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The application of a reinforced plaster mortar for seismic strengthening of masonry structures

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ABSTRACT

The effects of plaster mortar on the behaviour of 1/3 scaled, one storey, one bay masonry-infilled steel frames under horizontal in-plane static loading are experimentally investigated in this paper. Two types of steel frames are considered: one with high flexural rigidity of the beams and columns and another with low flexural rigidity of the beams and columns. Each frame was tested with three masonry variants: (i) bare masonry infill, (ii) masonry infill with pre-mixed plaster on both sides and (iii) masonry infill with pre-mixed plaster on both sides and reinforced with a polyvinyl chloride (PVC) net. All of the frames were loaded successively by a horizontal force in the beam direction until structural collapse. Afterward, the experimental results were compared to those from the presented numeric model for the nonlinear static analysis of planar structures made of concrete, steel and masonry. The model was upgraded by including the effect of plaster on the overall stiffness and strength of the masonry and verified using the experimental tests. This experimental investigation shows that plaster significantly contributes to the strength and load-bearing capacity of masonry and therefore to the strength and load-bearing capacity of masonry-infilled frames.

1. Introduction

Masonry walls are often plastered in practice. Herein, the thickness of a plaster mortar (in further text "plaster") usually varies from several millimetres to several centimetres. The plaster connects brick elements and strengthens the masonry. Also, the plaster increases load-bearing capacity of the masonry and reduces cracking zones in it. The relative contribution of plaster to the overall load-bearing capacity of masonry can be significant, especially for thin masonry walls of poor quality. However, this contribution is often neglected in the practical design of masonry structures. Dispersing the fibre reinforcement in the plaster improves its tensile strength and especially its ductility. Compared to a conventional plaster, the fibre-reinforced plaster has reduced cracking zones and width of cracks. In practice, a fibre-reinforced plaster is more preferred than conventional plaster, especially for masonry structures in the area of high seismicity. Many researches have been done on the benefits of synthetic fibre reinforcement on the mechanical properties of mortars (e.g. Spadea et al. [1,2], Fraternali et al. [3], Song et al. [4], Chen and Chung [5]). The load-bearing capacity and ductility of masonry structures under horizontal forces can be further improved by reinforcing the plaster with adequate nets. Here, nets made of stainless materials, with adequate cross-section area, strength, deformability and fibre spacing, are more favourable. If the plaster is reinforced with stronger net, its contribution to the overall load-bearing capacity of the masonry wall can be very significant. This solution can be very rational and effective in the sense of improving the seismic resistance of new unreinforced and confined masonry structures, as well as for strengthening the existing masonry structures. Also, this solution can be successfully used for strengthening masonry-infilled concrete and steel frames.

In recent years, there has been an increasing interest in strengthening and retrofit of existing and new masonry structures using composite materials (FRP, GFRP laminates, etc.). Experimental researches on the application of reinforced plaster for strengthening masonry are still rare. Several investigations (e.g. Ahmad et al. [6], Xu et al. [7], Zhang et al. [8]) showed that reinforced plaster overlays can be a powerful rehabilitation technique to strengthen masonry. Arisoy et al. [9] studied the behaviour of

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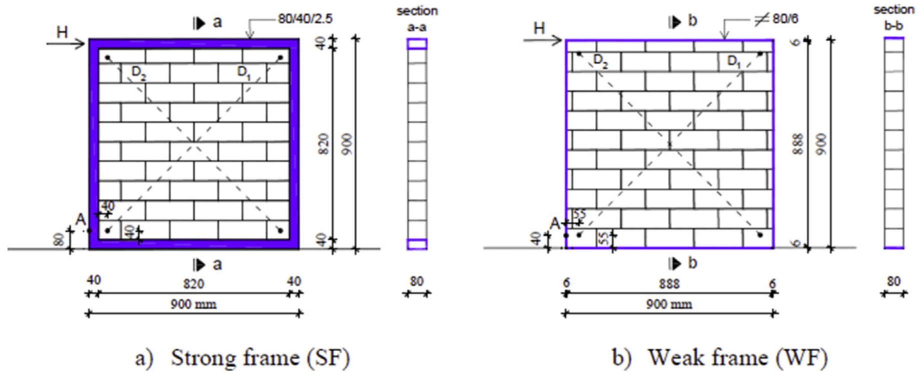

Fig. 1. Basic geometry data of tested masonry-infilled steel frames.

