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Innovative solution for seismic-resistant masonry infills with sliding joints: in-plane experimental performance

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A R T I C L E I N F O

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A B S T R A C T

Within the European FP7 Project "INSYSME", a new seismic-resistant clay masonry infill system was conceived with the purpose of controlling damage in the masonry and reducing detrimental effects of the panel-frame interaction, through a combined use of sliding joints inserted in the masonry and deformable joints at the wall-frame interface. Although the idea behind the proposed solution stems from principles already implemented in the past, the originality of this work lies in the innovative development of the materials and of the construction details of the components. In order to assess the seismic performance of this new system, in-plane cyclic tests on one-storey one-bay RC frames with two different infill configurations (one solid and one with a central opening) have been performed within the framework of a wider experimental campaign and are discussed here. These in-plane test results have proved the ability of the proposed solution in limiting the level of damage along with the attainment of a wide margin towards the life safety requirements in comparison with traditional infill systems. Although design and construction optimization of the solution still needs to be further implemented, the results of the in-plane tests appear very promising about its use as an efficient seismic resistant non-structural component in RC buildings.

1. Introduction

Traditional masonry infill solutions, where the panels are built in complete contact with the surrounding RC frame without provision of any gap or connection around the boundaries and after the hardening of the RC members, have evinced a series of critical aspects related to in-plane and out-of-plane seismic response. These issues have been commonly observed both in post-seismic surveys, e.g. in L'Aquila 2009 [1], Emilia 2012 [2] and Central Italy 2016/2017 [3], with in-plane failures and out-of-plane collapses/expulsions of single leaf infills and partitions and/or external veneers in double leaf panels (see Fig. 1a) as well as from experimental outcomes. Reduced out-of-plane resistance due to uncontrolled levels of in-plane damage was detected for weak/slender infill panels (e.g., Calvi and Bolognini [4]), while local detrimental effects on RC members due to the thrust of the adjacent infill are known to be one of the most critical issue in the case of strong/thick masonry infills (e.g., Paulay and Priestley [5], Morandi et al. [6], da Porto et al. [7], see Fig. 1b). Most of these unfavourable effects can be associated to many factors, not only due to the intrinsic vulnerability of unreinforced masonry infills or the use of bad quality material and construction details, but also due to insufficient and unclear information in currently existing building codes for the seismic design of infilled frames (see, e.g., Fardis [8]).

Consequently, several studies oriented towards possible novel systems have been recently initiated, in an attempt to solve or at least limit the aforementioned critical issues. Nevertheless, a general consensus on an optimal solution that reduces in-plane/out-of-plane seismic vulnerability of masonry infills while guaranteeing thermal and acoustic performance as well as durability has not been achieved yet.

Solutions in current literature addressing such issues can be broadly classified into three different categories. A first category of such solutions is represented by systems where the in-plane/out-of-plane resistance (Fig. 2a) of the infill is enhanced thorough the inclusion in the masonry panel of vertical and/or horizontal reinforcement (steel bars or light trusses), steel wire meshes [4,9,10] or other types of fibre and composite material meshes in the plaster, as CFRP ("Carbon Fibre reinforced Polymer", e.g., Yuksel et al. [11]) or FRCM systems ("Fibre Reinforced Cementitious Matrix", e.g., Koutas et al. [12], De Caso et al. [13]) in the masonry panel. While these interventions undoubtedly allow an increase of the in-plane and out-of-plane resistance of the infill, do not limit the possible detrimental infill-frame interaction effects coming from high thrust forces exerted by the infill on the frame;

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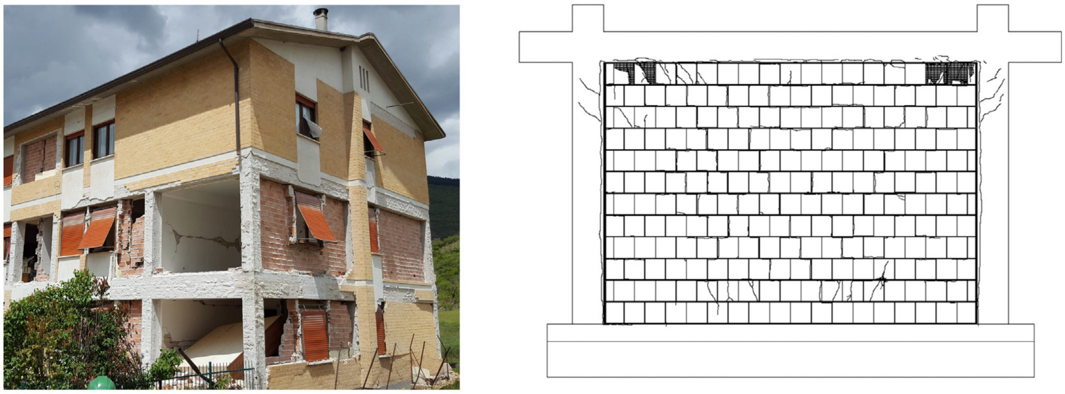

(a) (b)

Fig. 1. (a) In-plane damage and out-of-plane expulsion of traditional masonry infills after the Central Italy earthquake 2016, Amatrice [3]; (b) local interaction effects: damage pattern of the infilled RC frame with a "traditional strong" solution at drift of 1.0% [6].

