Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Considerations on the Vulnerability of Architectural Heritage. Case study: the church of El Sagrario, Cuenca, Ecuador

Ir a versión en español

Índice / Contents

DOI: 10.30763/Intervencion.229.v1n21.08.2020 • YEAR 11, ISSUE. 21: 294-327

Submitted: 10.11.2018 • Accepted: 26.03.2020 • Published: 21.09.2020

Gema Mariela Zamora Cedeño
Universidad Católica de Cuenca (UCACUE), Ecuador
Escuela Superior de Diseño de Barcelona, (EDDESIGN), Spain
gmzamorac.78@hotmail.com
ORCID: orcid.org/0000-0002-9422-7526

María del Cisne Aguirre Ullauri
Grupo de Investigación Ciudad, Ambiente y Tecnología (CAT)
Universidad Católica de Cuenca (UCACUE), Ecuador
Universidad Politécnica de Madrid (UPM), Spain
cisne2222@hotmail.com/maguirreu@ucacue.edu.ec
ORCID: orcid.org/0000-0002-3179-7839

ABSTRACT

Architectural heritage shows the processes and evolution of the human being in time. It allows the perpetual telling of history and transformations without the need for words. What would happen if the tangible and material chronology of a civilization were lost in seconds? This and other questions support the need and obligation to study architectural heritage as an element vulnerable to seismic activity, with emphasis on that whose constructive and ancestral technique does not guarantee its dynamic adaptation. The bibliographic study extensively demonstrates the damage caused to earthen architectural heritage after an earthquake. This is the basis for specific considerations to mitigate and avoid the loss of an architectural landmark in Cuenca (Ecuador), such as the church of El Sagrario or Catedral Vieja (Old Cathedral, in english). The architectural configuration, the roofs without trusses or reinforcements, and the unfavorable seismic behavior of the earthen structure are the critical points to be taken into account.

KEYWORDS

vulnerability; architectural heritage; earthquake; earthen architecture; heritage management

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

INTRODUCTION

The world contains about 1 200 cultural and natural sites declared as world heritage by the United Nations Educational, Scientific and Cultural Organization (UNESCO) since 1972. It is noteworthy that a large percentage of these sites belong to the category of architectural heritage. Reflecting on the increase of architectural works listed as heritage leads to the question of whether all of them are in a good state of conservation and whether, moreover, it ensures their permanence for many more years, taking into account that they are continuously exposed to common causes of deterioration, such as abiotic agents, weather conditions, humidity, pollution, dust, and exposure to the sun or the elements. However, due to the logical behavior of the element or construction system, time is almost always the main cause of aging and the loss of resistance of materials (López, Rodríguez, Santa Cruz, Toreño, & Ubeda, 2004, p. 2). The above deterioration factors generate visible pathological injuries, which are corrected with periodic maintenance or utilizing interventions when significant damage has occurred, but what are the actions to take for damage that has not yet occurred and whose occurrence cannot be controlled?

The architectural heritage located in a seismic zone is the most vulnerable because, in addition to being affected by the factors mentioned, it is at permanent risk due to the probability of a natural calamity. Although the magnitude of the damage cannot be anticipated or determined exactly, it is possible to foresee the monitoring of sensitive segments by the relevant public administration, professionals, and owners. The spectrum is reduced by the realization that a specific group of this heritage in a risk area (Figure 1) is, in turn, much more vulnerable than the others, because it is built using a construction technique that is sensitive to earthquakes, suffering severe structural damage or even collapse, in some cases (Blondet, García, & Brzev, 2003, p. 6).

Earthen construction, typical of the historical centers of Latin America (Guerrero, 2010), has unfortunately been affected and destroyed by earthquakes, whose damage is mostly irreparable. Because of this, the importance of disaster prevention and reinforcement interventions must be stressed since, although it is true that natural disasters cannot be avoided, the impact of the damage can be reduced. Having understood the irreparable loss that the collapse of heritage sites in the event of an earthquake would represent, in a stable globalized society where experiences and learning after an earthquake are replicated by different means, omitting risk management processes cannot be justified. These processes

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

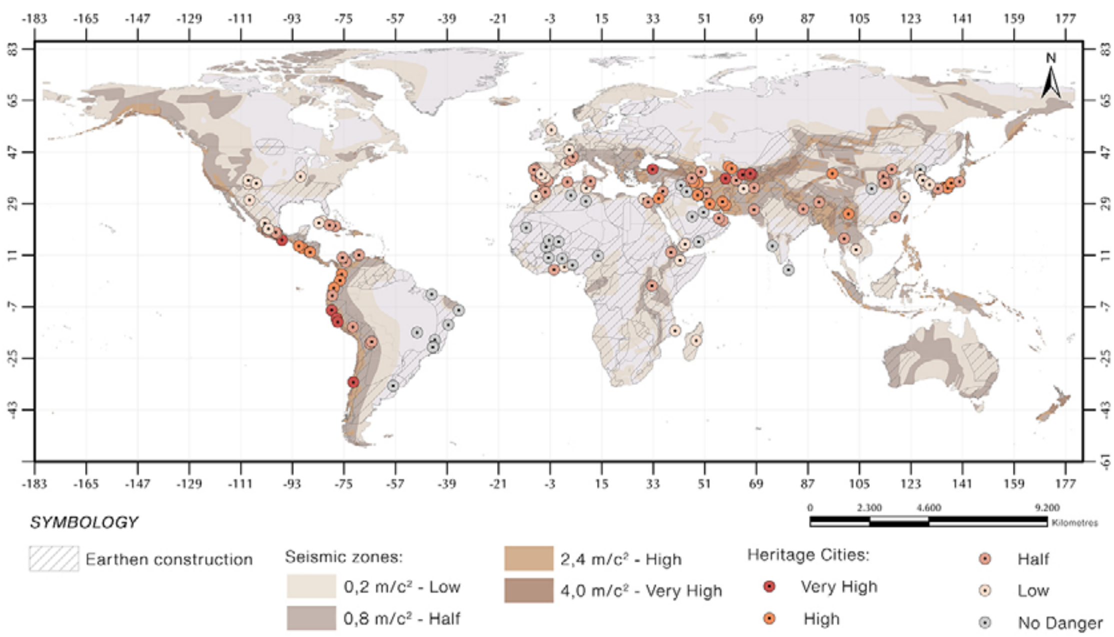

FIGURE 1. Coincidence between cities declared as world heritage sites, the delimitation of seismic zones, and those with traces of earth construction (Graph: Gema M. Zamora, 2019; source: Neves, & Faria, 2011, Brazil; Aguilar, & Quezada, 2017, Ecuador).

must be considered as a fundamental tool for prevention. These methods are established based on regulations in Ecuador, such as the *Guía de medidas preventivas para los bienes culturales patrimoniales ante la amenaza sísmica* of the *Instituto Nacional de Patrimonio Cultural* [INPC], 2011)[1] as well as through international documentation, such as the *Letter from New Delhi* (International Council on Monuments and Sites [ICOMOS], 2007), the *Lima Declaration* (ICOMOS, 2010), and others, in addition to the technical knowledge generated in the multiple and unfortunate experiences of other regions.

Analyzing the potential vulnerability of iconic buildings such as the church of El Sagrario or Old Cathedral is of theoretical, methodological, and technical interest. The purpose of this research is the specific recognition of the particulars that define this condition, so that the study can become a reference for broader studies that, within the framework of the demands of heritage conservation, cover everything from prevention to the mitigation of the possible impacts of seismic activity in churches.

[1] English: *Guide to preventive measures for cultural heritage property in the event of the threat of earthquakes* (Editorial translation).

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

BACKGROUND

The numerous experiences of loss of architectural heritage due to natural events are the starting point of the theoretical concept relating to seismic vulnerability. Understanding the need for protection and prevention for those vulnerable buildings in risk areas that have not, since their construction or during subsequent renovations, benefited from a construction process calculated to withstand the seismic forces, the article analyzes the evident threat in the region and the immediate context to open the dialogue to new and appropriate mitigation alternatives.

Ecuador is located within the Pacific Ring of Fire, so its seismic activity is high (Quinde & Reinoso, 2016, p. 2). Ecuador has a history of seven earthquakes of magnitude equal to or greater than 7 M_w that have occurred on the Ecuadorian coast since 1900 (Secretaría Nacional de Gestión de Riesgos y Emergencias [SNGRE], 2016, p. 2). It was precisely in 1906 when an earthquake of magnitude 8.8 Mw —the most serious incident to date— with an epicenter in the Pacific Ocean occurred in the province of Esmeraldas. By 2016, another one of magnitude 7.8 M_w, with the epicenter in Pedernales (province of Manabi), was considered, according to SNGRE (2016, p. 15), as a national disaster. 10,506 affected buildings in urban areas and 8,157 buildings in rural areas were reported, which shows the impact of the event.

The INPC of Ecuador (2017, p. 13) states that 53 of 284 heritage assets were affected and subsequently demolished in Manabi, while 35 more are highly affected.

Regardless of the quantity, the loss of heritage sites means that future generations will not know those historical, artistic, and above all antique attributes that the sites held as a tangible sign of a different era. For this reason, this document analyses the seismic vulnerability of the church of El Sagrario, an earthen architecture building, through *in situ* observation and an initial technical assessment exercise; in this way, the need to draw up an intervention project for structural reinforcement to mitigate the demands of earth tremors is corroborated.

METHODOLOGY

The development of the research has the following methodological structure: it begins with a review of the literature. It then studies the mechanisms of collapse that occurred in church-type religious buildings in the particular cases of the 2007 earthquakes in Peru and 2010 in Chile. Finally, in extrapolates the knowledge and ex-

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

perience of the loss of built heritage, highlighting the possibility of similar situations in this case study and similar ones.

The process is based on the importance of generating knowledge to identify heritage sites with probable inadequate performance in the face of earthquakes, not only from the vulnerability of the construction system but also from the elements that accentuate and catalyze the damage mechanisms. For the analysis of the latter, the Italian methodology proposed in the document *Linee guida per la valutazione e la riduzione del rischio sismico del patrimonio culturale con riferimento alle norme tecniche per le costruzioni*[2] (MIBAC, 2006, p. 61) was used. This work describes nine macro elements and twenty-eight damage mechanisms in the specific case of church-type buildings (Figure 2), each of which displays indicators of vulnerability, seismic protection elements, and damage before and after the natural phenomenon which, through statistical calculation, defines an index of vulnerability and seismic damage.

