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

María Inés Suilan Hau Espinosa, Thomas Sebastien Richard Jarpa

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 "*
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> *(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.

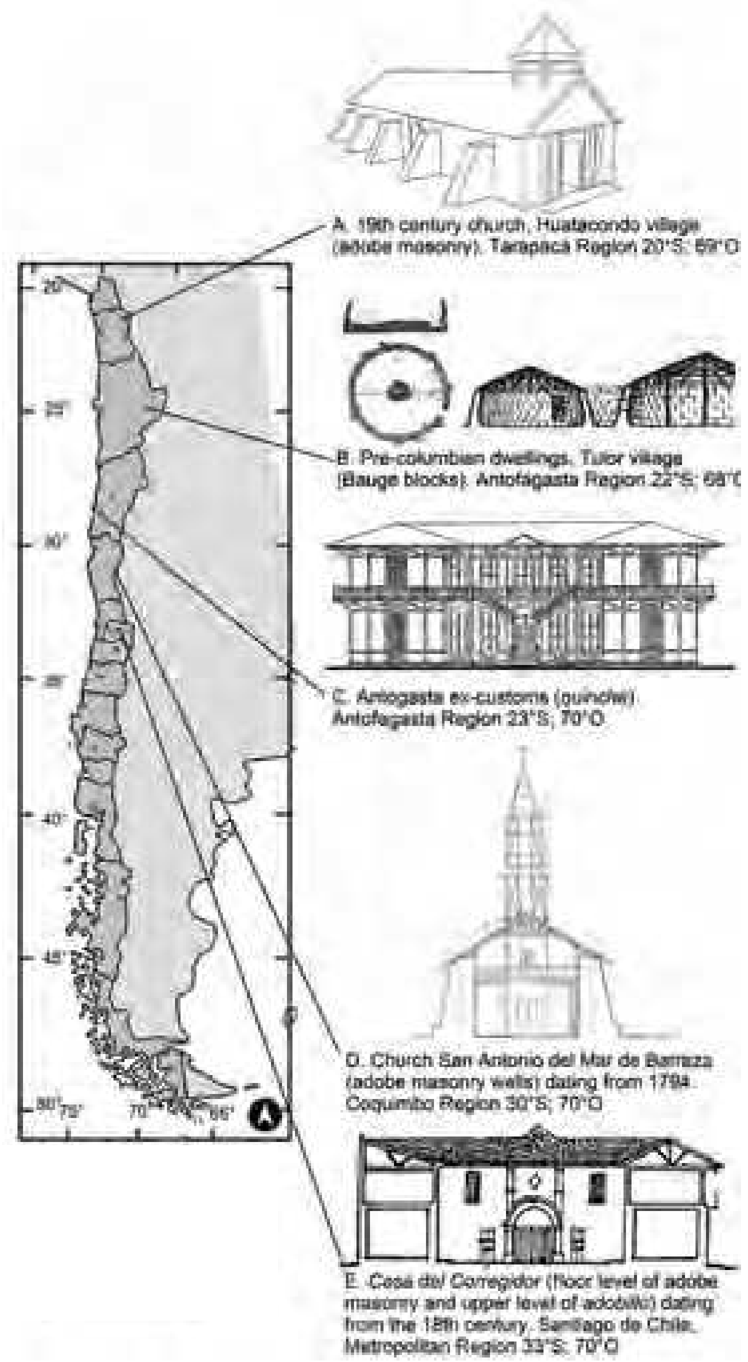

Fig.1 Local seismic culture in Chile (credits: *A.* María Inés Suilan Hau Espinosa, Thomas Sebastien Richard Jarpa; *B.* Gygogne & CYTED (1995) p.53; *C.* Arquitectura Universidad del Norte, Chile (1983); *D.* Archivo CMN Intervención Iglesia de Barraza, Mónica Bahamondez; *E.* Antonio Sahady, (1996)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

Louise Cooke, Peter Brimblecombe

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