Engineering Structures 156 (2018) 145–160

Contents lists available at ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

In-plane behavior of cavity masonry infills and strengthening with textile reinforced mortar

Farhad Akhoundi[a,*], Graça Vasconcelos[b], Paulo Lourenço[b], Luis M. Silva[b], Fernando Cunha[c], Raúl Fangueiro[c]

[a] Faculty of Architecture and Urbanism, Islamic Art University of Tabriz, Iran
[b] ISISE, Department of Civil Engineering, University of Minho, 4800-058 Azurém, Guimarães, Portugal
[c] C-TAC, Department of Civil Engineering, University of Minho, 4800-058 Azurém, Guimarães, Portugal

ABSTRACT

The seismic vulnerability of masonry infilled reinforced concrete (rc) frames observed during past earthquakes in some south European countries resulted in losses of human lives and huge repair or reconstruction costs, justifies the need of deeper study of the seismic behavior of masonry infills enclosed in rc frames. Therefore, the main goals of this study are related to: (1) better understanding of the cyclic in-plane behavior of traditional brick infills built in the past decades as enclosures in rc buildings in Portugal; (2) analysis of a strengthening technique based on textile reinforced mortar (TRM) aiming at enhancing the in-plane behavior. To accomplish the objectives, an extensive experimental campaign based on in-plane static cyclic tests on seven reduced scale rc frames with masonry infill walls was carried out. The performance of strengthening of masonry infill based on textile reinforced mortar was also evaluated experimentally.

Among the conclusions of this research, it should be stressed that: (1) the presence of infill inside the bare frame could significantly enhance the in-plane stiffness and resistance of bare frame; (2) TRM technique could enhance the in-plane behavior of infilled frames by improving the lateral strength and by reducing significantly the damage of the brick infill walls.

1. Introduction

Masonry infills have been widely used in the building construction as enclosure walls in reinforced concrete (rc) or steel structures for many decades due to their good thermal and acoustic insulation properties and also reasonable fire resistance. Nowadays, masonry infills are still typically used in modern buildings as partition and also as enclosure walls in reinforced concrete frames. Generally, they are assumed as non-structural elements and are not considered in the design of the buildings. Although the infill panels are assumed as non-structural elements, their damage or collapse is not desirable, given the consequences in terms of human life losses and repair or reconstruction costs.

Past earthquakes such as Mexico City earthquake in 1985 [1], Kocaeli (Turkey) earthquake in 1999 [2] Bhuj earthquake in 2001 [3], L'Aquila earthquake in 2009 [4] have confirmed that masonry infills can affect the global and local behavior of the masonry infilled reinforced concrete (rc) or steel frames. This influence can be positive or negative. When it is positive it means that the presence of masonry infills increases the strength and stiffness of the structure to resist the lateral loads due to earthquakes. The negative influence mainly relates to the formation of soft storey and short column phenomena, which can result in the global or local failure of the structure.

In-plane interaction of infill panel with its surrounding frame was studied by different researchers, either considering reinforced concrete [5–7] or steel [8,9] as structural frames. From these experimental researches, it was concluded that for low levels of in-plane loading, the infilled frame acts as a monolithic load resisting system but when the lateral load increases, the infill tends to partially separate from its bounding frame and a compression strut mechanism develops. The assumption that infill wall behaves as a compression strut seems to be reasonable and has been supported in several experimental researches [10,11]. It was also concluded that the added infills significantly improve the lateral strength and initial stiffness of the bare frame and also change its dynamic properties [5,12], which results in a relevant change in the seismic demand of the structure. Another contribution of the masonry infill within the frame is the enhancement of the energy dissipation capacity during earthquake due to the cracking of the

* Corresponding author.
E-mail address: f.akhoundi@tabriziau.ac.ir (F. Akhoundi).

https://doi.org/10.1016/j.engstruct.2017.11.002
Received 31 December 2016; Received in revised form 26 September 2017; Accepted 3 November 2017
0141-0296/ © 2017 Elsevier Ltd. All rights reserved.

masonry infill, being possible to increase the damping ratio from 4–6% to 12% [12].

Based on experimental observations, five main failure mechanisms were considered by Mehrabi et al. [13] as probable failure modes that can develop in rc frames with masonry infills. Those failure modes depend on the relative strength and stiffness of the surrounding frame with respect to the infill wall, the geometric configuration of the frame, as well as the loading conditions.

The high seismic vulnerability of the masonry infilled frame structures observed during the last decades has promoted research on techniques and materials to strengthen the masonry infill walls and, thus, to improve their seismic performance. With this respect, conventional techniques or innovative materials for in-plane strengthening have been presented. The strengthening can change the behavior of the structure by changing its fundamental period as well as the center of mass and stiffness [14,15].

Composite materials have been received large attention from the research community and they have been already applied in real context. With this regard, different researchers investigated the effectiveness of using FRPs on enhancing the stiffness, strength and energy dissipation capacity of reference specimens in the in-plane direction [16,17]. In spite of many advantages associated with use of FRPs, this retrofitting technique is not problem-free. Some of its drawbacks are related to the poor behavior of epoxy resins at high temperatures, relatively high cost of epoxy, non-applicability of FRPs on wet surfaces or at low temperatures and incompatibility of epoxy resins with some substrate materials such as clay. Specific properties of clay such as porosity and roughness, which affects the epoxy-brick bond behavior may inhibit the use of FRP [18].

