

Principles for the Conservation of Earthen Architectural Heritage in Seismic Areas

Julio Vargas-Neumann

Catholic University of Peru, Lima, Peru



ABSTRACT

For Conservation guidelines of Earthen Architectural Heritage, the world could be divided into seismic and non-seismic areas. The destruction of earthen heritage (more vulnerable than average architectural heritage) in seismic zones is much worse and occurs at much faster rate than in non-seismic regions. Conservation principles should focus on preventing the irreparable collapse of the structures during strong earthquakes.

In accordance with the spirit of the international conservation charters, it's imperative to introduce a new performance-based design criterion that can complement the strength and stability based criteria already being used. This modern technology of reinforcement should follow a minimal intervention criterion and must be compatible with the original construction material to respect the authenticity of the fabric. Moreover, these reinforcements should constitute a reversible and modifiable solution.

The principles presented in this paper were validated officially by ICOMOS Peru, like a National Committee proposal.

Keywords: Earthquakes, earth, conservation, principles, vulnerability.

1. OBJECTIVE

To define the basic principles and criteria of seismic performance in Peru for the preservation of historic adobe structures so as to preserve their cultural significance and the value provided by their integrity.

Interventions consist of technical and management measures to redress damage already caused by and to assess the damage that may result from future seismic activity. The main interest guiding conservation is the preservation of heritage constructions.

2. DESCRIPTION OF HISTORIC EARTHEN STRUCTURES

These are works of heritage value where earthen building materials contribute stability to the structure. In this context, earthen historic structures are constructions using adobe, rammed earth, masonry using earthen mortar (including burnt brick and stone), stone-covered land structures, Also included are all types of constructions or buildings with such attributes, in whole or in part, provided they have a cultural significance or are part of a historic site.

3. INTRODUCTION

Earthen heritage buildings may have differing uses according to their archaeological or non archaeological, nature. Interventions in residential buildings differ from those in an archaeological site, as do their objectives.

In a non-archaeological heritage building, which can be used for the public benefit, the conservation of the historic property must take into consideration the property's aesthetic, historical and material value, which must remain entirely unaltered.

In archaeological buildings, conservation must start by learning the history of the building and defining its cultural value and meaning.

The best way to convey the historical message of the past for these buildings should be found, seeking a balance between preservation of the heritage property, and strengthening and preparing it so it can be better presented and understood. Defining the interventions and the technology they require is very important for preserving the value of the monumental site and should be the result of research.

Interventions in archaeological buildings should be a function of the property's value and the decisions reached by a cross-disciplinary team involving archaeologists, architects, engineers and other appropriate experts.

It is further desirable to set up an advisory committee of qualified experts to review and provide advice on relevant aspects of the conservation process.

4. FURTHER CONSIDERATIONS

The Principles for the Conservation of Earthen Historic Structures in Seismic Areas are based on the following considerations:

- The transcendental importance of earthen structures and the recognition of such works, which are the first human-built structures and are relevant to all periods as part of world cultural heritage;
- The great diversity of structures with such attributes;
- The diverse qualities of widely available earth (soil) and stone materials that have been used for these buildings worldwide.
- The high seismic vulnerability of these wholly or partially earthen structures where earth is the structural material providing overall stability, requiring special treatment for these structures when they are located in seismic areas (Lima Declaration for Disaster Risk Management of Cultural Heritage, 2010).
- Such structural vulnerability is caused by the mechanical properties of the earthen materials. This is reflected in the ease of cracking, deterioration, breaking up, structural degradation and sudden collapse of these constructions caused by weakness, brittleness and poor adhesion. Therefore, earth alone is not a material capable of providing structures that will survive destructive earthquakes of medium or severe intensity;
- The huge difference between the magnitude of the inertial forces produced by strong earthquakes and the generally low resistance of structures built of earth;
- Earthquakes are recurring natural disasters and therefore produce cumulative damage that threatens these buildings. Depending on the frequency of local seismic activity, these events can irretrievably destroy the heritage property (Lima Declaration for Disaster Risk Management of Cultural Heritage, 2010).

