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Experimental analysis of seismic resistance of timber-framed structures with stones and earth infill

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ABSTRACT

The seismic performance of timber-framed structures filled with natural stones and earth mortar is analyzed by introducing three scales of experiments during which both cyclic and monotonic loadings are considered. At the connection scale, tests are performed in both normal and tangential directions to obtain the hysteretic behavior of nailed connections. At the elementary cell and shear wall scales, push-over and reversed-cycle tests are performed to obtain the hysteretic behavior as a function of infill characteristics. Walls without any openings (doors or windows) were considered. Through these tests, the influence of the infill on stiffness, maximum load or equivalent viscous damping is analyzed. The present work is then compared with three other experimental studies on the same type of traditional structures in order to provide answers regarding their seismic-resistant behavior.

Based on this experimental multi-scale analysis, this article confirms that the timbered masonry structures have a relevant seismic resistant behavior and provides a full analysis useful for the development of a numerical tool aiming at predicting the seismic resistant behavior of this kind of structure.

1. Introduction

According to Gurpinar et al. [1], existence of timber frame structures with infill are several millennia old, originating from the Neo-Hittite states (northern Syria and southern Turkey) where timber frame structures filled with adobe were already used. In Italy, during the Roman period, an archaeological site excavation, located in Herculaneum, revealed a building with two levels of wood frame structure with infill. This type of structure was listed under the name of *Craticii* or *Opus Craticium* by Vitruvius [2].

Fig. 1, inspired by the work of Caimi [3], shows the worldwide distribution of the main timber frame structures with infill and especially in seismic prone area. The list is not exhaustive. For instance, timbered masonry structures exists all over the Europe (*colombages* in France, *half-timbered* in England, *fachwerkbau* in Germany, *intelaiata* in Italy, etc.). Likewise, similar to that used to build houses type *Bahareque* called *taquezal* technique can be found in Central America [4,5].

This kind of structure is widely used on the planet mainly due to the reduced cost of its construction thanks to the easy access to the materials contained therein, for its aesthetic and/or search of increased resistance to the seismic hazard (cf. Dutu et al. [6]). Indeed, traditional timber frame constructions with infill exhibited a remarkable behavior in recent large earthquakes (Turkey in 1999, Greece in 2003, Kashmir 2005 and Haiti in 2010) during which they have often suffered little damage. In comparison, the seismic resistant behavior of new construction made of masonry blocks or concrete was generally bad or disastrous (Haiti 2010). This is due to the lack of a building code and standards for the design of structures, due to the fact that seismic forces are not considered in the design of most buildings, also due to the poor quality of construction and/or materials (cf. [7]). Indeed, building such a structure whose implementation meets building codes has a relatively high cost makes these modern construction techniques inaccessible to the majority of local populations [8–11].

These findings raise an issue surrounding the minimal importance given to local architecture by the scientific community as well as those responsible for reconstruction efforts. Recently, some research project have been conducted in order to enhance the seismic resistant behavior knowledge of this kind of traditional wood frame structures. Regarding the experimental works, these authors can be cited encompassing the scale of the connection to the scale of the shear wall:

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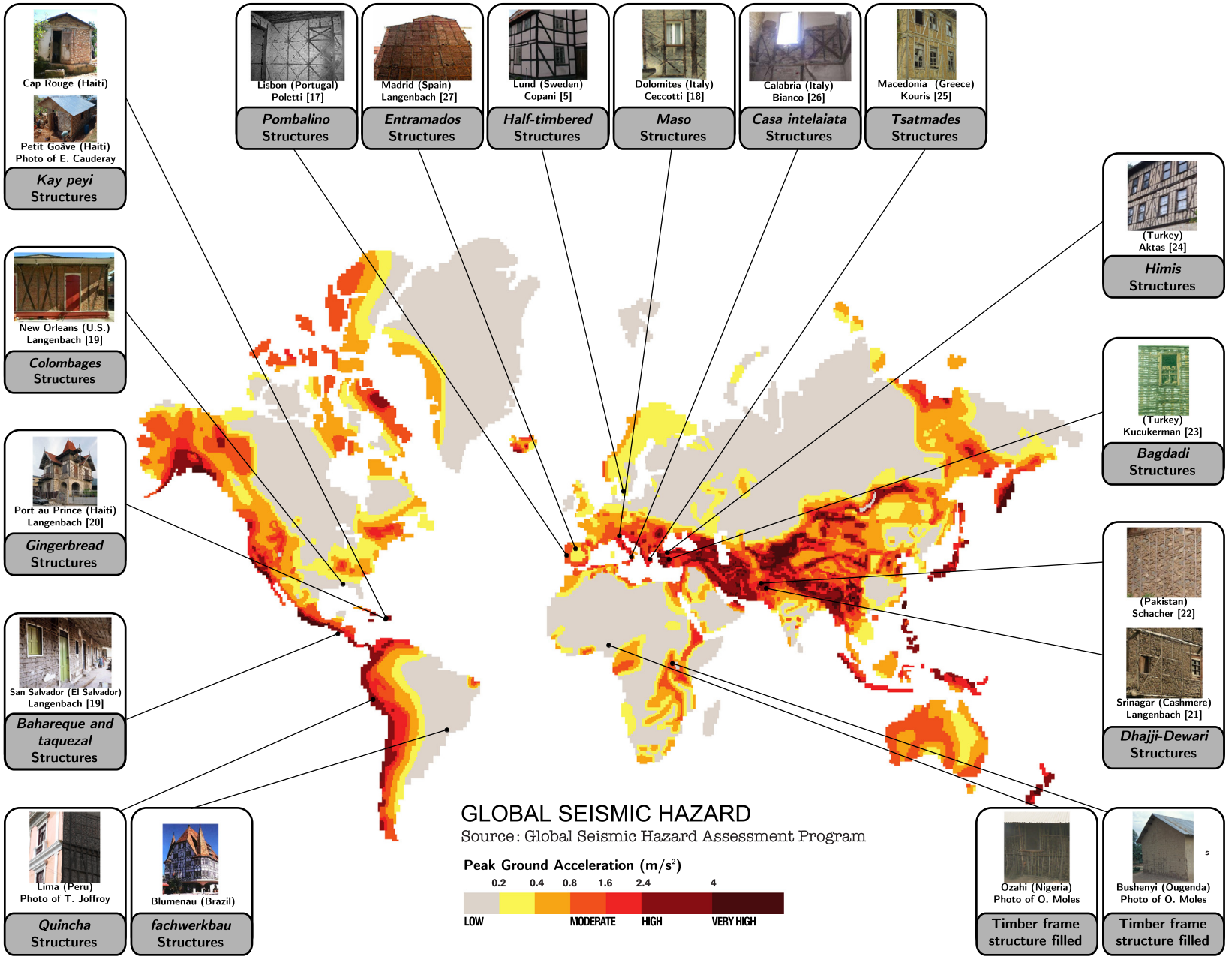

Fig. 1. Timber frame structures suitable with to the local constraints and potential ([5,17–27]), Base map: exhibition "Volcans, Séismes, tsunamis, vivre avec le risque" – Palais de la découverte (Paris) – October 12th 2007–May 11th 2008.