One possible solution to the above mentioned problems can be the replacement of organic binders with inorganic ones such as cement based mortars. The smeared fibers can be replaced by reinforcing meshes such as textile meshes with different continuous fibers. This results in the textile reinforced mortar technique (TRM) which is relatively new (it was started to use in early 1980s) [18–41].

The first studies on TRM technique were almost carried out on concrete specimens. In the research conducted by Triantafillou et al. [19] TRM is used as a means of increasing the axial capacity of RC columns through confinement. It was concluded that using TRM jacketing resulted in substantial gain in compressive strength and deformability of the specimens.

Bournas et al. [21,25,27] investigated the influence of TRM technique on confinement of RC columns and Triantafillou et al. conducted a research on shear strengthening of RC members using TRM technique as an alternative to fiber reinforced polymers (FRP). Also in the tests carried out in [23,30] the effectiveness of textile reinforced mortar (TRM) as a means of increasing the shear resistance of reinforced concrete beams is investigated.

The effectiveness of TRM technique on flexural resistance of two-way RC slabs was investigated in [41] by considering different parameters such as number of TRM layers, the strengthening configuration, the textile fibers material (carbon versus glass), and the role of initial cracking in the slab.

From the results obtained in [24], by comparing the effectiveness of TRM technique with respect to FRP and NSM methods, it is concluded that TRMs comprise an extremely promising solution for the structural upgrading of masonry structures under out-of-plane loading. In the similar study [26], masonry specimens were tested for their out-of-plane flexural behavior under static and cyclic loadings. The parameters investigated include the types of masonry wall (concrete block, sandstone, and brick), mortar (natural lime and cement-based), and textile (bitumen coated E-glass, basalt, or coated basalt fibers). It is concluded that the TRM specimens developed a substantial increase in their out-of-plane load and displacement capacities under static loading, and low stiffness and strength degradation, and considerable displacement capacities under cyclic loading.

Papanicolaou et al. [22] conducted a research by testing 22 medium-scale masonry walls subjected to cyclic in-plane loading. From the results it is concluded that TRMs hold strong promise as a solution for the structural upgrading of masonry structures under in-plane loading.

In a recent study carried out by Da Porto et al. [36], the effectiveness of different strengthening solutions for light masonry infills were investigated by testing eight full-scale one-bay one-storey clay masonry infilled frames, namely special lime-based plaster with geo-polymer binder, bidirectional composite meshes applied with inorganic materials and textile reinforced mortar (TRM) with anchorage of the mesh to the rc frame. The specimens were subjected to the combined in-plane/out-of-plane loading. It was concluded that the application of special plasters or TRM strengthening systems does not significantly change the initial stiffness or maximum in-plane resistance of the reference frame. The main contribution can be related to the reduction of damage in the infill. It was also concluded that TRM strengthening systems improve the out-of-plane behavior of infill walls.

The research conducted by Koutas et al. [35,37] focused on TRM strengthening of one-bay three-storey infilled frames. Connectors were used to fix the textile meshes to the upper and bottom rc beams. The specimens were tested quasi-statically and the results showed that the retrofitting scheme enhances the lateral strength by 56% and dissipates 22% more energy than the control unstrengthened specimen. It was also concluded that the presence of custom-fabricated textile-based anchors was proved to be particularly effective in delaying or even precluding the debonding of TRM.

Martins et al. [38] proposed an innovative reinforcing mesh to be used in the TRM strengthening technique for brick masonry infills. The textile meshes are composed of braided composite rods (BCR) manufactured from a braiding process. Fifteen wallets of masonry strengthened with different commercial textile meshes and with new mesh with braided composite rods were tested under four-point bending tests. It was concluded that the specimens strengthened with manufactured reinforcing meshes of BCRs with carbon fibers exhibit higher resistance to bending than other retrofitted specimens. It should be also mentioned that the specimens retrofitted with manufactured meshes of braided composite materials with a core of glass fibers presented remarkably better post-peak behavior than the other retrofitted specimens.

The evaluation of the performance of the above mentioned textile meshes composed of braided composite rods in masonry infill tested under in-plane loading is presented and discussed in this paper as part of an extensive research carried out on the mechanical behavior and strengthening of traditional brick masonry infills used in Portuguese reinforced concrete buildings and that can be also representative of the construction practice in other south European countries in the past decades. This paper presents and discusses the experimental results on in-plane static cyclic tests of double leaf (cavity) brick masonry infill walls before and after strengthening with textile reinforced mortar. Additionally, the masonry construction quality is also taking into consideration by using two different masons in the construction of masonry infills.

Although the effect of infills inside rc frames were studied by large number of researchers taking into account different configurations, there are some factors in this research that makes it relevant to strengthen the state of the art in this field of study: (1) the typical Portuguese masonry infilled rc frame from 1960 s are considered to be also typical construction practice in other south European countries. The infill consists of double-leaf masonry with horizontally perforated clay bricks of low compressive strength; (2) the strengthening based on textile reinforced meshes needs to be better studied, particularly when there is a need to study the strengthening of this type of constructive elements and when the performance of a new mesh is evaluated.

The results obtained in this research, by using textile meshes that were developed in the University of Minho and also using different type

Download English Version:

https://daneshyari.com/en/article/6738846

Download Persian Version:

https://daneshyari.com/article/6738846

Daneshyari.com