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Seismic rehabilitation of historical masonry buildings

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ABSTRACT

Masonry buildings frequently present unsatisfactory behavior under seismic activity, due to the poor resistance of the masonry walls to tensile stresses and to the presence of flexible wooden floors. This paper presents a comparative study of the performance of different seismic retrofitting techniques, implemented in a model of an existing masonry building. The first part of the study considers the testing of different methodologies to strengthen the building floors, to enable them to behave as stiff diaphragms. In the second stage, the seismic protection of the building is studied with these different solutions: insertion of concrete walls, the use of a base isolation solution, and the implementation of viscous dampers. A particular analysis is made on the use of viscous dampers since it improves the seismic behavior with little interference.

1. Introduction

All major cities are facing problems with a lack of space for new construction and a high number of buildings in deteriorated conditions — some of them presenting a severe risk of collapse, not only because of neglect in care but also due to damage by recent earthquakes — the 1986 Kalamata earthquake in Greece [1], the earthquake of 1998 in Bovec in Slovenia [2], or more recently, in 2009, the earthquake in L'Aquila, Italy [3].

Benedetti et al. [4] conducted several shake table tests. These tests led to a very important conclusion on the patterns of damage for seismic loading in masonry buildings. Of the degraded buildings, masonry construction is the typology that presents more problems and is more in need of rehabilitation. This kind of construction presents several structural deficiencies, such as fragility under tensile forces of the main walls and foundations, and the general absence of seismic design. Besides its poor capacity, it is also important to point out the contribution of a nearly absent maintenance and some interventions with poor quality which contribute to the reduction of the building's structural resistance [5].

Several techniques have already been studied for the strengthening of masonry buildings, namely the classical introduction of additional steel elements, and more recently the base isolation techniques and the use of viscous dampers [6–9].

Karantoni and Fardis [10] also addressed strengthening techniques with special relevance to the introduction of reinforced concrete elements in both the walls and the floors. Kilar and Marusic [11] present a retrofit proposal for the strengthening of an existing church in order to guarantee its structural safety.

Jushasova et al. [12] present several tests on the use of polymer grids and fiber mortars to improve the seismic resistance of masonry structures.

The main objective of this work is to make a comparative study of the efficiency of the above-mentioned techniques in seismic retrofitting using a model of a real masonry building built in the beginning of the 20th century, in Lisbon. The building, with a typology common in Lisbon in the period just before the use of concrete, presents exterior walls in stone masonry, wooden floors, and wooden partition walls. In the first part of this paper, four different techniques to strengthen the floors and make them behave as stiff diaphragms are studied. The second part presents a study of the increase of the seismic resistance of the building with the following techniques: the use of reinforced concrete walls, a base-isolated solution, and using viscous dampers [6]. A comparison is made about the efficiency of the three seismic retrofit techniques, exploring in detail the use of viscous dampers.

2. Building characteristics

The building considered in this study is located in Lisbon, and was built in 1911, during an important urban expansion which occurred at the beginning of the 20th century. Its original characteristics have been kept almost untouched since the building's construction [6]. The architectural characteristics of this building's typology led to the designation "Gaioleiro", due to its internal wood wall and floor framing. At present, there are several hundred buildings of this type in Lisbon, and as they are located in a "healthy" urban zone, their retrofitting, including seismic retrofit is considered important.

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