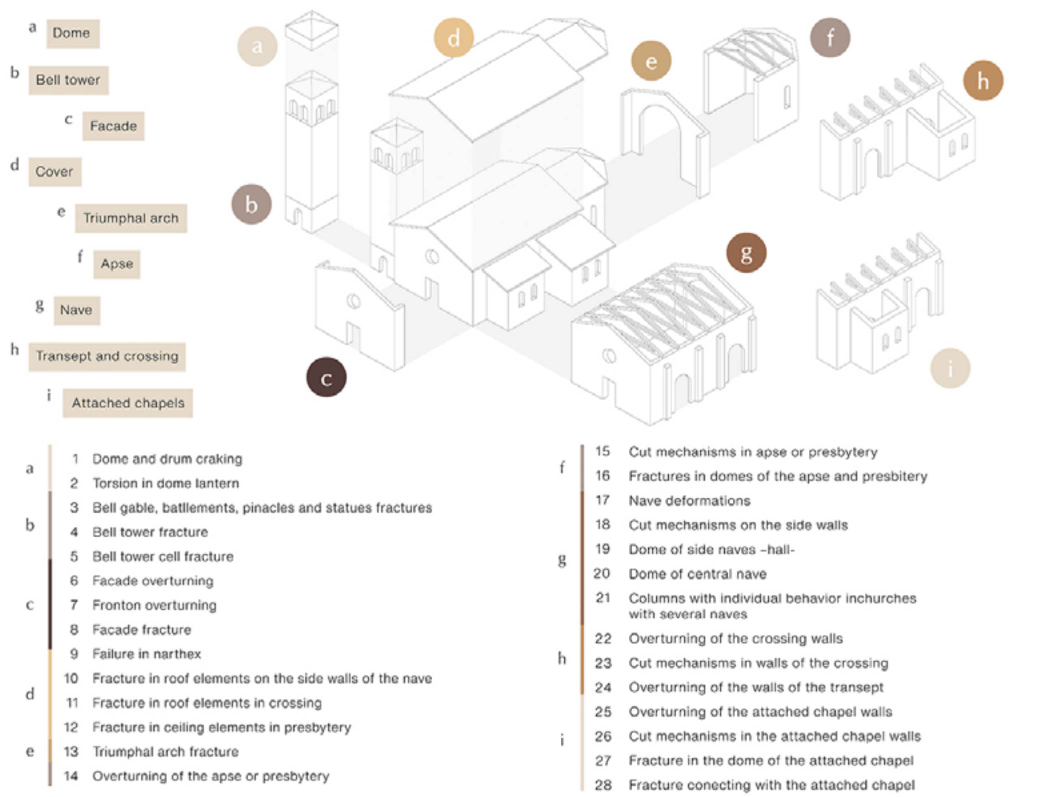

FIGURE 2. Macroelements and mechanisms of damage in religious buildings of a church type (Graph: Gema M. Zamora, 2019; courtesy: *Ministero per i Beni e le Attività Culturali* [MIBAC], Italy).

[2] English: *Guidelines for the Evaluation and Mitigation of Seismic Risk to Cultural Heritage with Reference to Regulations for Buildings* (Editorial translation).

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

In order to establish the objective and the rigorous development of research for this purpose, the methodology of the *Ministero per i Beni e le Attività Culturali* (MIBAC, 2006, p. 2) is applied to buildings affected by the earthquakes in Peru and Chile, from a general and strictly visual approach, with which the pattern of damage occurring in this type of building is determined and analyzed. With the information obtained and processed, the structural and spatial problems that can be a determining factor in the behavior of the church of El Sagrario when a high-intensity earthquake happens are highlighted using a didactic model. Additionally, general considerations are raised to protect earthen heritage from these phenomena.

Finally, it is worth noting that what has been presented is the introductory and problem identification stage of a larger multidisciplinary research on the vulnerability of built heritage, the strategies of reinforcement with vegetable fibers (reeds or *Arundo donax*) for the mitigation of the damage caused by earthquakes, and the methodology so that the intervention responds to the criteria of heritage conservation: minimum intervention, reversibility, compatibility, and authenticity historically embraced in the international documentation and adopted by the field.

International normative context and national projection

There is no doubt that there is a need for rules, statutes, and regulations that provide guidelines for the protection of built heritage from earthquakes, which is why many international charters, such as the one already cited from New Delhi, and the declarations from Quebec, Seoul, Assisi, Kyoto, Kobe, Lima, and Radenci refer to this requirement by addressing aspects of government policy, preventive actions, the international community, financing, and community building (Figure 3). Furthermore, they contribute with intervention criteria, solutions, proposals, and public calls to both communities of experts and non-experts, on the care and preventive actions in these assets so that they are protected as much as possible. The first time that "heritage in danger" was discussed was in the *Convention Concerning the Protection of the World Cultural and Natural Heritage* (UNESCO, 1972, p. 11) held in Paris, in which a list was drawn up of natural and cultural heritage sites that required major conservation work and were also threatened by anthropogenic causes or natural phenomena that caused damage.

It is public knowledge that intervention projects for the recovery of buildings before an earthquake require high investment, and when the event occurs, the budget may increase. One of the best

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención
ISSN-2448-5934
ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

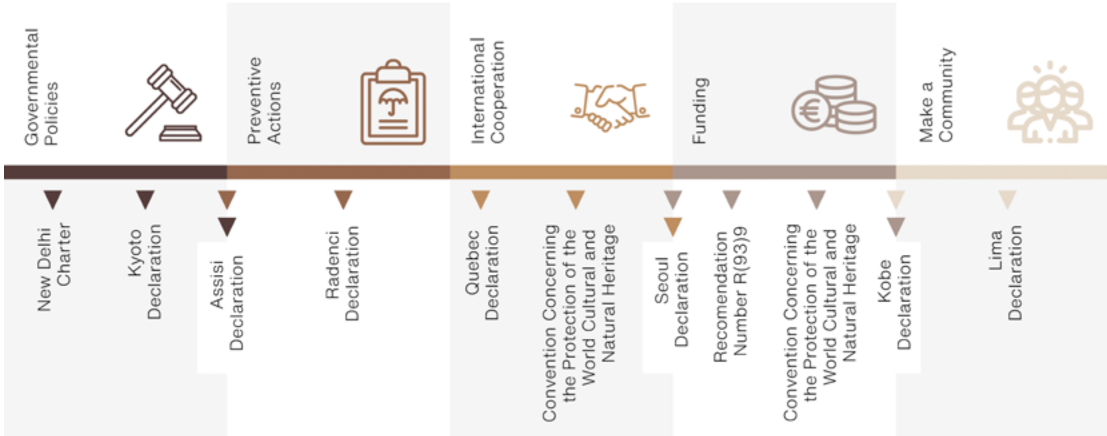

FIGURE 3. International normative context of conservation and risk management in heritage (Graph: Gema M. Zamora, 2019).

mitigation strategies is collective international participation. The Convention Concerning the Protection of the World Cultural and Natural Heritage (UNESCO, 1972, p. 1) states that it is an international matter to participate in the protection of heritage; declarations such as the one already mentioned from Quebec (ICOMOS, 1996, p. 129) propose leading and creating institutions with models of preparation of value and interest that encourage other heritage groups to join in networks; the Seoul Declaration (International Committee of the Blue Shield [ICBS], 2011, p. 2), which sets out the term *partnerships*, this time with the permanent participation of the founding organizations of the ICBS, agrees with this concept.

Government policies are permanently related to the international community because it is thanks to the latter that they are introduced and created in the territories that support the care of heritage assets. The Assisi Declaration (ICOMOS, 1998, p. 151) provides one of the most precise criteria, stating that: "When natural hazards threaten heritage monuments, sites or landscapes, preventive actions represent the best policy for the safeguarding of cultural heritage."

The New Delhi Resolution (UNESCO, 2007, p. 2) adds the process component and states that only institutional processes and policies can reduce the impact of natural phenomena on heritage; the Kyoto Protocol (ICOMOS, 2005, p. 2) indicates that national government policies are important, but that they are useless without a comprehensive disaster prevention approach to cultural property, historic areas and their environments. Furthermore, this protocol considers that one of the most complex segments to involve is that of national governments in terms of instilling, planning, and, of course, executing preventive actions for heritage in the face of

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

natural risks. However, strategies such as these, while providing resources for heritage protection, such as government policies and funding, report problems of implementation.

The Kobe Declaration (UNESCO, 1997, p. 137) calls the method of support for heritage interventions in emergencies the International Trust Fund, while the Seoul Declaration (ICBS, 2011, p. 3) names it the Immediate Cultural Relief Fund. Regardless of how these funds are determined, they serve the same purpose. Regarding financing, Recommendation No. R (93)9 of the Committee of Ministers of the Council of Europe (1993, p. 3) indicates that resources must be adequate, but above all, they must be readily available for maintenance; that is, priority must be given to those intended for prevention. On the other hand, the contrast in the Convention concerning the Protection of the World Cultural and Natural Heritage (UNESCO, 2006, p. 13) is interesting, when it states that: "The worst consequences of natural or man-made phenomena can often be avoided or mitigated if all concerned are prepared to act in accordance with well-designed risk reduction plans." In this way, it refers to the fact that all areas of the population must strengthen, from their roles and tasks, the emergency plans set out in national budgets, thus ensuring an effective response to the phenomenon of earthquakes.

Similarly, the declarations of Kobe (UNESCO, 1997, p. 127) and Lima (ICOMOS, 2010, p. 19) present statements on community education and training regarding architectural heritage: the first, on the importance of community awareness of institutional frameworks and relief activities in the fields of cultural heritage, and disaster preparedness, initially in existing education systems, including university networks; the second emphasizes, through education and the organization of refresher courses, seminars and similar activities, the conservation of the heritage achieved. It also emphasizes that academia plays a fundamental role if studies on cultural heritage and tourism are included for the sustainable development of settlements.

