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

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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

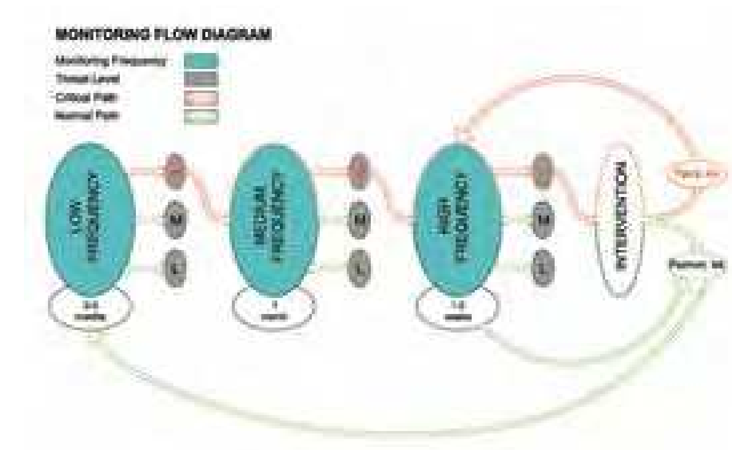

Fig.5 Monitoring flowchart (credits: © ADACH, 2011)

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.

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,

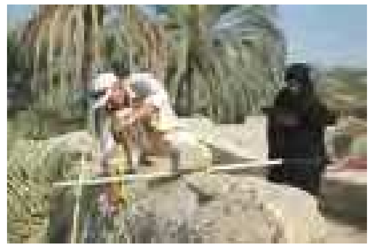

Fig.6 and fig.7 Documentation of Jimi Walls and monitoring of Abdullah Bin Salem Al Darmaki House (credits: Salman Muhammad © ADACH, 2010 - Ali Malekabbasi © ADACH, 2011)

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