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Experimental study on the contribution of masonry infill in the behavior of RC frame under seismic loading

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ABSTRACT

An experimental investigation is conducted to study the behaviour of masonry-infilled reinforced concrete (RC) frames with various lateral strengths. In addition, we study the behaviour of masonry units when the masonry walls are erected after the RC frame is cast. This construction technique is widespread in Kosovo. Eight 2/3 scale, single-bay, single-story RC frame specimens were tested. Six were infilled with hollow clay block masonry units and combined with RC frames with various strengths, one was infilled with solid clay bricks, and one was without infill (bare frame). The test results showed that the type of masonry unit influenced the failure mechanism of the masonry-infilled RC frames. Further, the results show that the main failure modes of the masonry-infilled RC frames, infilled with hollow clay blocks was the shear failure of the masonry infill, beam column joint failure, and the formation of flexural hinges in the part of RC frame. Whereas, the main failure mode of the masonry-infilled RC frames infilled with solid clay bricks was shear failure of the column and the masonry infill. Based on the experimental results, minimum lateral design strength criteria for RC frames infilled with hollow clay blocks is proposed in order to ensure the controlled ultimate failure mechanism.

1. Introduction

Masonry panels are widely used in building construction to divide the interior spaces of low buildings, as well as to form the external walls of medium-height buildings. They are used because masonry units, especially hollow clay blocks, are easier, faster, and cheaper to erect than other potential wall infill materials. In the traditional analysis of a masonry-infilled reinforced concrete (RC) frame structures, the masonry infill in the wall panel is treated as a non-structural element; however, neglecting its structural contribution results in an inaccurate analysis [1,4,5,9,11,12,14,19]. In reality, the masonry infill interacts with the surrounding RC frame and contributes to the overall strength and stiffness of the structure, particularly when the building is subjected to lateral forces. A comparative analysis of RC frames with and without masonry infill indicates that the presence of masonry infill causes a change in the predicted structural behaviour of the frame due to the participation of the masonry in the load transfer mechanism. This process is illustrated in Fig. 1. This change in the behaviour and load transfer mechanism of infilled RC structures can result in the distribution of forces to other components of the structure that are not designed to resist them.

The first experimental work on the contribution of masonry infill to RC frame behaviour was conducted by Polyakov, as reported by Crisafuli [4]. He suggested that masonry infill could be modelled as a diagonal strut. Later work by Holmes [18] investigated the behaviour of RC frames with clay and concrete masonry infill. Further research was conducted in this vein by Staford Smith [17], who conducted a series of tests to investigate the width of an equivalent strut. Zarnic and Tomazevicl [7] also investigated the behaviour of masonry-infilled RC frames with different types of masonry infill (reinforced and unreinforced masonry). They concluded that infill increased the frame stiffness by a factor of 20 on average and the lateral resistance of the frame by a factor of 2.5 on average. The experimental work conducted by Zovkovic et al. [12] on ten 1/2.5 scale, single-story, and single-bay RC frames showed that improvements in energy dissipation capacity, lateral resistance, and stiffness could be attained by using various types of masonry walls on RC frames. The masonry units used in this test were high-strength clay brick blocks, medium-strength hollow clay brick blocks, and low-strength lightweight AAC blocks. The behaviour of masonry-infilled RC frames was also studied by Crisafuli [4], who showed that their behaviour can be improved using tapered beam-column joints. An experimental study conducted by Basha and Kaushik [16] on eleven half-scale, single-story RC frames with different bricks concluded that in most cases, the columns failed in shear even though the masonry used was quite weak. Jiang et al. [9] conducted an experimental study on seven full-scale, single-bay, and single-story RC

