DISASTER-RISK MANAGEMENT OF CARAL WORLD HERITAGE SITE, PERU

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

Abstract

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

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

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

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

1. INTRODUCTION

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

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

2. TRADITIONAL SEISMIC-RESISTANT BUILDING KNOWLEDGE OF CARAL

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

Having existed for almost 1,000 years, this civilization flourished in Peru's most seismic area, withstanding no less than 20 strong earthquakes, according to this area's statistics of seismic recurrence (Shady et al., 2009). The people from this civilization were aware of the damage caused by recurring earthquakes, which destroyed their walls, made out of stone and earth mortar, and caused the collapse of their pyramids' platforms. Consequently, they attempted to implement seismic-resistant methods to their construction techniques. In order to build platforms at different heights, they realized that the core material should not cause any pressure on the external vertical borders or façades, also built with stonework joined with earth mortar. The main goal was to have a very stable core to resist earthquakes, while permitting some damage in the reparable façades.

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

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

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

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

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

3. METHODOLOGY FOR DISASTER-RISK ASSESSMENT OF CULTURAL HERITAGE

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

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

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

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

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

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

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

4. THE CARAL DISASTER SCENARIO AND ASSESSING RISKS LEVELS

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

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

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

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

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

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

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

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

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

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

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

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

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

5. CONCLUSIONS

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

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

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

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