and community centers returns identity and meaning to a world, which may have seen history and meaning eradicated by assimilation and loss of population, a situation often found in Native American pueblos and the small rural villages of the Southwest. When a place becomes 'known' through revitalization, the intangible sense of self-awareness, teamwork, pride and a deeper sense of patrimony cannot be quantified.

2.3 Cornerstones implementation

Cornerstones was extremely busy in its first decade. Our first responses to requests for help primarily involved technical assistance visits: performing assessments and lending tools and equipment. The phone rang three or four times a week as communities sought help in repairing a church. A staff member would travel to the site, assess the situation, and write up a report of the suggested scope of work. Based on this report, the community would meet and, with Cornerstones staff, plan for workdays, gather materials, and begin repairs. Most of the time, the workers were adults who had either never learned the traditional techniques of adobe building and repair or had an incomplete knowledge of material and process. The work was accomplished as the community learned the appropriate practices, be it adobe-brick making, repair of cracks in walls, basal repair, roof-overhang repair, and more. Cornerstones would occasionally provide extra labor – volunteers who would join in a community effort when the workload was too big or a community too small. But more often, the community would be in charge of the work, and would continue maintenance after Cornerstones left.

Another educational strategy was workshops for mayordomos. In the Southwest, the mayordomo is a community leader, typically involved in the maintenance of the acequias (water-irrigation ditches) or the religious center. Cornerstones periodically reached

Fig.1 La Capilla de la Sagrada Familia at Pajarito,New Mexico during community-preservation efforts (credits: Ed Crocker, 1992)

out to mayordomos with the idea that the mayordomos would use their position and influence to educate the community (and potentially their own replacement).

Cornerstones' response occurred only after the most important part of the process was established, that the community was committed to working on and at the site. Cornerstones goal is not to 'fix the problem' but to assist the community in 'owning' the solution to the problem. The community must become the force that will drive the work; Cornerstones becomes an assistant. Our ultimate goal is not to be needed. We refrain from involvement when communities are in contention.

3. CASE STUDIES: PAST AND PRESENT

3.1 Pajarito – a small community

La Capilla de la Sagrada Familia at Pajarito, New Mexico sits at the foot of Black Mesa, a rural and historically important location, particularly concerning the Pueblo revolt and its use as a refuge. The chapel was built in 1924 by the families who lived there, mixed descendents of Puebloan and Spanish ancestry. In early years, Father Miguel would drive his team of black horses and buggy, tie the horses to a fence, and celebrate mass once a month. But as land rights were bought out, the population decreased. The last mass was held in 1956. Eventually, the church was abandoned and deteriorated. In 1991, members of the original families gathered together to discuss restoring the Chapel. They approached Cornerstones for a technical assessment. Following this, the community made clear their commitment to save the building. Former residents, their children, their grandchildren and others volunteered to come work on the project. Over 1,200 adobes were made and laid to replace or repair deteriorated walls. A new metal roof was installed; the bell tower was stabilized and walls were re-plastered with earthen plaster. The work was accomplished with a budget of approximately $5,000 – an amazingly low cost due to volunteers and donated materials. As a model, Pajarito demonstrates the highest level of community

Fig.2 Nuestra Senora de la Limpia Concepcíon de Lós Piros de Socorro del Sur in Socorro Texas, surrounded by adobe bricks handmade by the community and other volunteers (credits: Pat Taylor, 1994)

involvement with the minimum of financial expenditure, with the result of a beautifully preserved chapel and a renewed sense of family commitment to maintaining the site. It is a perfect example of a Cornerstones core-mission project activity.

3.2 Socorro – a large community

A very large project that involved intersecting communities and partnerships can be seen in Socorro, Texas. One of the oldest missions in the United States, Nuestra Senora de la Limpia Concepcíon de Lós Piros de Socorro del Sur, the Socorro Mission was built between 1684-1692. Cornerstones was invited by La Purisíma Restoration Committee in Socorro to conduct a preliminary conditions assessment. The mission's exterior had been plastered with cement in the 20th century. Vigas and corbels were rotting, the roof was leaking and the east nave transept wall was beginning to fail. That assessment led to Cornerstones being asked to lead the preservation effort. Due to the scale of the project, which was much larger than anything Cornerstones had ever undertaken, organization and funding was a key challenge. Staff responded to the challenge and helped Socorro to become the beneficiary of a grant from Save America's Treasures (SAT), the nation's principal preservation-funding program. With that, major financial support, preservation efforts began in 2000. 20,000 adobe bricks, handmade on the site, replaced damaged adobes at the foundations, walls, and roof parapet. Extensive structural repairs and interior mud and lime plastering were completed. Roof leaks were fixed, the bell tower and façade were stabilized, and the interior re-plastered with yeso (gypsum) and the exterior re-plastered with lime.