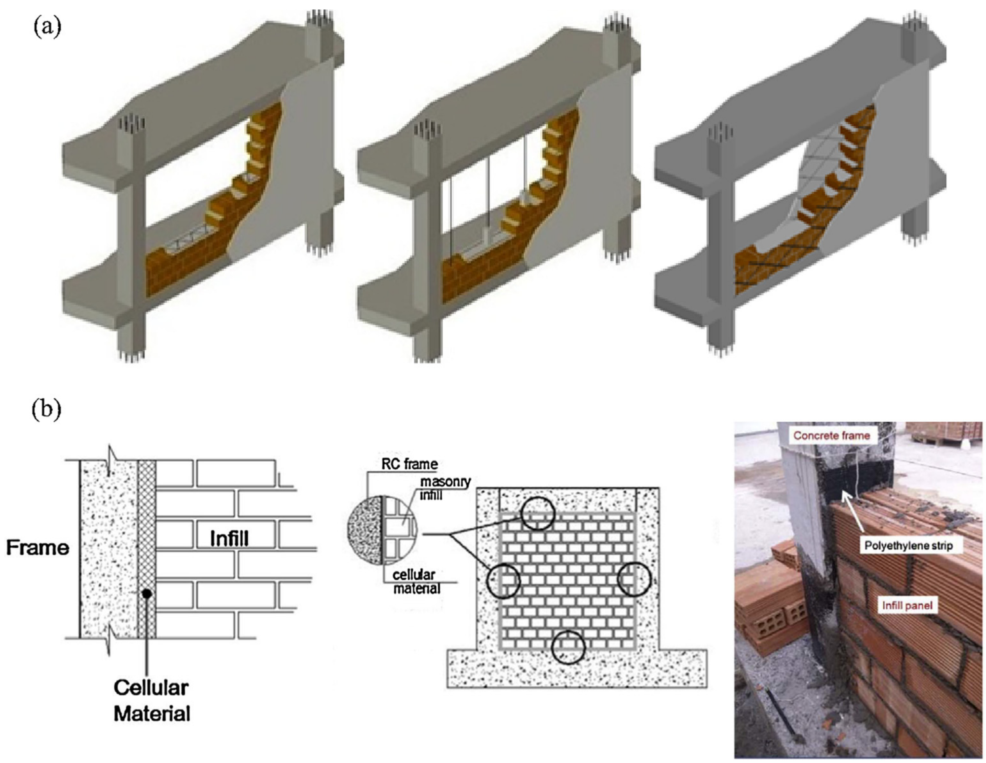

Fig. 2. (a) Solutions with enhanced in-plane/out-of-plane resistance; (b) "uncoupled" solution with flexible joints [16].

as a matter of fact, the strengthening of the infill could even increase such detrimental effects.

A second category of modern solutions found in literature (e.g., FEMA [14], Nasiri and Liu [15], Tsantilis and Triantafillou [16]) aims at uncoupling the infills from the structure by using flexible joints around the wall-frame interface supplemented by suitable out-of-plane restraints, to ensure the out-of-plane stability of the panel (see examples in Fig. 2b). These systems reduce the negative infill-frame interaction and the in-plane damage of the masonry. However, such solutions still remain to be experimentally validated and present several technological and design related complications for their practical implementation. Such complications include suitable joint dimensions to be used to prevent negative interaction between the infill and frame while still guaranteeing out-of-plane stability and allowing in-plane differential movement between the frame and the infill.

Finally, a third group of innovative systems consists of reducing the infill-frame interaction through solutions that make use of "sliding" or "weak plane" joints with the aim of concentrating the in-plane deformation and damage in selected planes, keeping the masonry panel undamaged, without losing the contact with the frame.

With reference to the principles of this last typology, the masonry section research group of the University of Pavia, involved in the European FP7 research project "INSYSME" [17], has developed and implemented an innovative masonry infill system with the purpose of controlling and reducing the in-plane damage in the masonry and the adverse panel-frame interaction, through a combined use of proper sliding joints inserted in the masonry and deformable joints at the wall-frame interface, while also ensuring out-of-plane stability. Other different solutions with "weak plane" joints have also been recently developed within the "INSYSME" project by other researchers (e.g., Verlato et al. [18] and Vintzileou et al. [19]).

Although the idea behind this solution stems from principles already implemented in the recent past [20–23], the originality of this study lies in an innovative development for real applications of the materials and