Fig. 2. A specimen prepared for testing.

masonry walls externally strengthened by polyvinyl alcohol (PVA) fibre reinforced cement plaster. The experimental results showed that retrofitting masonry walls with PVA fibre reinforced cement stucco increases the shear strength of the wall. Basaran et al. [10] tested 1/2 scaled masonry walls with polypropylene and steel fibre reinforced plaster mortars subjected to vertical loads at different angles. Costa et al. [11] performed both experimental and numerical tests on a real existing masonry pier recovered from a two storey house to investigate the retrofit/strengthening technique using reinforced connected plaster. D'Ambrisi et al. [12] performed experimental tests on masonry panels reinforced with polymeric nets embedded in the plaster layer. Juhasova et al. [13] used the polymer grids and fibre mortars in seismic tests of stone masonry structures.

Masonry-infilled concrete and steel frames are often used in practice. In these structures, plaster also contributes to their overall stiffness and load-bearing capacity. The relative contribution of the plaster to the load-bearing capacity depends on the stiffness of the bare frame and the frame-infill stiffness ratio. Some examples of previous experimental researches on the effect of plaster on the load-bearing capacity of masonry-infilled frames are given hereinafter. Zarnic [14] tested masonry-infilled concrete frames under cyclic horizontal load. The damaged specimens were repaired using two different techniques and re-tested. Calvi and Bolognini [15] performed several parametric push-over tests on infilled concrete frames with weakly reinforced plaster to investigate their in-plane and out-of-plane response. Karaduman et al. [16] studied the effects of infill walls on the behaviour of frames under horizontal loads, including the effect of a plaster. Altin et al. [17] used direct anchoring of the mesh reinforcement to the reinforced concrete frame and two alternative layers of materials such as high-strength plaster and shotcrete for improving the strength of the infilled frame. Sevil and Canbay [18] studied the application of steel fibre-reinforced higher strength mortar on the plaster of masonry-infilled concrete frames under reversed cyclic lateral loads. Mohammadi and Ghazimahalleh [19] conducted cyclic tests on the previously damaged masonry-infilled steel frames retrofitted by grout plaster. Their repaired specimens showed greater strength than the original ones. Korkmaz et al. [20] performed the experimental study on the behaviour of nonductile infilled concrete frames strengthened with external net reinforcement and plaster composite.

Many numerical models intended for simulation of the behaviour of composite structures have been developed (e.g. Apuzzo et al. [21], Barretta et al. [22–26], Zhang et al. [27]). The challenge is including the most important nonlinear effects of composite materials and structures to predict the overall structural response much more realistically.

In this paper, the effects of plaster on the behaviour of one-storey, one-bay masonry-infilled steel frames subjected to horizontal in-plane static forces are experimentally investigated. The tested structures were fabricated at a reduced scale (1/3), with realistic material properties and construction methods. Two types of steel frames were considered: one with high flexural rigidity in the beams and columns and another with low flexural rigidity in the beams and columns. Each type of frame was tested using three masonry variants: (i) bare masonry infill, (ii) masonry infill with pre-mixed plaster on both sides and (iii) masonry infill with pre-mixed plaster on both sides and reinforced with a polyvinyl chloride (PVC) net. Masonry elements made of lightweight concrete were used. All the frames were loaded successively by a horizontal force in the beam direction until the collapse of the structure. Characteristic displacements for the frame, strains in steel and masonry, as well as the state of cracking in the masonry were established for each force increment.