The community involved with the Socorro project went beyond the parish or the town. Collaborative research by archaeologists, historians, and architects were key components to the work. Interns from the International Council on Monuments and Sites (ICOMOS) came from Ecuador, South Africa, Ghana, Mexico, and Australia; while the North American Community

Service (NACS) supplied interns from Canada, Mexico and the United States. Work crews also consisted of 'welfare-to-work' adult trainees and clients with the felony- and juvenile-court systems. This was a multiyear, multifaceted, million-dollar-plus project, which demonstrated the potential for capacity building through partnerships and creative outreach.

3.3 San Miguel Chapel – building a community

Cornerstones' foremost project today is the preservation of San Miguel Chapel, purportedly one of the oldest religious structures in the United States (built between 1610 and 1628), located in a National Landmark District several blocks from the Santa Fe Plaza, New Mexico. The Chapel occupies a very prominent setting at the crossroads of two historic trails – the Santa Fe Trail and the Camino Real. The project itself exemplifies the current environment in which Cornerstones exists. The scope of work includes partnerships with the City of Santa Fe, the State, the National Park Service, the State Historical Preservation Office, archaeologists, engineers, architects, and many other interested parties. The work itself is being accomplished mostly by volunteers and youth trainees. Grants, including one from SAT, have provided approximately one quarter of the financial needs.

Just as many other churches, San Miguel was covered in cement stucco during the 1950s; the cement covered up cracks, substantial losses, water damage, and surface deterioration. Furthermore, the original subsurface-drainage system had collapsed. All rainwater and snow melt from the site and adjoining properties were accumulating in the front of the chapel saturating the camposanto and wetting the walls. These problems spelled out an urgency for the project.

In addition to these fabric-related problems, San Miguel presented a special issue in terms of community awareness. The chapel is not owned by the Catholic Diocese as is commonly thought but instead by St. Michael's High School (bequeathed in the 1850s). There is no specific parish, only those who attend mass regularly and, therefore, it does not have a dedicated constituency. San Miguel is perhaps better known outside of Santa Fe as a tourist attraction: over 50,000 visitors annually pass through its doors to view and experience the 400-year-old adobe icon. Therefore, the most compelling issue Cornerstones and St. Michael's faced was the challenge of building a local community of volunteers to adopt the project. This has become an evolving goal, which was achieved through 'a call for volunteers' in newspapers, our website, hotel and visitor-center brochures, and community liaisons. The active on-site program has an energy

Fig.3 Volunteers plastering walls at San Miguel Chapel in Santa Fe, NM (credits: Jake Barrow, 2011)
Fig.4 Volunteer day making adobes at Old Trading Post at Santo Domingo Pueblo (credits: Jake Barrow, 2011)

that itself engenders a spirit of volunteerism of which people want to be a part. Some of our volunteers included local people, visitors to the city, and groups from businesses, schools, and local government. We set up an adobe-making yard on-site, and volunteers and tourists responded with enthusiasm. Over a two-year period, more than 300 individuals have provided in excess of 4,000 hours of effort, which has effectively matched funds in-kind for the SAT grant which Cornerstones secured to provide funding for the project.

4. PUBLIC EDUCATION, OUTREACH AND YOUTH

The long-term benefit of involving diverse groups of volunteers in Cornerstones' projects has been profound. The tangible benefit is evident in the preservation of a community's significant historic buildings. As the years went by, Cornerstones' was able to see that their training efforts had taken hold; communities were able to continue to care for and maintain their important sites. Others watching from a distance copied the formula. However, while the phone calls for assistance have decreased, they have not vanished; and Cornerstones is now tackling the same old problems (need for repair and conservation) with new strategies for education and outreach. Many of the churches first repaired now need a touch up and a judicious bit of minimal intervention. We are ready to provide a mixer and scaffolding to anyone.

4.1 Problems surrounding the use of cement

Of these project examples, with the exception of the Trading Post, all are relational to the misuse of Portland cement. As with so many adobe structures throughout the Southwest and elsewhere, deterioration of Pajarito was initially engendered by disuse, lack of maintenance and the subsequent application of hard stucco. Socorro's problems (on a large scale) were the same. San Miguel suffered the ravages of time, so cement stucco was applied to cover and hide the problems. For a time, it appeared to have worked well, providing a seemingly maintenance-free surface. Faced with loss of populations in their parishes, towns, and villages and, therefore, loss of the labor force necessary to maintain adobe buildings using traditional materials and methods, caretakers of historic sites attempted to safeguard them by applying impermeable cement- based stuccos, installing concrete-slab floors and aprons (contrapared) in and around them. The basic idea driving these well-intentioned efforts was to keep water out. Unfortunately, it has not worked. Capillarity of earthen materials and the action of moisture moving underground has been a surprisingly difficult science to impart to laymen who have responsibilities for these historic earthen resources. Sometimes, even contractors and engineers cannot grasp the nuances of this issue. For 25 years, Cornerstones has persisted in delivering the simple message that when a traditional adobe building is encased in cement, its ability to breathe – its natural capacity to rid itself of the moisture that wicks up into its walls – is eliminated. During the mid-20th century, nearly all the historic Southwestern adobe buildings became covered with Portland cement stuccos. Our calling was established.