- An alarming increase in information and documentation revealing that historical properties restored after an earthquake, following accepted conservation principles, were subsequently damaged by new tremors, creating a vicious cycle of damage-restoration-damage, which results in rapid and cumulative degradation of the monument's heritage value. This vicious circle is the consequence of not taking into consideration the effects of the archaeological monuments' and heritage properties' location in seismic areas (Lima Declaration for Disaster Risk Management of Cultural Heritage, 2010).
- The massive and rapid disappearance of historic structures built with earth, because of their vulnerability, exacerbated by the gradual obsolescence and vanishing of the trades associated with traditional construction techniques. This disappearance of historical structures is caused not only by earthquakes but also by decisions following the earthquake to demolish the heritage property; involved in these decisions is not only the seismic damage, but also the lack of appropriate recovery technologies and in particular the lack of appreciation for the heritage value of the property (Lima Declaration for Disaster Risk Management of Cultural Heritage, 2010).
- The wide range of actions and treatments required for the preservation and conservation of these historic resources, where to the extent possible priority should be given to principles of minimal intervention, reversible reinforcements and compatible materials, as defined below:
 - a) Minimal intervention is the set of actions unavoidably necessary to prevent future deterioration of the historic construction.
 - b) Reversible strengthening, temporary or permanent, is that which can be replaced by a better solution, without significantly damaging the historical property.
 - c) Compatible materials are those that, even in advanced stages of deterioration, when the property is close to disintegration, help to control the displacement of the original structure, without additional damage to it or complication to its behavior;
- New technologies and statistical methods are available to clearly define the seismic geography associated with the causes of earthquakes and historical recording of seismic sources (location of epicenters in space, their recurrence in time, intensity and extent). It is therefore necessary to clearly identify the areas where these principles should be applied. In Peru, these methods should be used in zones 2 and 3 listed in the NTE E.030 Standard. Earthquake Resistant Design;
- The conservation principles and charters adopted by the International Council on Monuments and Sites, ICOMOS, and the universal ICOMOS and UNESCO doctrine for the protection and preservation of structures built with earth, where these have structural applicability.
- The importance of the principles for the Conservation of Heritage Sites as submitted by ICOMOS China, (Principles for the Conservation of Heritage Sites in China, 2004) and similar documents prepared by ICOMOS's National Committees.

5. BACKGROUND AND COMMENTS

This document is based on important principles adopted by ICOMOS and others made by western and eastern countries such as Canada and China, as well as on research and conservation experience in Peru:

- *"Ruins must be maintained and measures necessary for the permanent conservation and protection of architectural features and of objects discovered must be taken. Furthermore, every means must be taken*

to facilitate the understanding of the monument and to reveal it without ever distorting its meaning." (Venice Charter, 1964, Page 5).

- With regard to the techniques *"Where traditional techniques prove inadequate, the consolidation of a monument can be achieved by the use of any modern technique for conservation and construction, the efficacy of which has been shown by scientific data and proved by experience."* (Venice Charter, 1964). Application of these statements, initially to architectural heritage, is extended to aspects of archaeological works with unalienable architectural value. (Authors interpretation, Lausanne Charter, 1990).

The proven cycle of damage-restoration-damage, beginning long ago, but clearly documented in the last century, constitutes the starting point for technological change in heritage prevention in seismic areas.

- With regard to techniques and materials *"Traditional techniques and materials are preferred for the conservation of significant fabric. In some circumstances modern techniques and materials which offer substantial conservation benefits may be appropriate. The use of modern materials and techniques must be supported by firm scientific evidence or by a body of experience."* (Burra Charter, 1999, Art. 4.2).

Many experimental studies on earthquake-resistant earthen structures over the last 40 years confirm the availability of compatible materials.

- *"Recognize the vulnerability of structures wholly or partially in timber due to the material decay and degradation in varying environmental and climatic conditions, causing by humidity fluctuations, light, fungal and insect attacks, wear and tear, fire and other disasters."* (Mexico Charter, 1999).

In this regard, earthquakes create similar or worse vulnerabilities in earth structures located in seismic areas.

- Conservation accords generated in the West and principles generated in Asia, (Principles for the Conservation of Heritage Sites in China, 2004), have not yet recognized that the planet is divided geographically into seismic and non-seismic areas (Lima Declaration for Disaster Risk Management of Cultural Heritage, 2010). Some principles on architectural heritage protection advise urgent action to prevent the imminent collapse of structures, for example, from damage caused by an earthquake. (Zimbabwe Charter, 2003, 1.7). Today, however, as stated in the goals of ICOMOS ICORP, it is necessary to act before earthquakes happen, by creating a culture of prevention rather than responding to emergencies following an earthquake or when the damage is already irreparable.