On the other hand, regarding preventive actions, it is pointed out that it is not possible to think about recovering the destroyed heritage without first planning and taking action for the preservation and mitigation of damages due to seismic contingencies. This type of action is widely recommended in various international charters, but few of them propose forceful action. The Assisi Declaration (ICOMOS, 1998, p. 152) is a broad repertoire of arguments dedicated to the victims of the earthquake in the city and proposes alternatives on how to act before, during, and after a disaster. The Radenci Declaration (ICBS, 1998, p. 1) stands out for the specific alternatives

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

applicable to avoid the loss or damage of cultural heritage through strategies to "[...] assess and reduce risk, improve response capacity, ensure the cooperation of all parties concerned in the management of the local, national, and international emergency."

In the analysis of the immediate context, it is evident that in the current reality of the country, few legislative actions develop initiatives for the protection of heritage against natural risks. The most important of these is the Constitution of the Republic of Ecuador, which states that the preservation, maintenance, and safeguarding of heritage sites is the responsibility of municipalities (Asamblea Constituyente, 2008a) and, principally, of the State (2008b). Similarly, the *Guía de medidas preventivas para los bienes culturales patrimoniales ante la amenaza sísmica,*[3] prepared by the INPC, offers a justified statement about the cultural heritage sites of Ecuador: "Damage and disappearance are equivalent to a violation of the cultural rights of the population that surrounds them" (INPC, 2011, p. 12). It stipulates that the omission of adequate protection of the heritage sites can be considered aggression.

Among the preventive actions detailed in the guide mentioned above (INPC, 2011, p. 32), intervention is proposed in historical monuments with specific problems according to their architectural and construction typology, mainly in adobe or wooden structures. Vulnerability in this type of building is stressed.

According to Aguirre, Sanz, & Vela (2018, p. 1344), in the city of Cuenca the earthquakes do not present evident physical impacts from the point of view of the Leopold matrix and associated matrices,[4] but they must be taken into account as a probability. They also emphasize that through the ABC method[5] and the frequency parameters of the event and the effect on the property, it can be determined that earthquakes can reach critical levels, where the

[3] English: *Guide to Preventive Measures for Cultural Heritage Property in the Event of the Threat of Earthquakes* (Editorial translation).

[4] This is an environmental impact assessment method composed of three segments, each associated with a double-entry matrix. In the first segment, the existing or non-existent interactions between the object and the environment are identified through the interaction matrix; in the second segment, the impact factors of the environment are prioritized according to their capacity to have an effect. Finally, the interactions are quantified according to a predetermined quantitative and qualitative scale (between irrelevant and critical, and 0 and 100), by means of the Leopold matrix. For further applicability of the method, *see* Aguirre Ullauri et al. (2018).

[5] This refers to the methodological proposal for risk management, which is based on the application of risk assessments to a decision. The distinction with risk management is only a matter of degree. The methodology includes the phases of setting the context, identifying, analyzing, assessing risks, and addressing the causes of the risks. It takes guiding principles from ISO 31000:2009 and ISO 73:2009. For further applicability of the method, see Government of Canada, Canadian Conservation Institute (CCI) and ICCROM (2016).

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

FIGURE 4. National normative context of conservation and risk management in heritage (Graph: Gema M. Zamora, 2019).

damage assessment would correspond to anything from potential to catastrophic and extreme.

Fortunately, Cuenca has not been affected by an earthquake in the last 100 years, which does not mean that one cannot occur. According to seismic hazard maps for the southern region developed by the *Red Sísimica del Austro* (RSA, Ecuador), it is evident that this city has a peak ground acceleration on rock of 0.25 g, analyzed in a return period of 475 years, which is why it is determined to be a city of high seismic hazard (Jiménez, Cabrera, Sánchez & Avilés, 2018, p. 9). Therefore, its built heritage is highly vulnerable to such danger.

EARTH CONSTRUCTION AND THE CHURCH OF EL SAGRARIO

Since ancient times, due to the need for shelter, human beings have instinctively used the materials within their reach. With them, humans first built homes and then, due to the demand for urban living, all kinds of constructions. Nature provides countless materials (Hernández, 2013, p. 10), among them earth, which, over the years and with the feedback of empirical knowledge, has been exploited with increasingly perfected techniques for its use in construction.

Since earth is the most abundant raw material in the world (Hernández, 2013, p. 10), since 8000 bC several civilizations and cultures have made use of it. The first traces found in South America date back to 500 bC; from that time to the present day, more than a third of humanity has lived in earth dwellings (Minke, 2014, p. 13).

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

In 2010 in Ecuador, according to the Population and Housing Census conducted by the *Instituto Nacional de Estadística y Censos* (INEC, Ecuador), 212,934 properties (5.68% of the total) are made of adobe or rammed earth. It is noteworthy that there is an important urban-architectural heritage traditionally built with raw earth (Lara, 2017, p. 32). With regard to the Historical Center of the city of Cuenca, where the majority of its heritage buildings are built with adobe (Achig, Zúñiga, Van Balen, & Abad 2013, p. 78), according to the inventory carried out by the Decentralized Autonomous Municipal Government of the Canton of Cuenca (Spanish: *Gobierno Autónomo Descentralizado* GAD, 2010a), 43.2% have facades of this material, while 18.2% have it as a wall type structure (Figure 5).

Construction in adobe is accessible because of its low cost and because it generally does not require qualified personnel; rather, it is carried out by those involved using a simple traditional construc-

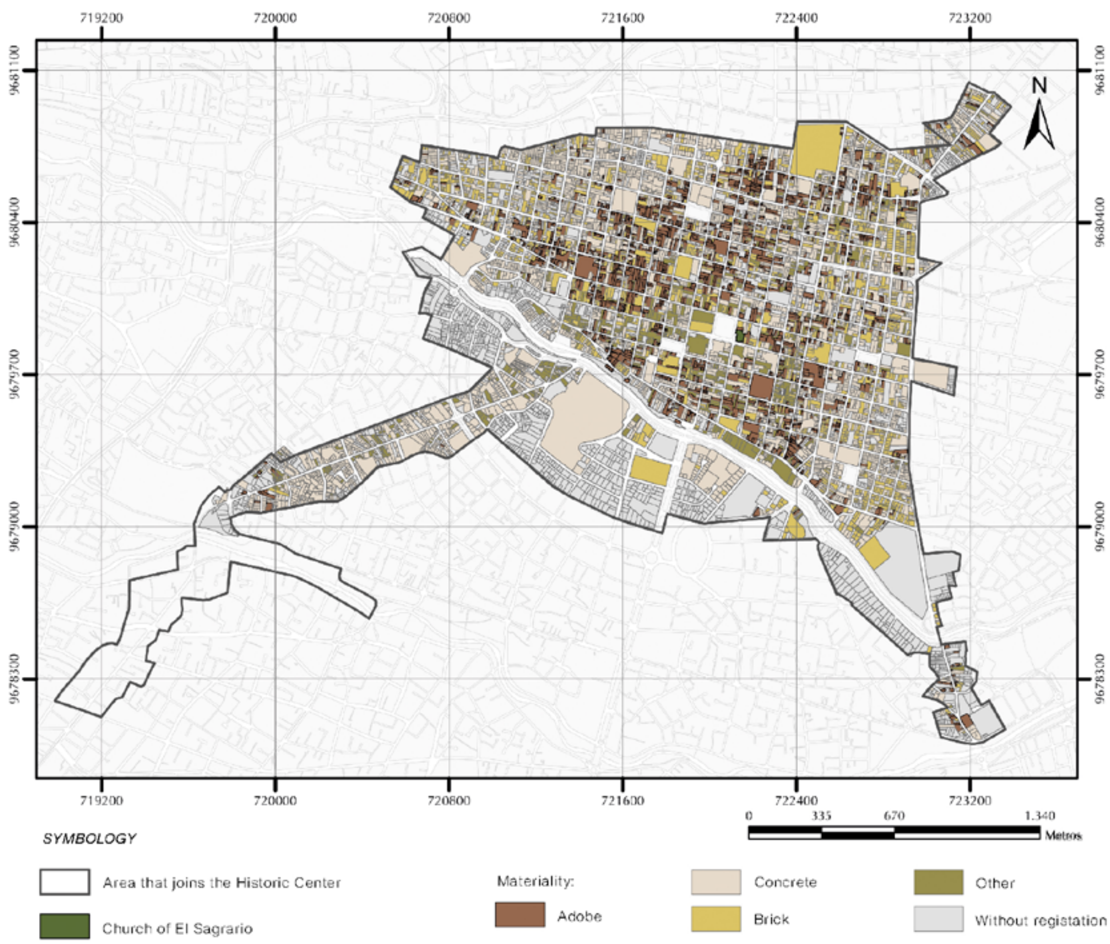

FIGURE 5. Materiality of heritage buildings in the city of Cuenca (Graph: Gema M. Zamora, 2019; source: Aguilar, & Quezada, 2017, Ecuador).

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

tion technique (Blondet et al., 2003, p. 6). The simplicity of the construction system, the attractive vernacular style, and the artisan knowledge are responsible for its protection and conservation as tangible and intangible cultural heritage.

The *Guía metodológica para salvaguardia del patrimonio cultural inmaterial*[6] proposed by the INPC (2013, p. 31) states that traditional building techniques, such as processes using raw clay, whether adobe, bahareque or rammed earth, are considered part of the heritage of the nation. Luis F. Guerrero (2007, p. 182) asserts that earthen architecture is the result of the oral transmission of knowledge of popular origin as traditional knowledge, assimilated and learned through experiences from one generation to another, rarely documented and therefore limited in dissemination. Therefore, when it receives external influences, it suffers alterations.

The above indicates how the protection and conservation of earth-built heritage entail the valorization of the architectural element, in addition to the knowledge involved so that it is built with certain characteristics and parameters. Therefore, looking after the building means, in turn, preserving the building technique and, ultimately, the building culture.

In this context, the church of El Sagrario or Old Cathedral is an ideal setting for study, analysis, and planning. Its construction began in 1557, at the same time as the Spanish foundation of the city. Throughout the years and the urban, social, and economic transformations of the area, the building was adapted both formally and functionally, and in 1924 the morphology that it maintains today was defined. Among the most significant changes are the reconstruction of the bell tower, the construction of new enclosures, the addition of adjacent chapels, and the increase in height of the central nave (Figure 6).