Over the years, Cornerstones has preached this story and the basic needs of positive-site drainage to a choir who have mostly listened. A few have not. While recognizing the hazards of cement use on historic earthen structures, Cornerstones also has recognized the need to evaluate each situation for its own merits. There are cases where drainage is adequate and the walls of a structure are protected by good roof overhangs. If the adobe has been maintained and no damage or excessive moisture exists, cement stuccos can be benign. We recommend leaving them until the stucco life has reached the end of its viability. Eventually, it cracks and separates from the substrates and has to be removed. At that time, a new more compatible surface may be considered and rendered.

Despite the lack of knowledge of traditional building techniques among the younger generations, Cornerstones has been fortunate to find community members who remember "the old way of doing things." Sometimes, just the acknowledgement that new techniques and materials are not always the best is all that is needed to stir community memory and bring "the old ways back." For us, this remembering is preferable to didactic lectures. Recent collapses of adobe walls at the historic Lemitar and Questa churches in New Mexico as a result of inappropriate and incompatible preservation practices are indicators that our work and message are still vitally needed. Questa did not deal with a severe drainage issue and Lemitar kept adding cement-based surfaces at every opportunity and every location. Lemitar is a lost cause, having been recently demolished, and Questa is busy with fundamental and properly planned repair. Cornerstones is part of an advisory committee there.

4.2 Education and youth training

Education is the key to success and sustainability of all community-based preservation. Cornerstones utilizes community hands-on workshops as a means of disseminating important technical information regarding the restoration and maintenance of historic buildings to a large number of people. Participants can take skills learned in these workshops and teach them to others in their respective communities. Workshops are scheduled on a periodic basis in different regions throughout the Southwest, and have included mud plastering, historic pigment-conservation workshops, viga-repair workshops, log-cabin work, stained-glass window conservation, adobe-brick making, and stone and earthen-mortar repair. Partnerships with other organizations have enlarged our constituency. In 2010, Cornerstones joined the Desert Southwest Cooperative Ecosystems Network, a consortium of government and non-government non-profits working out of the University of Arizona providing resources for research, training and technical solutions for cultural- and natural-resource challenges. Workshops for students, volunteers and maintenance personnel held at Organ Pipe Cactus National Monument, Joshua Tree National Park, Walnut Canyon National Park and Arches National Park in 2010 and 2011 are case studies for how this actually works. Working with other partners, we are planning distance-learning opportunities for adoberos – adobe-crafts people.

4.2.1 Youth-training program

The uniqueness of Cornerstones' community-based philosophy emphasizes youth involvement. Many young people in the Southwest are unaware of the cultural and historic significance of the buildings in which they live, work, or play. Recognizing the important role young people have in carrying on cultural traditions, Cornerstones has developed specialized youth-training programs. We offer workshops and training through which young people can develop job skills and learn more about their community's heritage. This training can lead to employment opportunities during projects. The ultimate effect is that students can learn valuable skills, sometimes as simple as work ethic, and also learn to value themselves. Intergenerational teaching is an important part of this program. Youth meet with community leaders who act as mentors, teaching not only the traditional skills but also the significance of these skills within the history and culture of their society. Equally important is the knowledge that without job skills and training, disenfranchised youth are susceptible to problems, such as gang involvement and drug addiction. Cornerstones' aim is to intervene in the lives of youth in a positive and effective way, as well as to promote a greater appreciation of their cultural heritage.

4.3 Outreach

For the past 25 years, word of mouth and the immediacy of watching a project in progress have been the most successful tools in promoting Cornerstones' work to communities. At the invitation of communities throughout the state, Cornerstones has given many presentations about its community-based preservation process. Cornerstones has compiled techniques and methods to share in an Adobe Architecture Conservation Handbook (available on line or through Amazon.com) and a Flood Mitigation Handbook, both of which have had wide circulation. And Cornerstones is responsible for maintaining a photograph-archival database – both in hard prints and digital form, upon which communities and other organizations may rely.

Cornerstones approach has endeavored to disseminate and teach traditional building strategies and techniques in as many ways as possible. During 2009, a milestone was achieved with the acceptance of the Historic Earthen Structures Building Code by the State of New Mexico. Cornerstones' participation was key. But today's outreach is more electronically centered. So Cornerstones has learned how to develop and implement marketing and public-relations plans to promote workshops and projects. While Cornerstones is most conversant with a technology that began centuries ago, it is rapidly catching up with today's modern communications techniques, with websites, email newsletters, Facebook, internet links with partnering organizations.