- *"The feelings aroused by the contemplation and knowledge of past works can greatly facilitate mutual understanding of peoples, and to this end, these works should benefit from international collaboration while the accomplishment of their social mission should be fostered through all available means."* (New Delhi Charter, 1956).

The seismic hazard of old structures must be overcome and controlled through technologically efficient reinforcing. This will help to choose between either conservation or eventual burial.

- *"The protection of fragile and nonrenewable archaeological patrimony must be based on effective collaboration of high level academic and scientific multidisciplinary teams, government, private companies and the public at large."*, (Lausanne Charter, 1990, Introduction).

- *"The Charter has to reflect very basic principles and guidelines with global validity. For this reason it cannot take into account the specific problems and possibilities of regions or countries. The Charter should be supplemented at regional and national levels by further principles and guidelines for these needs"* (Lausanne Charter, 1990, Introduction).

• *"Reconstructions serve two important functions: experimental research and interpretation. They should however, be carry out with great caution so as to avoid disturbing any surviving archaeological evidence , and they should take account from evidence of all sources in order to achieved authenticity.", (Lausanne Charter, 1990, Art. 7).*

These statements are relevant and important, especially for earthquake-prone regions.

• *"The protection of archaeological heritage cannot be based solely on the application of archaeological techniques. It requires a broader base of skills and professional and scientific knowledge. Some elements of the archaeological heritage are part of architectural structures and, in this case, must be protected in accordance with the criteria for such heritage under the Charter of Venice of 1964 for the restoration and conservation of monuments and sites. "(Lausanne Charter, 1990, Introduction).*

• *"When knowledge of archaeological remains is not complete, there may be special cases, such as when structures must be stabilized during excavation. The structural characteristics of a construction that is being uncovered can be completely different from another that is exposed. Urgent solutions are required to stabilize a structure as soon as it is excavated. The overall significance of the building should not be jeopardized, both as regards its form and its use. "(Zimbabwe Charter, 2003, 2.4).*

6. GUIDELINES

In this section, we have found common responses and similarity of views with Asian countries, especially those that historically have suffered the brunt of disasters and seismic events. We must be clear, however, that these experiences have led to different solutions. China, Japan (seismic activity countries), New Zealand and Canada have helped to establish the following principles and procedures.

6.1. Recognition of site value. Inspection, Data collection and Documentation, Safety conditions.

In historical earthen constructions built in seismic areas, where the main components are massive earthen structures and/or walls, the tasks to be planned and methodically documented for execution by a multidisciplinary team are the following:

- Conduct research to assess and establish the value and historical significance of the heritage property.
- Define the geometry and structural design of the building including its conservation status and types of damage suffered.
- Investigate the characteristics of the materials, and select models and methods of analysis.
- Evaluate the actions that daily affect the structure and those that may occur during earthquakes to estimate the maximum stresses acting on the structure's elements, including probabilistic methods to analyze the effects of earthquakes, or the structure's behavior under a combination of forces. When appropriate, the site's characteristics may necessitate inclusion of previous specialized seismic risk assessments and studies of underground soil dynamics, taking into account the likelihood of amplifications of seismic energy.

All tasks must be carefully documented pursuant to Article 16 of the Venice Charter and the ICOMOS Principles for the Recording of Monuments, Groups of Buildings and Cultural Sites. The relevant documentation, including representative samples of structural or decorative materials, and elements extracted from the construction, and all information concerning techniques, traditional ways of

construction, and historical information, should be collected, cataloged, stored safely and be accessible as appropriate.

6.2. Diagnosis of the current status of the site.

"The diagnosis must be based on qualitative and quantitative historical research methods. The former must be based on the observation of structural damage and material decay as well as historical and archaeological research itself. The latter should be based primarily on tests of materials and structure, on ongoing monitoring of data and on structural analysis." (Zimbabwe Charter, 2003, 2.5).

With the above information a thorough and accurate diagnosis of the structures' conditions and causes of decay and degradation can be made. This diagnosis will be based on documentary evidence, field inspections, careful analysis of information gathered and, if necessary, not only on checks of the physical condition of the property, but also on non-destructive testing methods. None of these should impede minor necessary interventions, and emergency preventive interventions.

