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Behavior of masonry strengthened infilled reinforced concrete frames under in-plane load

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Abstract Experimental tests have been carried out to study the behavior of different single story frames infilled with brick masonry under the in-plane lateral load influence. Three phases of frames were tested. The first phase was conducted on individual reinforced concrete bare frame used as control frame. The second phase was conducted on two model frames representing individual reinforced frame infilled with masonry panels constructed between two columns, then constructed the top beam, and the other one constructed as bare frame and then infilled with masonry. The third phase was strengthened with different methods to improve its behavior. Glass fiber reinforced polymer (GFRP) sheets, steel rebar impeded in frame, plastering and ferrocement meshes were used.

The drift, toughness, ductility and failure load were improved by using such masonry wall due to like-shear wall effect which also increased frame capacity to resist lateral load. The ferrocement strengthening method was recommended to improve the ductility and ultimate failure loads of the existed frames. Also casting concrete of frame over the masonry "Balady" method; increases the ultimate load capacity of frame by 145% of bare frame ultimate failure load. Also it increases its ductility and toughness by 33% and 195%, respectively.

The ductility of infilled frame strengthened with ferrocement was the best of all strengthened frames, while strengthening with GFRP increases its ultimate load carrying capacity but reduces its ductility.

Introduction

The infilled frame is a structural composite system, which consists of reinforced concrete frame with masonry panels filling the planar rectangular voids between lower and upper beams and side columns. This system has proven to be effective and efficient in bracing low-rise and medium-rise buildings to resist in-plane lateral loads due to wind or earthquake. As a dual system, its structural behavior depends on individual components. The frame is strengthened by the infills to form a

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shear-resisting element and, in turn, the infill panel is strengthened by the beneficial containment effects of the concrete frame. After initial cracking of the infill, the frame prevents it from disintegration by its confining action while the infill maintains its stiffening effect on the frame. The combined effect results in a system, which has a high level of stiffness and strength of the infill with the ductility of the surrounding frame.

It is a common practice in the Middle East to use reinforced concrete frames infilled with red brick-type wall in buildings subjected to lateral loads like seismic and wind loading. The bond between the skeleton and the infill is usually considering either to be of complete bond or non-integral infill panel.

Strength of RC members

Infill panels can attract substantial forces to adjacent frame members. These forces can be more demanding of the strength and inelastic deformation capacity of beam and column members than those resulting from lateral design forces applied to a bare frame. Because a stiff masonry infill panel can attract more lateral force than a frame can resist, frames must be checked to see if they are capable of resisting infill forces in the ductile manner that is assumed for their design or evaluation as shown in Fig. 1.

The proposed research aims to providing insight into the behavior of infilled frames at cracking and ultimate loads under lateral loads and many strengthening techniques such as GFRP sheets, ferrocement, plastering and dowel bars and also choosing the best method of strengthening before and after construction of the masonry wall. Significant parameters affecting the system's strength such as geometry and strength of infills, relative infill-to-frame stiffness, plastic bending moment capacity of the frame members, strength and rigidity of joints, beam-to-column relative stiffness, infill reinforcement, effect of adjacent bays and upper stories were tested, also workmanship, climatic effects, grout and mortar variations, work stoppage, random variation of materials, and human error were taken into consideration.

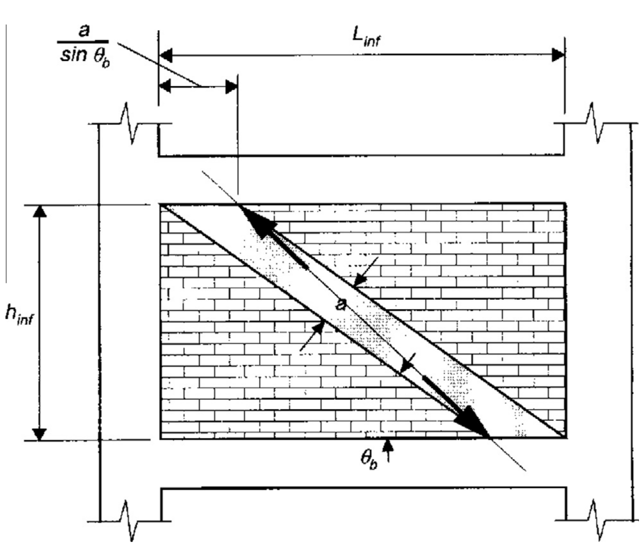

Fig. 1 Estimating forces applied to beams [1].

Literature review

Many experimental works on several infilled frames with various relative strengths between frame and infill panel were done. It was found that, a weak bare frame when subjected to monotonically increasing lateral load, exhibits a fairly flexible and ductile behavior. However, severe shear cracks were developed in the beam to column joints due to inadequate lateral reinforcement in these regions. Although considerable research has been devoted to the study of infilled frames for more than four decades there is no widely accepted design method for such structures yet. Because panels are often considered to be structurally inactive, they are rarely taken into consideration during the design process. This is explained partly by the complexity of the interaction between frame and infill and the great number of variables which influence the behavior of such a composite structure.

Mehrabi et al. [2] investigated the influence of masonry infill panels on the seismic performance of reinforced concrete (RC) frames. He investigated the effect of infill panels with respect to that of the bounding frame, the panel aspect ratio, the distribution of vertical loads, and the lateral-load history. He concluded that infill panels could significantly improve the performance of RC frames in terms of the load resistance and energy-dissipation capability.

Baqi et al. [3] studied the effect of some important variables such as masonry compressive strength, cross-sectional dimensions, pre-stressing cable's profile, and the bond between the pre-stressing steel and the surrounding masonry. Also Flanagan et al. [4], performed several bidirectional tests on structural clay tile infilled frames to assess the interaction of in-plane and out-of-plane forces and to understand the behavior of damaged infills.

Al-Chaar et al. [5] investigated the behavior of a type of popular building in high seismic zones with a lateral-load-resisting system consisting of masonry-infilled reinforced concrete (RC) frames. The results indicated that infilled RC frames exhibit significantly higher ultimate strength, residual strength, and initial stiffness than bare frames without compromising any ductility in the load–deflection response. Also Ali [6], conducted an experimental and theoretical program to study the same effect on the seismic performance of reinforced concrete frames tested under cyclic in-plane loading.

Perera et al. [7] investigated a seismic retrofitting technique for masonry infilled reinforced concrete frames based on the replacement of infill panels by K-bracing with vertical shear link. Results had shown an energy dissipation capacity.

Experimental program

Outline of the program

The experimental program was planned to evaluate the effect of many parameters such as: method of masonry construction – "*Balady method*" or ordinary method, – strengthening techniques using the following methods:

A. Glass fiber reinforced polymer (GFRP) sheets cover the strip of the two adjustment elements of concrete and masonry.