5. CONCLUSION

Cornerstones has now built a national and international reputation for the creative use of historic preservation as a tool for community revitalization, the affirmation of cultural values, and the training of youth in traditional building skills and sustainable-construction methods. The largest portion of this work has been skills and methodologies used for centuries to maintain and perpetuate earthen architecture while complying with the Secretary of Interior's Standards for Historic Preservation. Partnerships with other organizations have enlarged our constituency. Cornerstones recognizes that a key element of our work continues to be funding. With the economic downturn, many individual, corporate, and foundation sponsors have had to decrease their financial support. Like many other not-for-profits, we must be inventive and flexible in finding new funding for our operating expenses and our projects. Cornerstones' approach thus successfully integrates historic preservation with apprenticeships for youth, on-the-job adult training, cross-border collaborations, and economic development through revitalization of culture and tourism. For the past 25 years and for the next 25 years, the work has been and will be focused on historic preservation and cultural traditions. Thanks to friends, supporters, donors, volunteers and others, Cornerstones helps communities to help themselves, to maintain the heart of their place, *corazón del lugar.*

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TERRA EUROPAE - EARTHEN ARCHITECTURE IN EUROPE: A PROJECT FOR EARTHEN-ARCHITECTURE AWARENESS

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Theme 9: Education, Dissemination and Outreach
Keywords: European network, heritage preservation, contemporary sustainable architecture

Abstract

Traditional and contemporary earthen construction can be identified in most European countries. The ecological and sustainable advantages associated with European earthen-building traditions make it a relevant material for construction nowadays. However, despite recent technology, earthen heritage remains fragile and threatened. This is why, this unique heritage and contemporary earthen architecture in Europe deserve to be further acknowledged and supported.

In that aim, a European project was implemented in 2006-2007 making a state of the art of earthen architecture in Europe, particularly in France, Italy, Spain and Portugal. In order to complement these results at the scale of the European Union and to ensure a widest dissemination, the project 'Terra InCognita – Earthen Architecture in Europe' was launched from 2009 to 2011. The aims of this last research project were challenging: a scientific publication gathering the contributions of authors from the 27 European Union countries; an updated European Atlas concerning traditional earthen techniques; a scientific exposition and a photography exhibition, a European label, as well as a comprehensive website (www.culture-terra-incognita.org). The research project also initiated the launch of a European network during a symposium held in Marseille (4-6 May 2011).

This paper presents the results of the Terra InCognita project, as well as a reflection concerning the relevancy of this kind of research initiatives, as they can contribute for the advancement of knowledge regarding earthen heritage, as well as the establishment of strategies to protect earthen heritage.

1. INTRODUCTION

In the framework of Cultura 2000 – Education and Culture, European Union Programme, a first project named "Terra Incognita – Conservation of European Earthen Architecture" was approved and implemented in 2006-2007. The project provided a general state of the art concerning earthen architecture, particularly in Italy, France, Spain and Portugal. A referenced publication was edited with two scientific books focused on discovering and preserving a common heritage (Guillaud, 2008) (1).

With the conclusion of the project, it became relevant to complete an assessment of the state of art of earthen architecture in the European Union, but also to promote initiatives to raise public awareness for earthen architecture, its heritage and its current applications. These aims provided the need for the development of a new project untitled "Terra InCognita – Earthen Architecture in Europe". The project was approved in the framework of Cultura Programme 2007-2013. It started in November 2009 and was completed in October 2011. The project leader was École d'Avignon (France) and its project partners: Escola Superior Gallaecia (Portugal), University Polytechnic of Valencia (Spain), University of Florence (Italy) and CAUE - Adviser in Architecture, Urban Planning and Environment of Vaucluse (France).

The principal aims of this new Terra InCognita project were restructured for a profounder and richer impact and a real contribution to knowledge. Therefore, the project was organized in three complementary stages of work: a Scientific axis; an Educational and Dissemination axis; and a Networking axis.

2. SCIENTIFIC AXIS

To integrate scientific procedures into the research project, it was fundamental to define a more accurate methodology of work, with more consistent and systematic outcomes. This was possible due to different undertakings:

2.1. Scientific missions

The institutional partners undertook scientific missions to the 27 countries of the European Union in 2009 (the starting year of the project). Their assignments were: i) The definition of a state-of the-art earthen architecture, in terms of available expertise regarding earthen heritage and contemporary architecture, conservation and related training, education and academic research, professionals and producers, etc. ii) To identify accurate earthen-heritage data in order to establish an up-to-date cartography of each country. iii) To identify key contacts (experts and institutions) contributing to earthen-architecture awareness regarding national and European networks.

2.2. Comprehensive questionnaire

Prior to their missions, partners prepared a comprehensive questionnaire that circulated throughout European contacts, with the assistance of National and International ICOMOS Committees. This questionnaire was designed to identify key actors in architecture and conservation of earthen-architectural heritage in each country, as professional categories or joint sectors. It also aimed to identify the state of the art of the earthen-materials industry in Europe today.