6.3. Planning of project interventions.

The above considerations and background have defined a set of principles to be considered in each particular case. The planning of the intervention project is the culminating stage of the multidisciplinary laboratory investigation.

Planning will take into account not only the stages of implementation but also specialized organization and management considerations. Finally, a master plan must be established for site conservation, to be reviewed periodically to correct and refine it with knowledge acquired during execution.

A conservation master plan may include four aspects: preservation, proper use, display and interpretation, and management. (Principles for the Conservation of Heritage Sites in China, 2004, Art.13).

With the information that has been gathered and evaluated, and the resulting diagnosis, conservation measures may be proposed, describing the structural details, connections, precautions and materials to be used in treatments.

The documentation must also explain the specific reasons which led to the selection of materials and methods used for conservation work. Historical, archaeological, architectural, conservation, engineering, seismic, dynamic amplification (seismic), subsurface and other specialized reports, descriptive narratives, technical standards, sketches and working drawings may be used, as appropriate.

If the structural risk associated with seismic activity is high, attention should be paid to conservation criteria based on stability or performance, designed to control cracking of the structural elements and excessive movement that may result in irreparable damage. This means the use of compatible, minimal impact and reversible reinforcements. Special attention will be paid to avoid compatible reinforcements damaging the original construction in any stage of the structure's dynamic behavior during earthquakes.

A conservation plan for an archaeological site must determine the actions to take before, during and after excavation. Excavation and conservation work must be planned simultaneously to ensure the care of the physical remnants. (Principles for the Conservation of Heritage Sites in China, 2004, Section 26).

The plan must provide for ongoing decision-making regarding further excavations, the use and sustainable management of the site, and preparing the site for presentation to the public by way of tourist circuits and other plans.

Presentation and providing information to the public must be understood as an educational process that discloses the state of scientific knowledge about the cultural property and therefore should be subject to frequent revisions by the multidisciplinary team who will also design the site's presentation and enhancement.

Decisions must be made regarding the degree of conservation needed, seismic stability of the remains and personal safety. These issues could lead to alternative decisions and set limits on the excavation, opt for reburial, or lead to the development of new solutions for efficient, integrative, discreet and reversible structural reinforcement. The site's subsequent management should enforce the previously adopted conservation plan.

The minimal intervention needed for the archaeological site should always be the first option, leaving open future opportunities to understand and conserve using new technologies that may better resolve the issues raised.

6.4. Surveillance, monitoring and maintenance.

It is crucial to maintain a coherent strategy for monitoring and regular maintenance, as recommended by the conservation charters for the stability of structures. Ongoing maintenance is a very important conservation task, including minor damage repair.

6.5. Conservation interventions.

Earthquake disaster prevention should assess the potential damage to the site and to persons. Visitors should be allowed only in places that are reasonably safe in case of earthquakes. All activities posing risks to the site and its occupants should be avoided.

Conservation interventions are technical activities for the treatment of damage and deterioration, maintaining historical authenticity and integrity of a cultural heritage site. Any intervention should be based on appropriate studies and assessments, not only for durability against weathering and wear and tear, but also against weather-related disasters and seismic activity. Problems should be solved according to the existing conditions and needs, respecting the aesthetic, historical, scientific (physical, material, technology, stability) and social values of the historic structure. Any proposed intervention should aim to:

- Ensure the safety of the occupants;
- To preserve and prevent deterioration of the work;
- Preserve techniques and traditional materials of special value;
- Limit intervention to a minimum for the sake of respecting authenticity;
- Be technically compatible and reversible to preserve the original materials;
- Permit conservation work that may subsequently become necessary;
- Document interventions for future reference

The choice between "traditional" and "innovative" must be weighed case by case and preference given to those that produce a lower impact and are more compatible with the values of cultural heritage, without forgetting seismic safety and durability.

Ideally, the historic fabric of structures should be disturbed as little as possible. However, in the case of earthquake damaged structures, preservation may require partial dismantling and subsequent reassembly to allow proper maintenance and eventual reinforcement.

Anastylosis methods, using mortar solutions or injections of liquid earth (sieved soil) as integrating material, should be preferred while trying to maximize the use of original soil or similar material. The injections should avoid incorporating industrial chemicals and binders whose durability has not actually been proven, or whose behavior over time may result in new discontinuities, dismemberment or subsequent deterioration.