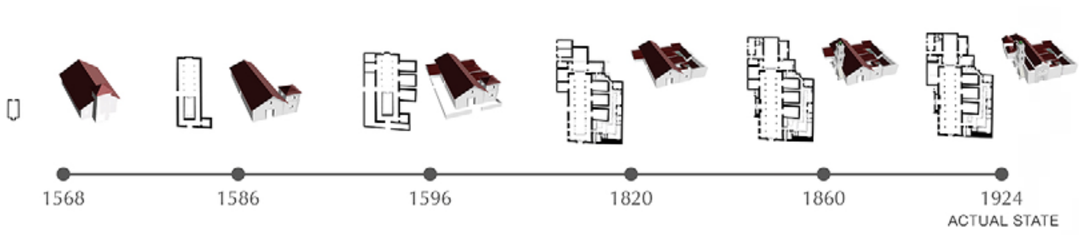

FIGURE 6. Constructive chronology of the case study (Graph: Gema M. Zamora, 2019; source: Muñoz, & Lloret, 2006, Ecuador).

[6] English: *Methodological Guide for the Safeguarding of the Intangible Cultural Heritage* (Editorial translation).

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

The modifications over time involved the use of different materials and mixed techniques; the walls were built in adobe and the bell tower in brick with glazed green tile finishes (Urgilés, 2009, p. 98); the foundations in stone; and the pillars of the central nave in wood. The improvements to the building were set aside with the construction of a new urban landmark, the *Catedral de la Inmaculada Concepción* or *Catedral Nueva* which meant that the poor maintenance and inherent degradation of the Old Cathedral led to its becoming disused around 1981.

However, after six years of restoration work, it finally opened its doors to the public in 2005 as a Museum of Religious Art and Cultural Center. It is valued not only for its architecture but also for the paintings, sculptures, and movable heritage found inside.

According to the *Ordenanza para la gestión y conservación de las áreas históricas y patrimoniales del cantón Cuenca* (GAD, 2010b)[7], the church of El Sagrario is an emerging value building (E), because of its aesthetic and historical characteristics and its special significance for the community. Furthermore, it plays an exceptional role in the urban fabric, which is why the same ordinance determines that this type of building can only be preserved and restored.

Currently, the church of El Sagrario has sporadic elementary maintenance and, in general, is in a good state of conservation; this statement influences but does not determine the aspects that classify it as vulnerable to seismic movements. It is necessary to emphasize that in the case study, no programs or projects have been developed for the mitigation of the seismic risk; therefore, the investigation represents the processing of the inputs for later directed strategies.

VULNERABILITY TO SEISMIC PHENOMENA

The Ring of Fire, the region in which Latin America and the Caribbean are located, is a highly seismic area with a large number of cultural world heritage sites (ICOMOS, 2010, p. 17), and due to its pre-Hispanic roots, many of these sites were built with earth. While it is true that most of the historic centers built in this traditional system remain standing, unfortunate experiences have shown that they are vulnerable to earthquakes of intermediate or high magnitude (*Asociación Colombiana de Ingeniería Sísmica* [AIS], 2010,

[7] English: *Ordinance for the Management and Conservation of the Historical and Patrimonial Areas of the Cuenca Cantón* (Editorial translation).

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

p. 12). If there are irreparable losses of property constructed with earth, which have been documented and analyzed to prevent and mitigate the risk of those who have not yet suffered an earthquake, is there justification for the loss of heritage caused by earthquakes and similar events? Tyabji and other panelists who participated in the Kyoto Declaration rightly stated that: "Cultural heritage represents the accumulated knowledge in disaster prevention based on past experiences and traditional practices" (ICOMOS, 2005, p. 2). Furthermore, they also emphasize the importance of research in conjunction with modern science and technology.

Disaster Risk Management for World Heritage (UNESCO, International Centre for the Study of the Preservation and Restoration of Cultural Property [ICCROM], ICOMOS and the International Union for Conservation of Nature [IUCN], 2014, p. 27) proposes that, in order to reduce the possibility of property loss, it is necessary to analyze the factors that cause it; these include primary threats, which have catastrophic consequences (a clear example is earthquakes). Secondary hazards are presented as factors that affect the property, such as pathological injuries. On the other hand, vulnerability is contextualized in an inherent quality of the building that it acquires from the construction system and the architectural configuration, which, in the case study, is associated with raw earth construction, irregularity in the plan, and the slenderness of the bell tower.

Risk is the degree of damage or loss that an element can suffer when a hazard is presented as a primary threat (Committee of Ministers of the Council of Europe, 1993, p. 2); thus, a seismic phenomenon can be evaluated according to three criteria: probability, severity, and consequences or loss of value (UNESCO et al., 2014). Therefore, the architectural heritage located in historic centers considered as World Cultural Heritage and in seismic zones has a high degree of risk because, although its probability is low, its severity is potentially catastrophic: it affects not only buildings with an artistic and cultural character but also housing and the population in general. The closest example in this context is the Historic Center of Cuenca.

The studies carried out by Arteaga (2016), Quinde and Reinoso (2016), and Bustos (2010) and other researchers on the danger and seismic threat of Cuenca agree that the Girón fault is the main one[8] (Figure 7), since it crosses the provinces of Azuay, Cañar, and

[8] This fault crosses the city from southwest to northeast, and along its length includes consolidated areas, including the one incorporated into the historic center, 1.54 km from the church of El Sagrario.

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

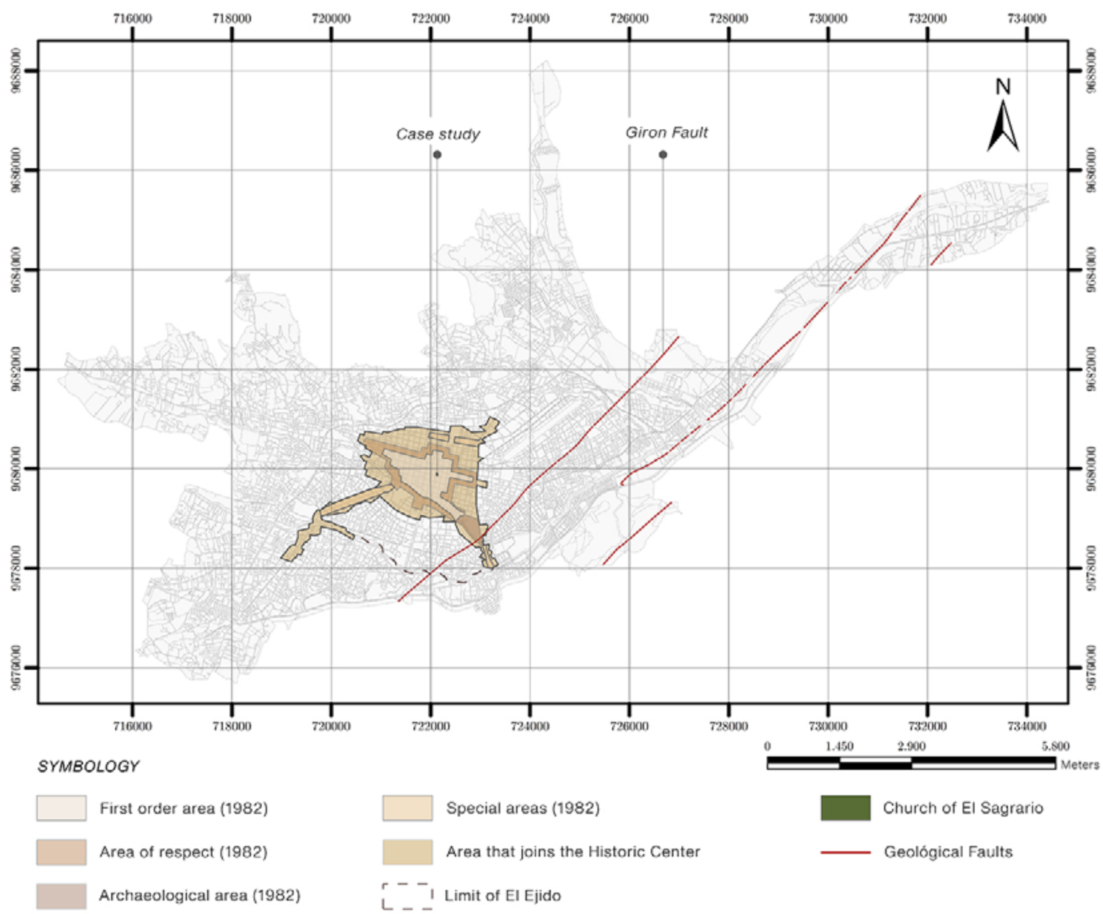

FIGURE 7. Seismic threat in the city of Cuenca (Graph: Gema M. Zamora, 2019; courtesy: *Ministerio de Desarrollo Urbano y Vivienda,* [MIDUVI], & *Cámara de la Industria de la Construcción,* [Camicon], Ecuador).

Chimborazo for 200 km, causing incalculable damage if an earthquake were to occur. The Girón fault was blamed for an earthquake in 1913 that caused the collapse of several buildings in the provinces of Loja, El Oro and Azuay, especially in parishes such as San Felipe de Molleturo in the canton of Cuenca and Jesús María in the canton of Naranjal.

The adobe buildings and similar construction systems are characteristic of the Historic Center of the city of Cuenca. These buildings have a particular construction typology with irregular floor plans, wide adobe walls, spans of inadequate dimensions and separations, and heavy roofs, among other aspects that make them prone and vulnerable to earthquakes; "frequently the age of these buildings and the deterioration of the mechanical properties of their materials mean that in the event of an earthquake their support capacity is minimal" (AIS, 2010, p. 42). This same vulnerability

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

is evident in the heritage cities of Peru (7.9 M_w in 2007), Guatemala (7.4 M_w in 2012), and Mexico (8.4 M_w in 2017), where 595, 165, and 200 registered heritage buildings from the colonial and republican periods were lost, respectively, and had to be demolished days after the disaster (Palma, 2015, p. 92).

From experience, the AIS (2010, p. 12) states that if the mechanical properties of buildings based on earth construction systems are fully known, in addition to the different alternatives for rehabilitation, the selection of appropriate methods for integrating safety and prevention criteria into heritage conservation is facilitated.

Earth construction regulations are a contemporary legislative framework that protects new buildings from structural failures inherent to the construction system; unfortunately, sites built in adobe are older than these precepts and, due to their artisan nature, many do not comply with the basic requirements (Figure 8) to face an earthquake and its consequences.

