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Numerical simulations of retrofitting interventions on timber floors in unreinforced masonry

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Abstract

Unreinforced masonry buildings with flexible timber floors are amongst the most vulnerable building typologies for seismic loading. Though flexible diaphragms play a role in the seismic behaviour of unreinforced masonry buildings, the impact of the connections between floors and walls is less commonly discussed or explicitly modelled when simulating the behaviour of such buildings. These flexible diaphragms are commonly composed of timber planks and beams, which are simply supported on the masonry walls and can slide when the friction resistance is reached. At the same time, retrofitting timber floors and wall-to-diaphragm connections are efficient interventions that can assure the box-behaviour of the building - preventing local out-of-plane collapses and improving the global behaviour of the building. Using equivalent frame models, we capture the effects of both the diaphragm stiffness and the finite strength of wall-to-diaphragm connections on the seismic behaviour of unreinforced masonry buildings. To do this, we model a case-study building using a newly developed macro-element that can simulate both in-plane and out-of-plane behaviour of the masonry walls and non-linear springs to simulate wall-to-wall and wall-to-diaphragm connections. As a case study, we model an unreinforced masonry building with timber floors tested on a shake table, which developed large in-plane and out-of-plane displacements. Afterwards, we simulate three retrofitting interventions: (i) retrofitting diaphragms, (ii) retrofitting connections, and (iii) retrofitting diaphragms and connections. We show that strengthening wall-to-diaphragm connections is critical to improve the performance of the building, or even to make subsequent retrofit of diaphragms effective. At the same time, we highlight the need for modelling nonlinear connections in equivalent frame models, as modelling an unstrengthened wall-to-diaphragm connection with infinite stiffness and strength may lead to an unrealistic box-type behaviour.

Keywords: unreinforced masonry, seismic assessment, equivalent frame models, incremental dynamic analysis, timber floors, flexible diaphragms, retrofitting