2.3. Scientific publication

Terra Europae: Earthen Architecture in the European Union is a scientific publication dedicated to selected outcomes of the two years of research. The book's content starts with a photography overview, followed by 27 articles from 47 authors from all of the European Union countries, overviews of seven European regions, and to complement this extensive and inclusive publication, cartography of European earthen-architectural heritage in 2011. An intensive and valued teamwork generated maps and texts from the selected regions. The outcomes were systematically and consistently combined to create a relevant overview of the state of the art of earthen architecture in Europe (Correia et al., 2011) (2).

2.4. European Atlas of Earthen Architecture

As a result of the scientific missions, an accurate cartography was developed and verified by at least three to four experts from each country. The European atlas brought some clarity to the presence of earthen architecture in common geographic areas of the European regions.

3. EDUCATIONAL AND DISSEMINATION AXIS

Improving educational knowledge, raising awareness for the recognition of earthen architecture and providing information regarding earthen architecture in each European country defined this axis.

Fig.1 *Terra Europae* publication (editors: Correia, Dipasquale and Mecca, 2011)

3.1. European symposium

Project findings were presented on the 4th and 5th of May 2011 at the Hôtel de Région Provence-Alpes-Côte d'Azur in Marseille, France during the European symposium organized by Terra Incognita partners and ICOMOS France. The first day was dedicated to the outcomes of the European research project and the second day, organized by ICOMOS France, was committed to earthen-architecture preservation. 37 speakers, representing European experts and researchers, discussed the theme "Building with earth: from cultural heritage to contemporary architecture". An overview of earthen architecture in Europe was addressed from heritage and its conservation through material innovation and its contemporary application. All were embedded in wider issues, such as education and training, economic development of the industry, and earthen-architecture regulations. The symposium received 160 participants, representing 23 countries, from which 17 were European Union countries. Digital proceedings of the symposium were also prepared and distributed during the event (École d'Avignon and ICOMOS France, 2011) (3).

3.2. Website

The website (http://www.culture-terra-incognita.org) has become an important tool for contact. Initially, the aim was a simple page for dissemination, but through the project, it became a platform for communication and contribution of all the findings: availability of photos from each European country (under 'Photo Gallery'); download of the scientific exposition; access to questionnaires; reports per country of each scientific mission (key people identified; key institutions identified; key

Fig.2 *Terra Europae* chapter on regional approaches (editors: Correia, Dipasquale and Mecca, 2011)

people contacted; sites identified; sites visited; contributors to cartography; notes), information concerning the European symposium; data regarding European Label; etc.

3.3. European label

The Award for 'Outstanding Earthen Architecture in Europe' was a distinctive recognition of earthen-architectural quality. Three categories were established: 1) Buildings with archaeological, historical or architectural interest; 2) Buildings subjected to a remarkable and relevant intervention (restoration, rehabilitation or extension); and 3) Buildings built after 1970. The initiative received a considerable number of candidacies from 15 European countries. An international jury of nine members appointed by ICOMOS ISCEAH (International Scientific Committee on Earthen Architectural Heritage) and the different project partners awarded the label to 42 European buildings. The award initiative brought an insightful perspective of the existent earthen-architectural heritage, significant earthen-architectural heritage interventions and contemporary earthen architecture.

3.4. Scientific exposition

An important contribution was made by a scientific exposition with an educational and academic purpose. The exposition was developed based on the findings of each European region. Additionally, an important illustrated overview of the variety of European earthen-building cultures enhanced the exposition. This synopsis was most relevant to understand the contribution of each region to the diversity of earthen architecture in Europe. The exposition is itinerant and will be exhibited in several European countries. It is also available for free download, on the Terra InCognita project website.

3.5. Photographic exhibition

Another input was developed through the conception of a photographic exhibition. The synopsis results emerged from a photographic campaign of earthen architecture in the four countries representing the Terra Incognita partners: France, Italy, Portugal and Spain. From June to September 2010, the Belgian

Fig.3 Atlas of earthern architectural heritage in the European Union, from *Terra Europae* book (editors: Correia, Dipasquale and Mecca, 2011)

photographer, Pierre Buch, travelled through Normandy and the southwest of France, Andalusia and Castile in Spain, Alentejo in Portugal, and Piedmont in Italy. The photographic campaign revealed his search for the art of building long forgotten or overlooked. The selected images are the subject of an itinerant exhibition composed of 20 images focusing on public awareness.

3.6. Booklets for general dissemination

Two booklets were also published contributing to the general dissemination of earthen architecture. The first was a photography catalogue, A photographer's look at earthen architecture – Terre en vues: Regard d'un photographe sur l'architecture de terre (Buch, 2011). It presented an overview of Pierre Buch's photographic exhibition. The second booklet concerned the Label catalogue dedicated to the 42 awarded structures , selected and recognized as Outstanding Buildings for their architectural quality (CAUE de Vaucluse, 2011) (4).

4. NETWORKING AXIS

To strengthen the existing partnership and to extend it to a national and European platform for knowledge exchange were the main aims of this stage.