RESULTS

The seismic threat, the vulnerability of the constructions, and the importance of conservation describe latent risk. Despite the constant experiences of destruction and reconstruction, there are heritage cities that have built an earthquake-resistant culture over the years. They are immersed both in such dangers and in the tireless search for solutions to mitigate damage to heritage structures. As evidence of this, this work analyzed the cases of high-intensity earthquakes in Pisco (Peru) (8.0 M_w) and Maule (Chile) (8.8 M_w), which have been recorded as the seismic phenomena with the greatest loss of earthen heritage, which shows the fragility of these systems and the importance of protecting them.

The earthquake in Peru of August 15, 2007, is of remarkable relevance, presenting the highest mortality rate since the earthquake of 1970 (Barreau & Peña, 2010, p. 21), with alarming figures due to the collapse of vernacular and patrimonial sites (Cancino, 2009, p. 1). The earthquake was classified as **VIII Severe** due to its magnitude of 8.0 M_w and depth of 39 km, which affected several cities in Peru, such as Pisco, Ica, Cañete, and Chincha.

The post-disaster assessment showed that buildings made of adobe and with similar construction systems, such as quincha or bahareque, presented greater and considerable damage, even leading to the general collapse of homes, churches, and other monuments that were many years old (Tavera, Bernal, & Salas 2007, p. 8; Blondet, Vargas, & Tarque 2011, p. 44; Valcárcel, 2013, p. 24).

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención
ISSN-2448-5934
ENERO-JUNIO 2020
JANUARY-JUNE 2020
OJS

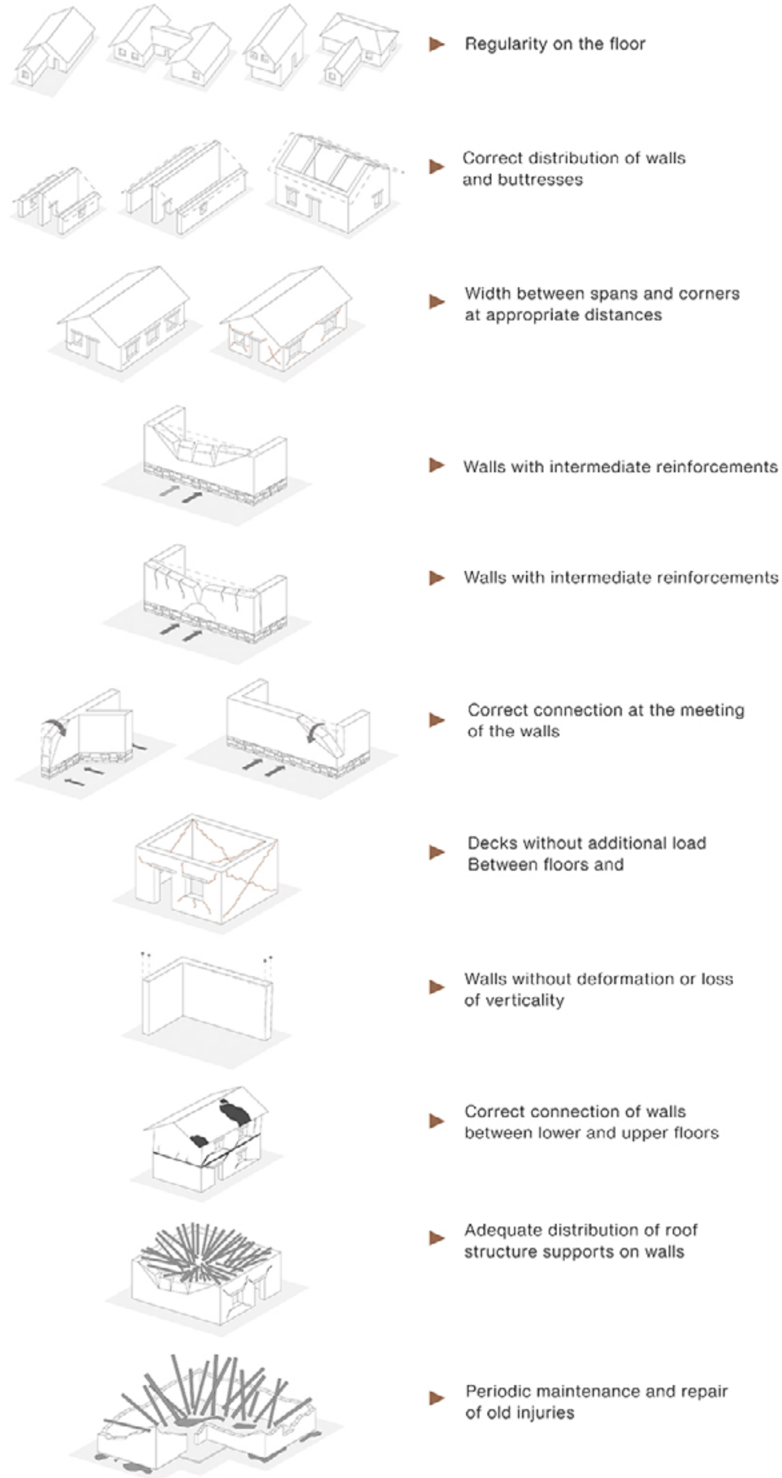

FIGURE 8. Common damage in earth constructions due to telluric movement and basic requirements to prevent it (Graph: Gema M. Zamora, 2019; courtesy: Minke, Germany; Yamin Lacouture, Colombia; & *Asociación Colombiana de Ingeniería Sísmica,* [AIS], Colombia).

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

This earthquake was reviewed to obtain the answers to the prevention and conservation of the earthen architecture heritage located in seismic zones. It is in this context that it is verified that the churches are even more vulnerable than any other architectural typology due to their slender walls in wide naves, irregular floors with attached side chapels, structures with fragile covers, and high towers with individual and differentiated behavior to the structure of the nave (Cancino, 2009, p. 30). In addition to this, the low level of maintenance of these buildings, even after a natural phenomenon, is noteworthy.

The accumulated seismic impact was evident when analyzing the collapse of different buildings, such as the church of Coayllo (1594), which was damaged by previous earthquakes without any of this damage having been repaired in time, which accentuated the extensive deformations in the central nave and the crumbling of the facade. On the other hand, the church of Chilca (1674) underwent inefficient repairs with concrete to repair damage caused by previous earthquakes, which modified the seismic behavior and caused damage to the bell tower, cracking in the dome, fracture in the vault of the central nave, among other things. As for the church of San Javier de Ingenio (1746), it underwent partial collapse of the vault and arches since the earthquakes of 1940 and 1942, which were also not repaired at the time, so the earthquake that occurred in 2007 aggravated the situation by completely fracturing the vault and causing the wall of the facade to crumble (Cancino, 2009, pp. 40-61). The analysis and comparison of damages show a pattern in the behavior of this type of property in the face of seismic phenomena according to the damage mechanisms involved (Figure 9).

The situation is similar when analyzing the earthquake of February 27, 2010, in Chile: it destroyed entire settlements in Cobquecura and Curanipe, and was felt in almost all the country, due to its great magnitude (8.8 M_w) and depth (30.1 km). The epicenter was on the seabed, which caused not only havoc due to the movement on land but also caused waves of up to 30 m high. The Maule earthquake is the sixth most intense earthquake ever recorded by humanity (*Consejo Nacional de la Cultura, las Artes y el Patrimonio*, 2013, p. 14) and the third for the most significant damage recorded in the country, and has been classified as **IX Violent** due to the massive collapse of homes, churches, and monuments (Saragoni, 2011, p. 50) in general.

The record of damage concludes that the collapse and presence of serious structural flaws in buildings are directly proportional to

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

		Mechanisms of damage	Church of Huaytará (XV Century)	Church of Coayllo (1594)	Church of Chilca (1674)	Church of Guadalupe (XVII Century)	Church of Carmen (1743)	Church of the Hacienda San José (1744)	Church of San Javier de Ingenio (1746)	Cathedral of Ica (1759)
1	1	Dome and drum cracking			x	x		x	x	x
	2	Torsion in dome lantern			x					
2	4	Bell tower fracture	x		x	x	x	x		x
3	6	Facade overturning		x		x		x	x	x
	7	Fronton overturn			x		x			x
	8	Facade fracture				x	x			
4	10	Fracture in ceiling elements in walls		x	x	x		x		x
5	13	Triumphal arch fracture			x					
7	17	Warps in naves		x		x		x	x	x
	18	Sidewall cut mechanisms	x				x			
	20	Central nave vaults		x	x	x		x	x	x
	21	Columns with individual behavior		x	x	x			x	x

FIGURE 9. Mechanisms of damage to heritage after the earthquake in Pisco. (Graph: Gema M. Zamora, 2019).

the material with which they were built. It was found that the highest percentages of destruction were in those made of earth, such as adobe walls or similar systems. This reality visualizes irreparable damage to built heritage after the 2010 earthquake, as 40.7% of the buildings constructed in the country are made of earth. Of that percentage, 40.3% is adobe, and the rest is mixed techniques, such as *adobillo* (0.34%; *adobillo* is another form of adobe) and others (0.06%) (Hernández, 2016, p. 13).

In the analysis of structural damages, those caused to religious buildings stand out, due to the vulnerability studied in the earthquake in Pisco (Peru) and even to the widespread effects on the territory. The pattern of damage (Figure 10) describes the cutting mechanism in sidewalls, which is evident as an intermediate degradation that, although it needs immediate resolution, does not entirely compromise the stability of the structure. On the other hand, conditions such as the fracture of the roofing elements in the lateral walls of the vault do cause severe damage before the collapse, so it should be properly repaired before the degradation advances to irreversible levels. Given this, authors such as Hernández (2016, p.

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

		Mechanisms of damage	Church of La Matriz de Curicó (1750)	Church of Concepción de Maipo (1775)	Parrish of San Andrés de Ciruelos (1778)	Chapel of N. S. Rosario de la Torina (1793)	Church of La Matriz (1837)	S. San Sebastián de Yumbel (1859)	Temple San Antonio de Padua (1883)	Parrish N. S. Buena Esperanza Panimávida (1895)
2	4	Bell tower fracture	x		x					
	5	Bell tower cell fracture	x		x					
3	6	Facade overturning					x			
	7	Fronton overturn	x							x
	8	Facade fracture		x		x				
	9	Portico failure - nártex	x							
4	10	Fracture in ceiling elements in walls	x	x		x	x	x		
6	14	Overturning of the apse or presbytery					x			
7	17	Warps in nave				x			x	
	18	Sidewall cut mechanisms			x			x		x
	19	Side aisle vaults - corridor						x	x	
	20	Central nave vaults						x		
	21	Columns with individual behavior		x						
8	22	Cruiser walls overturning						x		
	23	Cut mechanisms in the transept walls		x						
9	26	Cut mechanisms in chapel walls							x	

FIGURE 10. Mechanisms of damage to heritage after the earthquake in Maule (Graph: Gema M. Zamora, 2019).

