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Numerical analysis on seismic resistance of a two-story timber-framed structure with stone and earth infill

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ABSTRACT

Due to their seismic resistance, traditional timber-framed structures with masonry infill suffered little damage during recent earthquakes. Moreover, timber-framed structures can be built with reduced costs thanks to the use of locally available materials such as wood, stone, and earth. Based on an experimentally validated numerical simulation for a one-story house, the seismic resistance of a similar two-story house is investigated. A simplified Finite Element Model with linear and nonlinear truss elements is proposed to analyze the seismic resistance of a two-story building. Nonlinear hysteresis constitutive laws are defined only for two majorcomponents of the structure which are assumed to be representative of the global structure behavior: diagonal X-crosses (concentrating the interaction with the infill material) and steel strip connections. These kinds of structures have been overlooked due to a lack of knowledge of their potential behavior in seismic prone area and a lack of building codes and standards for their own design. To promote them, a failure criterion, that might easily be used in engineering studies, is required. This article proposes a simple criterion based on Eurocode 8 to quantify the seismic resistance of one- and two-story houses. The simulation shows that, even in case of high intensity ground motion, the two-story building should not be collapsed. This study may help at designing two-story timber-framed structures in seismic prone areas for (re)construction projects.

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Introduction

Seismic resistance of traditional timber-framed structures

Traditional timber-framed structures with masonry infill can be found in many countries all over the world, numerous of them are built in seismic prone areas (Vieux-Champagne et al. 2014b):

- *Pombalino* in Portugal,
- *Maso* in Italy,
- *Dhajji dewari* in Pakistan,
- *Bagdadi* in Turkey,
- *Kay peyi* in Haiti,
- *Colombages* in France,
- *Fachwerk* in Germany,
- *Casa baraccata* in Italy,
- *Quincha* in Pero.

Traditional timber-framed buildings are known to be efficient earthquake resistant structures (Langenbach (2007), Dutu, Sakata, and Yamazaki 2014) and suffered little damage during recent seismic events. Timber-framed structures can be built with better economic efficiency thanks to the use of locally available materials such as wood, stone, and earth. These kinds of structures are also relevant for sustainable development and to cease wasting the precious natural resources which are available in limited quantity (Sieffert, Huygen, and Daudon 2014). In Haiti, multiple timber-framed structures are built within various reconstruction projects (Joffroy et al. 2014). The selected house is prevalent in Haitian timber-framed reconstruction programs initiated after the 2010 earthquake; it provides an enhancement over traditional buildings by improving the connection of the timber structure with both the basement and foundation, and by introducing bracing via San Andrew's crosses (X-cross) filled with natural stones and bonded by earth mortar using sisal, as shown in Figure 1. To enhance the knowledge about the seismic resistant behavior of traditional timber-framed structures, experimental and numerical investigations were conducted (Ruggieri, Tampone, and Zinno 2015). Focusing on ongoing reconstruction projects in Haiti, the seismic resistance of a one-

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