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Journal	Advanced Materials Research (Volumes 133 - 134)
Volume	Structural Analysis of Historic Constructions
Edited by	Xianglin Gu and Xiaobin Song
Pages	665-670
DOI	10.4028/www.scientific.net/AMR.133-134.665
Citation	N. Claudia et al., 2010, Advanced Materials Research, 133-134, 665
Online since	October, 2010
Authors	N. Claudia, B. Cancino
Keywords	Damage Assessment, Earthen Architecture, Earthquake, Seismic Damage
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Advanced Materials Research Vols. 133-134 (2010) pp 665-670
Online available since 2010/Oct/19 at www.scientific.net

doi:10.4028/www.scientific.net/AMR.133-134.665

Damage Assessment of Historic Earthen Sites after the 2007 Earthquake in Peru

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Abstract: The Pisco earthquake of August 15, 2007 resulted in 519 deaths and 1366 injured, with a total of 650,000 people affected and 80,000 dwellings damaged. Preliminary reports indicated that significant earthen sites were damaged. A few months after the earthquake a rapid assessment to better understand the failure of the affected sites was performed by a multidisciplinary team convened by the Getty Conservation Institute (GCI) in response to a request from the Instituto Nacional de Cultura del Perú (INC). This paper presents the highlights of that evaluation and its implications for the future design and retrofit of earthen buildings.

Key words: Earthen architecture, earthquake, seismic damage, damage assessment

Background

The existence of earthen architecture in Peru goes back to the formativo temprano or initial period (1800/1500–900 BC). It has been a construction technique used all over the country for over more than 4,000 years and has proven to be a sustainable resource for the evolution of Peruvian culture. In response to their understanding about the effects of seismic activity on earthen structures, early Peruvian cultures wisely choose to build their sites over rocky soils and developed reinforced construction techniques to dissipate the energy generated by seismic events (Williams 1980, Bryce 1980).

The Pisco earthquake tragic human losses resulted from the collapse of buildings in the states of Ica, Lima, Huancavelica, Ayacucho and Junín among others (Johansson et al., 2007). The damages have been described by several national and international organizations that traveled to the affected region immediately after the earthquake. From October 28 to November 2, 2007 the GCI in collaboration with other Peruvian institutions lead a multidisciplinary team of national and international earthquake engineers, preservation architects and conservators, visiting a total of 14 buildings (Fig. 1). The main objective of the GCI rapid assessment was to evaluate the damaged sites while recording pre-existing conditions (abandonment, deterioration or structural interventions) that might have affected their seismic performance.

The Pisco Earthquake

On August 15, 2007 at 18h 40min 59sec (local time) a M_W 7.9-8.0 magnitude *inter*plate earthquake occurred off the coast of central Peru. It had a maximum local Modified Mercalli Intensity (MMI) of VII-VIII (Instituto Geográfico del Perú – IGP) and its epicenter was located at 13.35S and 79.51W at a depth of 39 km (USGS). The earthquake was generated in the boundary between the Nazca and the South American plates, in which the Nazca plate slid underneath the American one (Alarcón 2007). A total of 18 accelerometer stations recorded the time histories of Pisco earthquake indicating a total duration of approximately 300 seconds. The principal explanations for the duration and distribution of these ground motions are the rupture model having two zones of large displacements which generated the two packs of motions (Tavera et al. 2009).

There have been numerous studies carried out by several national and international institutions to define the geology of the affected area (Lermo 2008, CISMID et al. 2008). According to those, most of the visited sites were located over alluvial deposits from the Quaternary era, not suitable for constructions unless with reinforced, strong and expensive foundations; and where geotechnical effects such as liquefaction and landslides could have occurred. These types of soils amplified the