6) point out that a large part of the damage to destroyed buildings is due to non-existent or incorrect structural-architectural repairs, and that even the lack of maintenance is of great importance.

From this perspective, the study of seismic vulnerability is specific to the buildings in the Historic Center of the city of Cuenca, since most of them belong to the inventory drawn up between 1860 and 1940. However, its origin dates back to the Colonial period and is still being developed and must be evaluated qualitatively (Arteaga, 2016, p. 8). The configuration of the architectural plan is fundamental because the stability of the construction depends on it. As the construction is irregular, there are usually torsional effects in the tremors that cause notable cracking and displacement, often leading to collapse (AIS, 2010, p. 43). Authors such as Minke (2005, p. 9) state that the more compact the floor plan is, the greater stability it will have, emphasizing that a circular shape

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención
ISSN-2448-5934
ENERO-JUNIO 2020
JANUARY-JUNE 2020
OJS

is optimal and that a square one is better than a rectangular one. Minke also adds that, if there are angles, the recommendation is that they be separated so that they work individually at the time of an earthquake. Among other causes that accentuate the damage are the absence of buttresses, slenderness of the bell tower and its vulnerable dome, roofs without trusses, flexible mezzanines or large spans, absence of diaphragms, thin walls and complementary stabilization elements, superficial lintel in masonry, considerable spans, heavy roofing without adequate bracing, absence of horizontal reinforcement, inefficient corner meeting, and the absence of socles.

In this statement regarding the remarkable inherent vulnerability and the number of heritage buildings located in the Historic Center of the city of Cuenca that do not meet the standards of a structural design resistant to seismic loads, the following question arises: Is heritage prepared to withstand a medium-high intensity earthquake? The answer calls for an urgent need for an intervention project for the reinforcement of the most fragile architectural elements, in order to ensure their correct behavior during the occurrence of natural phenomena.

In the analysis carried out on the building under study, typical faults inherent in adobe construction were identified, among which are: shear failure due to high horizontal thrusts in the roof without trusses and with overloading; deterioration due to bending perpendicular to the plane of the wall because there is a very long wall without transversal restrictions in the area of the presbytery and the altar (AIS, 2010, p. 57); the wooden pillars in the central nave can fail by disconnecting from the walls and causing the collapse of the entire structure; as minor, non-structural damage, the covering of these pillars can come off (Cancino, 2009, pp. 51, 54).

The structural faults of the church of El Sagrario are detailed with greater precision, where the aspects in the architectural morphology that classify it as vulnerable are determined (Figure 11). The configuration of the floor plan reveals asymmetry due to the annexed bodies that were included in the transformations of the building, a harmful characteristic, as they had to withstand external forces; the absence of trusses or correct distribution of support in these structures can cause the collapse of the roof toward the interior and fractures in the upper area of the walls; the tubular organ in the choir, on the upper floor of the building, represents a considerable load and is, therefore, harmful in a high-intensity earthquake; the slenderness of the bell tower and the additional loads of the bells describe a possible individual behavior of these com-

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

FAULT DESCRIPTION

I. The architectural plan is irregular and unstable with possible torsion in an earthquake.
II. The architectural distance between the window openings is narrow.
III. The architectural space between the altar and the presbytery is long and has no stabilizing elements; without regularity in its configuration.
IV. The pillars in the central nave are clad in wood with pink travertine imitation, same ones that can break off in an earthquake.
V. The Chapel dedicated to the Virgen de los Dolores has a wooden roof without trusses or reinforcements.
VI. The tile roof is too heavy for the building to support it.
VII. The bell tower is vulnerable by horizontal forces due to its displacement and impact against the facade.
VIII. The bell in the tower is incorrectly subject to a temporary intervention.
IX. The dome in the bell tower can collapse before the displacement of its supporting element.
X. The organ located in the upper part of the narthex is an overhead furniture for the mezzanine.
XI. Separations between elements potentially affected in the impact.

SYMBOLOGY

SAFE PLACE
DANGEROUS PLACE
POTENTIAL THREATHS

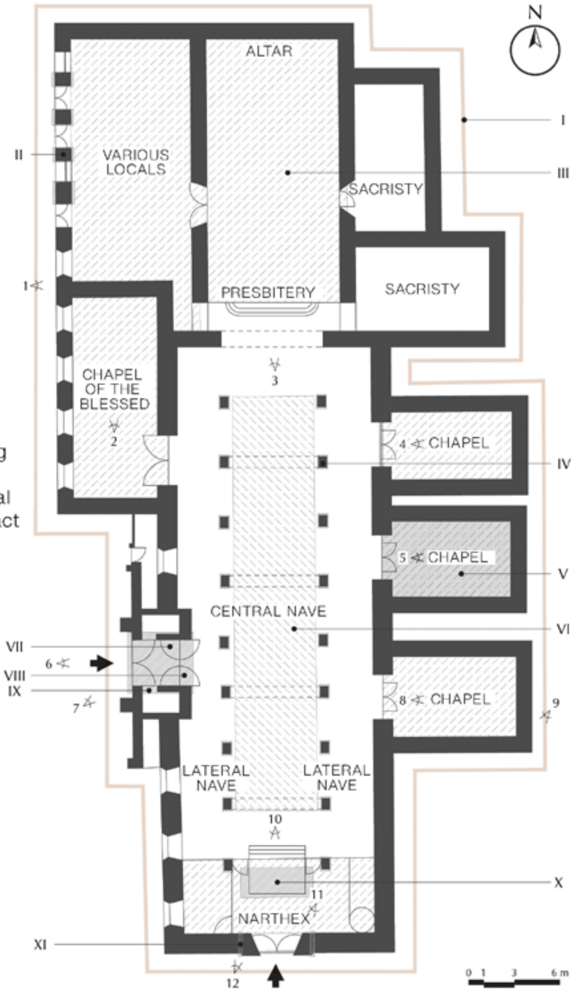

FIGURE 11. Thematic plan of structural flaws in the church of El Sagrario (Photo: Gema Zamora, 2018; courtesy: the church of El Sagrario, Ecuador).

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

ponents causing significant fractures; finally, in addition to what is described in the thematic plan of the case study (Figure 11), the low or zero resistance to tensile stresses that the adobe construction system has is emphasized.

The initial technical assessment culminates in the analysis of the presence or absence of the damage mechanisms determined by the *Ministero per i Beni e le Attività Culturali* (2006, p. 2) (Figure 2), which shows a contextualized outline of the possible seismic vulnerability of the building. It was revealed that 20 of the 28 mechanisms could be activated in an earthquake and, therefore, risk the loss of this landmark in the city (Figure 12).

+A1:D22Mechanisms of damage				YES	NO
Dome	1	1	Dome and drum cracking	x	
		2	Torsion in dome lantern		x
Bell Tower	2	3	Fracture in cattails, battlements, pinnacles, statues, etc.		x
		4	Bell tower fracture	x	
		5	Bell tower cell fracture	x	
Facade	3	6	Facade overturning	x	
		7	Fronton overturn	x	
		8	Facade fracture	x	
		9	Portico failure - nártex	x	
Cover	4	10	Fracture in ceilimg elements on the side walls of the nave	x	
		11	Fracture in roof elements in cruise		x
		12	Fracture in ceiling elements in chancel	x	
Arch	5	13	Triumphal arch fracture	x	
Apse	6	14	Overturning of the apse or presbytery	x	
		15	Cut mechanisms in the apse or presbytery	x	
		16	Fracture in vaults of the apse or presbytery		x
Naves	7	17	Warps in ships	x	
		18	Sidewall cut mechanisms	x	
		19	Side aisle vaults - corridor	x	
		20	Central nave vaults	x	
		21	Columns with individual behavior in churches with several naves	x	
Transept and cruise	8	22	Cruiser walls overturning		x
		23	Cut mechanisms in the transept walls		x
		24	Overturning of transept walls		x
Attached chapels	9	25	Overturning of adjoining chapel walls	x	
		26	Cut mechanisms in adjoining chapel walls	x	
		27	Fracture in vaults of attached chapel		x
		28	Attached chapel connection fracture	x	

FIGURE 12. Damage mechanisms in the case study (Graph: Gema M. Zamora, 2019).

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

It should be noted that, if the building is to undergo renovation, it is necessary, according to ICCROM, that all improvements and reinforcement work be fully documented and allow for long-term revisions to bring the process into line with international standards. Furthermore, these renovations should be carried out in such a way as to generate a minimum impact on the heritage values of the property (ICOMOS et al., 2001, p. 28). The Lima Declaration (ICOMOS, 2010, p. 21) also states that the reinforcements to these earthen buildings, and in general, must be compatible with the original materials and their construction technology, and it requires that they be reversible. Additionally, it is emphasized that proper maintenance is the most effective means of reducing the amount of potential damage or loss (Committee of Ministers of the Council of Europe, 1993, p. 4).

Regarding conservation considerations, in order to prevent the loss of built heritage, the INPC (2011, p. 32) recommends intervening in those buildings that, like the church of El Sagrario, show instability in the supports and roofs and have cracks on both sides (Figure 13), mostly present in the earthen ones. If the building is in a state of instability, it is necessary to shore it up without coming into direct contact with the original building materials; the joints of the beams in wooden mezzanines should be checked to avoid possible slipping. Another recommendation is to draw up a risk map of the building, as was done in the building that is the subject of this study (Figure 11), in order to understand in detail the fragile points of the building and to intervene correctly in structural reinforcement and damage mitigation.

FIGURE 13. Secondary threats of urgent intervention in property (Photo: Gema Zamora, 2018; courtesy: Aguirre Ullauri, Cajamarca Zúñiga, & Zamora Cedeño, Ecuador).