On the 6th of May 2011, following the Symposium, a formal reunion was organized by the project partners to focus on the launching of a European network on earthen architecture. Participants attending the meeting represented 18 European countries: Belgium, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Poland, Portugal, Romania, Spain, Sweden, Turkey and UK. The 80 participants present in this first meeting recognized the importance of launching a European Federation or Association. This could well sustain the work of research and reflection undertaken by the project, and ensure in the long term, an exchange of knowledge and experience in preservation and new construction, as well as earthen-architecture standards and regulations. This structure will encourage an intensification of professional and scientific exchange, and the sharing of technical expertise and joint projects dedicated to earthen architecture.

Scientific missions confirmed that the actors in earthen construction wanted to unite efforts and energy to contribute to the development of a European-level sector. As a result, professionals, researchers and interested people contacted during the scientific mission chose to keep in contact and attend the European meeting on the 6th of May 2011.

The visit of the project partners during the scientific missions had a definite impact regarding the creation of national informal and formal networks. This was the case, for instance, for Belgium and Hungary. The result of this work exceeded the goals that the project set. It has since led to identify the needs and expectations of the experts, predicting that similar missions might be assigned to a future European structure concerned with earthen architecture.

5. CONCLUSION: OVERALL CONTRIBUTION

The project findings were relevant for the state of the art of earthen architecture in Europe. Also, it brought together experts who, until then, believed there were a few that were interested in earthen architecture in their country. The project contributed to create awareness for each European Union country's heritage and an inspiration to start research, to go beyond and to discover an unrevealed earthen-architectural heritage.

Fig.4 European label (booklet) (credits: CAUE de Vaucluse 2011)

The research project also provided the opportunity to identify European institutional partners for future research and consultancy, for professional projects or networking. It brought acknowledgment of other experts, academics and professionals involved in the field and a real interest for national collaboration and European networking. This will result in more coordinated efforts to establish research projects and continued scientific research responding to actual challenges.

It is undeniable that the outcome that the Terra Incognita research project brought was an important contribution to knowledge. This was possible due to the general commitment of the project partners; due to their perseverance to carry through the project and to present more results than the initial aims and, especially, due to their demand for higher quality and exceptional results.

The involvement of all the authors, key contacts and key institutions made this project a reality with relevant findings, which definitely made a difference.

Notes

(1) This publication was made possible through the contribution of a Scientific Committee and an Editorial staff established within the project partnership: CRATerre-ENSAG (France), École d'Avignon (France), Università degli Studi di Firenze - Facoltà di Architettura (Italy), Escola Superior Gallaecia (Portugal), Universidad Politécnica de Valencia - Escuela Técnica Superior de Arquitectura (Spain).
(2) This publication was made possible through the contribution of a scientific committee and an editorial staff established within the Terra InCognita's partnership: École d'Avignon (France), Conseil d'Architetcure d'Urbanisme et de l'Environnement (CAUE) de Vaucluse (France), Università degli Studi di Firenze - Facoltà di Architettura (Italy), Escola Superior Gallaecia (Portugal), Universidad Politécnica de Valencia - Escuela Técnica Superior de Arquitectura (Spain).
(3) Proceedings of the symposium held in Marseille, 4 and 5 May 2011. This publication on CD-Rom was made possible through the contribution of a Scientific and Editorial Committee established within the Terra InCognita's partnership and ICOMOS France "Earth Working Group".
(4) The publication was made possible through the contribution of a Scientific and Editorial Committee established within the Terra InCognita's partnership.

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Chan Chan, Peru (credits: Luis Fernando Guerrero)

TERRA 2012 | 12th SIACOT
REFLECTIONS AND RECOMMENDATIONS

1. IMPACT OF TERRA CONFERENCES

Although general recommendations of TERRA conferences could be useful if they were adapted to local, social and cultural contexts, as well as natural conditions, experience shows that there are difficulties in their integration and application.

The effort and the responsibility has to be focused on each participant, who with their contact networks and institutions should become the agent for the transmission, integration and implementation of the recommendations to their local context, and to the associated political, academic, cultural, business and society representatives.

2. CHANGE AND INNOVATION

The speed and complexity of today's challenges has changed.

Earthen architecture as a discipline should not be isolated to its own field, but be integrated with other disciplines to address issues of material, technological innovation, and the design of habitat and heritage conservation linked to local development.

3. NATURAL DISASTERS AND CLIMATE CHANGE

In several regions of the world, there are conditions where the conservation of earthen architecture is vital from the historical, cultural and social standpoint, due to the country's vulnerability to natural and manmade disasters that accelerate its disappearance.

For this, a culture of prevention and risk management must be developed and strengthen based on sound principles for better conservation, as proposed by ICOMOS-Peru at TERRA 2012.

4. ACADEMIA AND SOCIETY

In addition to education and research, academia intervenes more actively in response to social needs.

Earthen-architecture actors have the responsibility to integrate themselves into this growing global reality, in order to make appropriate operational policies at regional and local levels.

5. CONTEMPORARY CONDITIONS

There is a latent risk of losing the continuity of the architectural and construction culture, which has a direct impact on the preservation of earthen-architectural heritage.