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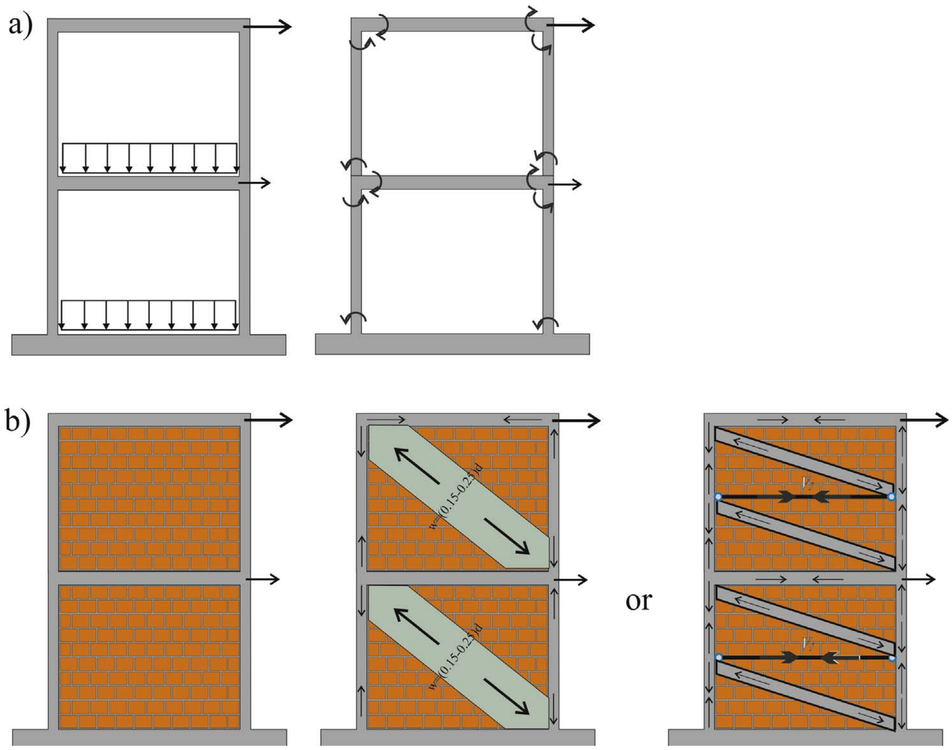

Fig. 1. Load transfer mechanism, (a) in a bare frame and (b) in a masonry-infilled RC frame.

frame specimens with different connections between masonry infill and RC frames. It was noted that the peak load of the specimens with a flexible connection was 23–35% larger than that of the bare frame and smaller than that of the specimen with a rigid connection. Further, a flexible connection between the masonry infill and RC frames is recommended as an alternative method to achieve adequate resistance to out-of-plane loads instead of infill isolation, which is a difficult and hazardous task. Although out-of-plane resistance is very important, it will not be analysed in this study. Based on the previous experimental tests conducted by Mallick and Garg [21] and Sigmund and Penava [20], it was observed that the contribution of the masonry infill to the RC frame strength is significantly influenced by the type and positions of the openings on masonry panel. Even though the openings are listed as a main factor that contributes to the lateral strength of masonry-infilled RC frames, they are outside the scope of this study.

Despite the large number of experimental investigations performed by various researchers, it is rare to see compared results of two or more identical infilled RC frames with the same geometry, masonry units, and materials, from two or more sources. Thus, it is difficult to provide a final conclusion for infilled frames or the effects of various parameters.

Therefore, in the absence of compared results of identical infilled RC frames from different sources, and knowing that the behaviour of masonry structures is quite complex and dependant on many different factors, the research program discussed in this study is focused on the following:

- The analysis and investigation of the behaviour of masonry-infilled RC frames when the masonry wall is erected after the RC frame was cast, a common construction practice for mid-rise buildings, with the intent of determining the factors that have the greatest influence on the behaviour and ultimate structural failure mode.
- The investigation of the behaviour of an infilled frame is performed in order to define the minimum ratio of bare frame to infill lateral design strength, which allows for a controlled failure to be ensured.

In order to meet these objectives, the current study tested and analysed eight RC frame specimens. The first specimen was a plain RC frame without masonry, and the remaining specimens contained masonry infill and a variety of dimensions, masonry unit types, and RC frame lateral resistances.

2. Experimental program

2.1. Description of test specimens

This research program involved the testing of eight 2/3 scale, single-bay, single-story RC frame specimens. Six were infilled with hollow clay masonry block units and combined with RC frames of various lateral strengths, one was infilled with solid clay bricks, and one without infill. The specimens were representative of the lower part of a two-story building. The specimens are designed and constructed according to current codes followed in Kosovo.

Different cross-sections for the columns and beams were used in the specimens. Fig. 2a illustrates the general geometry of the specimens, and Table 1 lists the specific geometric and design details of each individual specimen. Similar hollow-block masonry units with holes constituting over 50% of their volume were used to construct the masonry infill for all specimens, except specimen 11, which is shown in Fig. 2b. It used solid clay brick units to construct the masonry panel. In specimen 6, the masonry panel was constructed such that the holes in the masonry units were oriented horizontally.

Based on the construction technology applied in real structures, the construction of the test specimens began with the preparation of the reinforcement cages for the foundation beam, columns, and top beam. Next, the foundation beam was formed and poured, followed by the columns, and then the top beam. The masonry walls were built after removing the formwork from the frame (after a 28-day curing time).

2.2. Material property

The basic mechanical properties of the masonry units, mortar,