Concerning the reduction of vulnerability, actions are detailed such as the change of roof and mezzanine floors to lighter systems

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

to reduce weight; the placement of perimeter beams to ensure the continuity of the anchorage of the wall; and, finally, the rehabilitation with steel mesh and sand and lime mortar that confines the wall to obtain better performance in the event of an earthquake is considered (AIS, 2010, p. 65). The latter is valued for the results it offers, but it is also questioned regarding the compatibility of the intervention in a heritage building. In this sense, any action taken must be supported by an adequate contingency system and, above all, risk assessment before the event, prioritizing preventive interventions rather than restoration after the disaster (Palma, 2015, p. 96).

It is not necessary to wait for the disaster to intervene appropriately in order to safeguard a heritage building. UNESCO is ready to intervene and provide the necessary assistance to settlements considered as world heritage sites that present some emergency, such as the destruction of their heritage by seismic phenomena. This organization is in charge of making new inscriptions to the List of World Heritage in Danger and to spread the news for international aid (UNESCO, 1972, p. 6).

In conclusion, emphasis must be placed on the Yokohama Strategy and Plan of Action for a Safer World (UNESCO, 1994, p. 8), which states that all actors in society need to make disaster risk reduction a priority obligation at national and local levels, and to establish and implement strong institutional foundations.

The protection of heritage strengthens its foundations when people take ownership of it, rooted in the need to care for it and watch over it. The relevant authorities and restoration technicians will also do so to direct the budget and the resources needed to correctly intervene built earthen heritage without eliminating its historical and aesthetic values or creating a false history and to be able to act on these buildings that are so vulnerable to seismic phenomena—which are very unlikely but a high and catastrophic risk—in the certainty that the strategies for the protection of the architectural heritage will also protect human life (Committee of Ministers of the Council of Europe, 1993, p. 2).

CONCLUSIONS

A great number of the existing heritage buildings in the Ecuadorian highlands are built with earth. Even though the country is located in a highly seismic area, which increases the risk of collapse of these assets, there is no manual, direction or particular regulation that indicates the appropriate ways to implement risk prevention

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

interventions. On the other hand, the scarcity of research and viable proposals on these issues, added to the lack of interest of the relevant organizations, stagnates progress in obtaining concrete results for the seismic-resistant stabilization of buildings. The bibliographic review of cases in similar contexts points to the need to regulate first, since it does not contextualize actions that can be replicated, so the particular body of legislation should be carried out based on the reality of the context and the intrinsic characteristics of the construction of buildings in the Ecuadorian Andean area.

Because of this problem and the imminent danger of the loss of heritage due to seismic phenomena, it is necessary to ensure that, from academia to professional practice, a contribution is made to the scientific knowledge of solutions and conservation practices, with compatible materials and versatile and reversible interventions, which ensure the mitigation of the potential consequences of earthquakes.

Regarding the case study, the church of El Sagrario has spatial distribution faults that can be crucial when undergoing a high-intensity earthquake. Moreover, the earth-based construction system is not reinforced to reduce or avoid damage. The discovery of the appropriate seismic-structural alternative to be applied in this type of building involves a detailed investigation of the mechanical behavior of the wall, in addition to the analysis of the intervention criteria (authenticity, reversibility, minimum intervention, compatibility) inherent in the reinforcement process. Furthermore, the recommendation is that the integral study, although it can be adapted in similar buildings, be replicated to corroborate its effectiveness before being applied to elements of great heritage value. It must be emphasized that, just like this landmark in the city of Cuenca, many heritage assets throughout the Andean area are under latent threat, and there is no mitigation plan or emerging actions in the face of risk.

Finally, since built heritage cannot be recovered if it collapses, the experience of April 16, 2016, as well as some accounts and studies from neighboring countries that have lost their earthen architecture heritage due to causes beyond human control, demands that actions be taken with responsibility and rigor regarding its preservation, prioritizing seismic-resistant stabilization interventions and the generation of studies to mitigate their effects or impact. Ultimately, the loss of tangible history is not justifiable for a lack of concrete and timely actions.

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

ACKNOWLEDGMENTS

We thank the professors of the *Universidad Católica de Cuenca* (UCACUE) Ecuador, Master of Science Architect Jorge Toledo, and Master of Science Engineer David Cajamarca, for their reviews and corrections.

REFERENCES

Achig, M. C., Zúñiga, M., Van-Balen, K., & Abad, L. (2013). Sistema de registro de daños para determinar el estado constructivo en muros de adobe. *MASKANA*, *4*(2), 71-84. doi:10.18537/mskn.04.02.06

Aguilar, E. D., & Quezada, R. A. (2017). *Caracterización física y mecánica del adobe en el cantón Cuenca* (Bachelor thesis). Universidad de Cuenca. Retrieved from http://dspace.ucuenca.edu.ec/handle/123456789/28143

Aguirre, M. del C., Sanz, D., & Vela, F. (May, 2018). Los materiales en la ciudad histórica: identificación, valoración y conservación. El caso de Cuenca, Ecuador. In Universidad de Cantabria/Universidad de Extremadura (Organizers). Paper presented at the*Construction Pathology, Rehabilitation Technology and Heritage Management.* REHABEND 2018 7th Congress held in Caceres, España.

Aguirre, M. del C., Solano, J. L., García, A. P., López, D. M., Carrión, P. E., Segarra, C. P., & Yamunaqué, L. L. (2018). Evaluación del impacto ambiental en la arquitectura patrimonial a través de la aplicación de la matriz de Leopold como un posible sistema de monitoreo interdisciplinar. *ASRI: Arte y Sociedad. Revista de investigación*, 14, 17-34.

Arteaga, P. A. (2016). *Estudio de vulnerabilidad sísmica, rehabilitación y evaluación del índice de daño de una edificación perteneciente al patrimonio central edificado en la ciudad de Cuenca-Ecuador* (Bachelor thesis). Universidad de Cuenca, Ecuador.

Asamblea Constituyente. (September 28, 2008a). *Constitución Política de la República del Ecuador, Decreto Legislativo 0, Registro Oficial 449, Art. 264, 2008*. Montecristi, Ecuador.

Asamblea Constituyente. (September 28, 2008b). *Constitución Política de la República del Ecuador, Decreto Legislativo 0, Registro Oficial 449, Art. 379, 2008*, Montecristi, Ecuador.

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

Asociación Colombiana de Ingeniería Sísmica (2010). *Manual para la rehabilitación de viviendas construidas en adobe y tapia pisada*, AIS. Retrieved from http://www.hicgs.org/content/manual_rehabilitaci%C3%B3n_casas_adobe.pdf

Barreau, P., & Peña, P. (2010). *Gestión de crisis en terremotos pasados en el Perú. Los eventos de 1746, 1940, 1966, 1970, 1974, 2001 y 2007*: Institut de Recherche pour le Développement.

Blondet, M., García, G. V., & Brzev, S. (2003). *Construcciones de adobe resistentes a los terremotos: Tutor*. Retrieved from http://www.world-housing.net/wp-content/uploads/2011/06/Adobe_Tutorial_Spanish_Blondet.pdf

Blondet, M., Vargas, J., Tarque, N., & Iwaki, C. (2011). Construcción sismorresistente en tierra: la gran experiencia contemporánea de la Pontificia Universidad Católica del Perú. *Informes de la Construcción*, *63*(523), 41-50.

Bustos, J. D. (2010). Los movimientos telúricos en la ciudad de Cuenca, estrategias de comunicación no convencionales (Bachelor thesis). Universidad de Cuenca, Ecuador. Retrieved from http://dspace.ucuenca.edu.ec/handle/123456789/1769

Cancino, C. (2009). Patrimonio arquitectónico de tierra en la zona afectada. En *Estudio de daños a edificaciones históricas de tierra después del terremoto del 15 de agosto del 2007 en Pisco, Perú* (Research report) (pp. 40-61). Retrieved from https://www.getty.edu/conservation/publications_resources/pdf_publications/pdf/damage_assess_esp.pdf

Centro Internacional de Estudios para la Conservación, Restauración de los Bienes Culturales & Instituto de Conservación Canadiense. (2016). *The ABC Method: A Risk Management Approach to the Preservation of Cultural Heritage*. Ottawa, Ontario: Canadian Conservation Institute.

Comité Internacional del Escudo Azul. (1998). Declaración de Radenci. In *Actas del Congreso Internacional sobre la Protección del Patrimonio Cultural en Situaciones de Emergencia y Situaciones Excepcionales* (pp.1-2). Radenci: Comité Internacional del Escudo Azul.

Comité Internacional del Escudo Azul. (2011). Declaración de Seúl. In *Actas del Primer Congreso Internacional Sobre la protección del Patrimonio Cultural en Situaciones de Emergencia*. (pp.1-2) Seoul: Comité Internacional del Escudo Azul.

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Consejo de Europa y Comité de Ministros. (1993). Recomendación No. R (93)9. In *Convenio Europeo para la Protección del Patrimonio Arqueológico de Europa y de la Convención Europea sobre la Protección del Patrimonio Arqueológico* (pp. 1-12). Retrieved from http://www.culturaydeporte.gob.es/planes-nacionales/dam/jcr:82e29b9f-21ac-4e88-81cd-20af953ca0d5/normativa-reguladora-para-la-proteccion-de-bienes-culturales-de-ambito-europeo.pdf

Consejo Internacional de Monumentos y Sitios. (1996). Declaración de Quebec. In *Resolución de la primera cumbre canadiense sobre patrimonio cultural y preparación para desastres* (pp. 128-131). Québec, Canada: ICOMOS.

Consejo Internacional de Monumentos y Sitios. (1998). Declaración de Asís. In *Taller de análisis y restauración de estructuras de patrimonio arquitectónico* (pp.151-153). Asís: ICOMOS.

Consejo Internacional de Monumentos y Sitios. (2005). Declaración de Kyoto. In *Protección de bienes culturales, áreas históricas y sus escenarios de pérdidas en desastres* (p. 4). Kyoto, Japan: ICOMOS.

Consejo Internacional de Monumentos y Sitios. (2007). Carta de Nueva Delhi. In *Taller internacional sobre el impacto del cambio climático en el patrimonio cultural* (pp.1-2). New Delhi: ICOMOS.

Consejo Internacional de Monumentos y Sitios. (2010). Declaración de Lima. In *Simposio Internacional “Gestión de Riesgo del Patrimonio Cultural”* (pp. 16-25). Lima: ICOMOS.