To facilitate this continuity, it is necessary to innovate and explore new directions in contemporary design and human settlements. Again, being interdisciplinary is fundamental to a comprehensive vision.

6. EDUCATION AND TRANSFERENCE

There remains a devaluation of earthen architecture as a disciplinary area and, therefore, a lack of integration in education and training programs.

It is necessary to integrate earthen architecture with the other disciplinary areas and facilitate teaching, theoretical and practical pedagogical methods, as well as experimentation as a fundamental concept for knowledge.

7. RESEARCH

The lack of definition of research problems and the repetition and redundancy of research topics, due to lack of and access to information, is contributing to a waste of resources, energy and time.

It is, therefore, necessary to define knowledge gaps, facilitate open access to scientific information and encourage interdisciplinary research, and apply it to regional contexts.

8. COMMUNICATION

The existence of different groups, networks, associations and national and international entities engaged in earthen architecture is noted.

It is necessary to promote exchange, and to boost joint and collaborative activities, as well as the establishment of an international observatory to define priorities and strategies for research and communication.

Developed by the Advisory Committee of
TERRA 2012 | 12th SIACOT 2012

LIMA DECLARATION FOR DISASTER RISK MANAGEMENT OF CULTURAL HERITAGE

PREAMBLE

Cultural heritage professionals, architects, archaeologists, structural engineers and other specialists from Peru and Japan met during the "Symposium on Disaster Risk Management of Cultural Heritage. Sustainable Conservation of Urban Cultural Heritage in Seismic Zones. The symposium aimed to share post-disaster recovery experience and discuss the role of structural engineers and conservation architects" for the protection of Cultural Heritage located in earthquake zones. From the meeting emerged the following statements:

1. The world is divided into seismic and non seismic areas. Earthquakes occur mainly along two big circles: The Circum- pacific where more than 95% of seismic energy is dissipated and the Eurasian circle. Following the International Conservation Charters and conservation policies, now we address the cumulative damage to cultural heritage associated with severe earthquakes prone areas;
2. A significant number of World Cultural Heritage Properties is located in these seismic areas, especially in the Circum- Pacific region of Asia and Latin America, the Caribbean, Southern Europe, West and Central Asia. Potential damage due to large earthquakes is foreseen in these regions. Therefore these regions need to undertake urgent measures to safeguard lives and cultural heritage from disasters;
3. Arguing safety reasons, the local authorities often demolish historic fabric after a severe earthquake. New generation of professionals should change this tendency through multidisciplinary approach aimed at sustainable protection of heritage. All cultural remains must be conserved or restored by taking into account the principles of integrity and authenticity understood in local context;
4. ICOMOS National Committees are encouraged to contribute to the enrichment of the spirit of the Conservation Charters to consider the disaster mitigation on cultural heritage in seismic zones;
5. Heritage conservation can be accomplished through education by organizing updated courses, seminars and training activities. Academic institutions would play an important role by including cultural heritage and tourism studies for sustainable development of heritage sites;
6. Communication between community members and professionals from various disciplinary backgrounds, academics and authorities is necessary to explain and disseminate why restoration of heritage should be done with due respect to authenticity and integrity. Due attention should be given by journalists and other mass media professionals to spread this understanding;
7. The responsibility of the authorities towards preparedness for the next severe earthquake needs to be stressed. Even though human life is priceless, many heritage buildings at risk of collapse are also used for housing, business and/or other tourism facilities;
8. Disaster mitigation and preparedness requires a comprehensive assessment of risks to the site and its occupants and visitors. Detailed rescue and response plans should also be drawn up. For this purpose, it is mandatory to identify the carrying capacity of historic public buildings and places in order to prevent bottlenecks during disasters. Due consideration should be given to prior inspection to approve only those activities on the site that pose no risk to the life of habitants or visitors.

BACKGROUND AND STATEMENTS

1. World Heritage Convention has emphasized the responsibility of each State Party to formulate national policies for the protection of cultural heritage;

2. In response to disasters, the first priority is to save human life and provide for the basic needs of victims. Next, emergency response and recovery should avoid further harm to cultural heritage;

3. Interdisciplinary analysis and structural assessment of heritage buildings must include the use of traditional materials and technologies, if they are adequate. Considerations should be given to the deep understanding of the historical buildings and their seismic behavior through analytical or physical modeling, non destructive tests and other modern tools and to document it. Performance-based criterion complemented with strength-based criterion should be considered;

4. The earthquake history, especially the seismic activity in and around the heritage sites, and the impact of recent earthquakes on traditional and non-traditional structures, should be documented and made available;

5. In order to achieve the objectives of sustainable development and risk management, recommended by the Thematic Meeting on Cultural Heritage Risk Management on Kobe during UN-WCDR in 2005, following strategic goals should be taken into account;

6. Integrate cultural heritage into existing disaster reduction policies and mechanisms at the international, national and local levels including involving qualified heritage organizations and expertise;

7. Involve local communities in the preparation and implementation of risk management plans, and all stages of disaster recovery;

8.Include cultural heritage as a subject to develop scientific research and technical studies, educational and training programs associated with risk management and disaster recovery, to work out such operating methods will make the State capable of counteracting the risks that threaten cultural heritage.