In all interventions the historical earthen structure must be considered as a whole, all of whose parts should receive similar quality of attention. In principle, existing materials should be preserved to the maximum. Preservation efforts should include finishing materials, such as ornaments, friezes, plaster, paint, etc. If finishes must be renewed or replaced, harmonious solutions should be found but always distinguishable from the original materials, techniques and textures.

6.6. Intervention categories for conservation.

Four levels of intervention can be established: maintenance, physical protection and enhancement, major restoration, and minor restoration. Each intervention should have clear objectives, employ proven techniques and choose appropriate and compatible materials. (Principles for the Conservation of Heritage Sites in China, 2004, Art.28).

Maintenance, preventive measure to reduce the damage accumulated by nature or humans. This measure is generally applicable to all sites. (Principles for the Conservation of Heritage Sites in China, 2004, Art. 29).

Physical protection and enhancement, emergency measures to prevent or reduce damage. These should avoid affecting the original construction to the extent possible and respect the nature of the heritage property. Protection structures should be simple and minimally invasive. (Principles for the Conservation of Heritage Sites in China, 2004, Art.30).

Minor restoration, a set of measures that may be taken, such that the original work is not altered, no new components are added, and basically without modifying the existing conditions, to rectify distorted, displaced or collapsed elements, repair damaged elements, and remove late additions of no significance. Valuable elements from different periods must be respected, even if the resulting overall appearance is not uniform. (Principles for the Conservation of Heritage Sites in China, 2004, Art.31).

Major restoration, a measure having serious impact on the original work. This includes restoring stability of the structure with essential reinforcements or repairing missing elements. The decision to remove part or all of a structure may be undertaken with reservations and is acceptable provided it is necessary to restore the original structural stability for a considerable time and no better, acceptable options are available.

Restoration should, where possible, preserve the remains and traces that are deemed significant. The design and materials of replacement items must be consistent with the evidence provided by the existing construction. Only the elements responsible for the damage may be dismantled or removed. If possible, after the restoration these can return to their historical condition. (Principles for the Conservation of Heritage Sites in China, 2004, Art.32).

In situ reconstruction should take place only in exceptional cases.

Additions to the original fabric should be sited as inconspicuously as possible, and/or clearly differentiated from the original structure.

The restoration of the historical condition of structures must be based on existing physical evidence and not on conjecture from documentary records or hypothetical recreations. (Principles for the Conservation of Heritage Sites in China, 2004).

6.7. Repair, replacement, restoration and reinforcement.

In repairing historic structures, structural elements of the same original materials may be used to replace damaged ones but must respect the structure's historic and aesthetic value. Also, permanent and reversible structural reinforcements may be used where necessary for reasons of security and stability against earthquakes.

Reinforcements must be compatible with the earth materials and the original technologies employed. Compatible reinforcements are those that during earthquakes will control displacements to an acceptable level, ensuring overall stability, without damaging the original materials.

To replace part of a structural element essential to overall or local stability, traditional materials will be used where possible, supplemented by reinforcements linking the new and old portions.

The new elements or fragments thereof should be distinguished discretely from the original ones. It is not acceptable to reproduce wear or deformation of the original, nor match wall heights or lost alignments unless necessary for technical reasons. The authenticity cannot be altered for cosmetic reasons. (Principles for the Conservation of Heritage Sites in China, 2004, Art.23).

6.8. Contemporary materials and construction techniques.

Contemporary materials, structural reinforcements and modern techniques are to be avoided and used only with extreme caution in cases where their durability and structural behavior have been tested successfully for long periods of time or their durability has been proven by scientific methods. When using modern materials, chemicals will be avoided where possible.

6.9. Conservation training.

Providing specialized training, thus reproducing human resources, is an essential element of achieving sustainable conservation and development policies.

Training programs should be created and fostered for the protection, preservation, rescue and conservation of earthen historic structures in areas where disasters, particularly earthquakes, are recurring natural phenomena. This training should follow a strategic plan that builds the capabilities needed to properly restore earthen structures whose mechanical characteristics are weak and must work in extreme conditions of structural stress, such as those produced by earthquakes.

Cross-disciplinary local, regional, national and international, interdisciplinary programs should be developed to target all professions and trades involved in conservation and in particular archaeologists, architects, engineers, conservators, artisans and site managers.

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