Consejo Internacional de Monumentos y Sitios, Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura, Centro de Patrimonio Mundial & Centro Internacional de Estudios para la Conservación y Restauración de los Bienes Culturales. (2001). Terremotos y desastres relacionados. In L. Avancini (Ed.), *Preparación ante el riesgo: un manual para el manejo del patrimonio cultural mundial* (pp. 75-96). Santo Domingo: ICOMOS/ UNESCO/WHC & ICCROM.

Consejo Nacional de la Cultura, las Artes y el Patrimonio. (2013). *Reconstrucción patrimonial en Chile 2010-2012*. Santiago de Chile: Consejo Nacional de la Cultura, las Artes y el Patrimonio.

Estrategia Internacional para la Reducción de los Desastres. (January 18-22, 2005). Marco de acción de Hyogo para 2005-2015: Aumento de la

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

resiliencia de las naciones y las comunidades ante los desastres. In *Conferencia Mundial sobre la Reducción de los Desastres*. Conference held at the UN Office for Disaster Risk Reduction, (UNDRR), Kobe, Hyogo, Japan, 25.

Gobierno Autónomo Descentralizado Municipal de Cuenca. (2010a). *Actualización del inventario de las edificaciones patrimoniales del Centro Histórico de Cuenca. Base de datos del inventario a nivel de registro en formato digital*. Ecuador: Gobierno Autónomo Descentralizado Municipal de Cuenca.

Gobierno Autónomo Descentralizado Municipal de Cuenca. (2010b). *Ordenanza para la gestión y conservación de las áreas históricas y patrimoniales del cantón Cuenca*. Ecuador: Gobierno Autónomo Descentralizado Municipal de Cuenca, Ecuador.

Guerrero, L. F. (2007). Arquitectura en tierra. Hacia la recuperación de una cultura constructiva. *Apuntes. Revista de estudios sobre patrimonio cultural*, *20*(2), 182-201.

Guerrero, L. F. (November, 2010). *Las tecnologías tradicionales en la arquitectura actual*. Paper presented at the Meeting about Preventive Conservation, Monitoring and Maintenance of Monuments and Sites (PRECOM3OS). Universidad de Cuenca, Ecuador.

Hernández, F. A. (2016). *Intervención post terremoto en edificaciones de adobe con protección patrimonial* (Master´s thesis). Barcelona: Universitat Politècnica de Catalunya.

Hernández, I. (2013). *Restauración de arquitectura de tierra en zonas sísmicas: el caso de Costa Rica* (Master´s thesis). Valencia: Universidad Politécnica de Valencia.

Instituto Nacional de Estadística y Censos. (2010). Censo Nacional de Población y Vivienda. Retieved from https://www.ecuadorencifras.gob.ec/base-de-datos-censo-de-poblacion-y-vivienda/

Instituto Nacional de Patrimonio Cultural. (2011). *Guía de medidas preventivas para los bienes culturales patrimoniales ante la amenaza sísmica*. Quito: INPC.

Instituto Nacional de Patrimonio Cultural. (2013). *Guía metodológica para la salvaguardia del Patrimonio Cultural Inmaterial. Serie normativas y directrice*s. Quito: INPC.

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

Instituto Nacional de Patrimonio Cultural. (2017). *Rendición de cuentas enero-diciembre 2016*. Ecuador: INPC. Retrieved from https://issuu.com/inpc/docs/informe_de_2016_peq

Jiménez, J., Cabrera, J., Sánchez, J., & Avilés, F. (2018). Vulnerabilidad sísmica del patrimonio edificado del Centro Histórico de la Ciudad de Cuenca: lineamientos generales y avances del proyecto, *MASKANA*, *9*(1), 59-78.

Lara, M. L. (2017). Patología de la construcción en tierra cruda en el área andina ecuatoriana. *AUC Revista de arquitectura*, 38, 31-41.

López, F., Rodríguez, V., Santa Cruz, J., Torreño, V., & Ubeda, P. (2004). *Manual de patología de la edificación*, *vol. 1*. Madrid: Departamento de Tecnología de la Edificación (EUATM)-Universidad Politécnica de Madrid.

Ministero per i Beni e le Attività Culturali. (2006). *Linee guida per la valutazione e la riduzione del rischio sismico del patrimonio culturale con riferimento alle Norme tecniche per le costruzioni*, Italia. Retrieved from https://www.beniculturali.it/mibac/export/MiBAC/sitoMiBAC/Contenuti/Avvisi/visualizza_asset.html_1141304737.html

Minke, G. (2005). *Manual de construcción para viviendas antisísmicas de tierra*. Kassel, Germany: Universidad de Kassel.

Minke, G. (2014). *Manual de construcción en tierra: la tierra como material de construcción y su aplicación en la arquitectura actual*. Buenos Aires: BRC Ediciones.

Morales, R., Torres, R., Rengifo, L., & Irala, C. (1993). *Manual para la construcción de viviendas de adobe*. Lima: Talleres Gráficos.

Muñoz, P., & Lloret, G. (2006). *Memoria Técnica: Proyecto de Restauración "Catedral Vieja de Cuenca".* Cuenca. Unpublished document.

Neves, C., & Faria, O. B. (2011). *Técnicas de construcción con tierra*. Bauru: SP: FEBUNESP/PROTERRA. Retrieved from https://www.academia.edu/35702284/T%C3%A9cnicas_de_construcci%C3%B3n_con_tie-rra

Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura. (1972). Convención sobre la protección del patrimonio mundial, cultura y natural. In *Actas de 17a reunión* (p. 16). Paris: UNESCO.

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura. (1994). Estrategia y plan de acción de Yokohama para un mundo más seguro. In *La Conferencia Mundial sobre la Reducción de los Desastres Naturales* (pp. 1-17). Yokohama: UNESCO.

Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura. (1997). Declaración de Kobe/Tokyo. In *Simposio internacional sobre preparación para el riesgo de los bienes culturales* (pp. 123-132). Kobe & Tokyo: UNESCO.

Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura. (2006). Convención sobre la protección del patrimonio mundial, cultural y natural. In *Conferencia sobre Estado de conservación de los bienes del patrimonio mundial: estrategia para reducir los riesgos derivados de desastres en los bienes del patrimonio mundial* (p. 20). Lithuania: UNESCO.

Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura. (2007). Resolución de Nueva Delhi. In *Actas del Congreso Internacional sobre Impacto del cambio climático en el patrimonio cultural* (p. 2). New Delhi: UNESCO.

Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura, Centro Internacional de Estudios para la Conservación y Restauración de los Bienes Culturales, Consejo Internacional de Monumentos y Sitios & Unión Internacional para la Conservación de la Naturaleza. (2014). *Gestión del Riesgo de Desastres para el Patrimonio Mundial* (p. 2). Fontenoy: UNESCO/ ICCROM & ICOMOS.

Palma, S. (2015). Riesgos de desastre en patrimonio edificado, políticas públicas y defensa ciudadana en Guatemala, *Boletín de Monumentos Históricos*, 34, 89-99.

Quinde, P. & Reinoso, E. (2016). Estudio de peligro sísmico de Ecuador y propuesta de espectros de diseño para la ciudad de Cuenca, *Ingeniería Sísmica*, 94, 1-26.

Saragoni, R. (2011). El megaterremoto del Maule de 2010: una lección de buena ingeniería, pero con sorpresas y nuevos desafíos, *Revista Anales*, *7*(1), 1-22.

Secretaría de Gestión de Riesgos y Emergencias. (2016). *Informe de situación N° 65-16/05/2016. Terremoto 7.8°-Pedernales*. Retrieved

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

from https://www.gestionderiesgos.gob.ec/wpcontent/uploads/downloads/2016/05/Informe-de-situaci%C3%B3n-n%C2%B065-especial-16-0520161.pdf

Tavera, H., Bernal, I. & Salas, H. (2007). *El sismo de Pisco del 15 de agosto, 2007 (7.9 M_w)*. Lima: Instituto Geofísico del Perú. Retrieved from https://www.eeri.org/wp-content/uploads/Pisco150807.pdf

Urgilés, D. P. (2009). *Valor turístico y usos de 25 edificaciones patrimoniales civiles y religiosas del centro histórico de la ciudad de Cuenca* (Doctoral dissertation). Universidad de Cuenca, Ecuador. Retrieved from http://dspace.ucuenca.edu.ec/handle/123456789/1682

Valcárcel, J. A. (2013). *Análisis y gestión del riesgo sísmico de edificios y sistemas esenciales* (Doctoral dissertation). Barcelona: Universitat Politècnica de Catalunya.

ABOUT THE AUTHORS

Gema Mariela Zamora Cedeño
Universidad Católica de Cuenca (UCACUE), Ecuador
Escuela Superior de Diseño de Barcelona, (EDDESIGN), Spain
gmzamorac.78@hotmail.com
ORCID: orcid.org/0000-0002-9422-7526

Bachelor of Architecture from the *Universidad Católica de Cuenca* (ucacue), Ecuador. Student of the Master's degree in interior design at the *Escuela Superior de Diseño de Barcelona* (EDDESIGN), Spain.

María del Cisne Aguirre Ullauri
Grupo de Investigación Ciudad, Ambiente y Tecnología (CAT)
Universidad Católica de Cuenca (UCACUE), Ecuador
Universidad Politécnica de Madrid (UPM), Spain
cisne2222@hotmail.com/maguirreu@ucacue.edu.ec
ORCID: orcid.org/0000-0002-3179-7839

Architect with a Master's degree in conservation and restoration of architectural heritage and student of the Doctorate program in Architectural Heritage at the *Universidad Politécnica de Madrid* (UPM), Spain. Assistant professor and coordinator of the Engineering, Industry, Construction and ICT Research Center at the *Universidad Católica de Cuenca* (UCACUE), Ecuador. Member of the Research Groups City, Environment, and Technology

CONVOCATORIA 2020
CALL FOR PAPERS 2020

Intervención

ISSN-2448-5934

ENERO-JUNIO 2020
JANUARY-JUNE 2020

OJS

Índice / Contents

(Spanish: Ciudad, Ambiente y Tecnología, CAT) and Science and Diversity (*Ciencia y Diversidad,* C&D), of UCACUE (2017 and 2019), *Red Ecuatoriana de Mujeres Científicas* (REMCI, 2017), and the Organization for Women in Science for the Developing World (OSDW, 2018).