ACTION RECOMMENDATIONS

General Recommendations

1. Undertake awareness raising initiatives to involve decision makers and local communities in the development and implementation of disaster risk reduction strategies for cultural heritage;

2. Encourage established national and international networks of cultural heritage and disasters to promote the integration of cultural heritage protection into broader disaster management field.

For Intergovernmental and International Nongovernmental Organizations

3. International Intergovernmental and Nongovernmental Organizations concerned with cultural heritage, such as UNESCO, ICCROM, ICOMOS, ICOM, IFLA and ICA, as well as the International Committee of the Blue Shield (ICBS) and related international instruments such as the World Heritage Convention, should act, enhance and promote disaster risk reduction within their policies, programs, and activities;

4. Special consideration should be given to countries located in seismic areas to ensure safety in cities with living cultural heritage with due consideration to their ecological reality. Recurrent earthquakes cause cumulative damage to historic urban areas and sites. Development of new technology with necessary reinforcement that is compatible to original materials and technology and is reversible should be encouraged;

5. Include disaster risk management of cultural heritage in the scope of the assistance programs of various international development and cooperation agencies, which should also promote this policy among other multilateral development institutions to which they are a party.

For Central, Regional and Local governments

6. Governments should establish expert committees that would enable exchange of opinions to formulate coordinated policies by bringing together multidisciplinary specialists such as structural engineers, architects, archeologists and other cultural heritage specialists. The government should also promote administrative and financial measures that are necessary to establish comprehensive disaster mitigation facilities for cultural heritage properties as well as their surrounding urban environment;

7. Governments should strengthen the institutional support and governance for disaster preparedness, through due regulations developed in consultation with the civil society. Public institutions, owners, and other stakeholders should be encouraged to work together in formulating policies to preserve Cultural Heritage;

8. Responsible authorities of Cultural heritage and Disaster Mitigation should jointly develop special tools for periodical inspection of structural stability of heritage buildings for their mitigation against earthquakes, in order to preserve their heritage values and use appropriates technologies that would maintain these values over time;

9. Encourage national and international assistance to recover living heritage by including comprehensive understanding of the society in the rehabilitation programs, awareness and education activities for the habitants so as to improve their safety and daily life conditions;

10. In the context of the World Heritage Convention and other international instruments, adopt and implement

comprehensive policies, procedures, and legal measures to integrate cultural heritage in all disaster reduction programs and to include risk management plans as part of the management system for heritage properties;

11. Include governmental and non-governmental cultural heritage expertise in existing and future national coordinating bodies mandated to oversee the development and implementation of disaster reduction policy, programs and actions plans;

12. Cooperate with local administrations and provide adequate resources to ensure the adoption and implementation of consistent risk management strategies for cultural heritage assets in their territory, in particular, historic urban areas

and living cultural landscapes, and their settings; including identifying, assessing and monitoring disaster risks;

13. Encourage and support civil society and non-governmental initiatives in the field of disaster reduction for cultural heritage through measures that are aimed at reducing underlying vulnerability factors;

14. Initiate and support education and awareness campaigns to disseminate information widely for the protection of cultural heritage before, during, and after disasters; Use the knowledge, innovation and education to build a culture of disaster prevention;

15. Central, Regional and Local governments are encouraged to promote coordination between policies for cultural heritage earthquake risk management, urban planning and disaster management for the cultural heritage properties and the surrounding environment.

For educational/ research institutions

16. To develop training programs on repair and retrofitting aimed both, for cul- tural heritage professionals and emergency personnel, so as to achieve seamless integration;

17. Education is the starting point to understand the importance of disaster preparedness. Therefore younger generations should be made aware of the importance of cultural heritage, tangible and intangible and that they are responsible for its conservation;

18. Academic institutions such as universities, technical schools and research centers are encouraged to promote education and research on comprehensive disaster management of cultural heritage sites located in earthquake prone zones, and are especially encouraged to engage in international activities such as establishing networks to improve the quality of their activities by cooperating with the activities of regional cultural heritage centers.

The "Lima Declaration for Disaster Risk Management of Cultural Heritage" was drafted and proposed by the professionals below, and adopted with the applause and common consent of all the participants of the International Symposium on "Disaster Risk Management of Cultural Heritage. Sustainable Conservation of Urban Cultural Heritage in Seismic Zones. Post-disaster recovery experience: Role of structural engineers and conservation architects", hosted by CISMID-National University of Engineering (UNI), Ritsumeikan University (RITSDMUCH), with the support of ICOMOS-ICORP, ICOMOS Peru, which was held at the Jinnai Hall, Japan Peru Cultural Center, on 3rd December 2010.

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