Behaviour of Infill Walls under Lateral Loads in Reinforced Concrete Frames - A Review

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Abstract: In modern day construction practices, one of the most feasible choices of erecting concrete buildings is to construct concrete frame structures as it allows the contractors to follow a smooth pattern of work during the various construction stages with ease and appreciable economy. The frame members are infilled with concrete masonry units, bricks, cast-in-place concrete or wood etc. The design of reinforced concrete frames usually ignores the beneficial or adverse effects of incorporation of infill walls within a frame. The interaction of masonry units as framing elements and the adjoining frame members might not be noteworthy during static load analysis procedure however when the same reinforced concrete frame undergoes lateral drifts due to dynamic forces, the behavior of the infill walls becomes noteworthy. A review of the various approaches has been presented in this paper that addresses the performance of masonry infill walls under lateral loads i.e. the application of dynamic forces.

Keywords: Infill wall, Concrete Masonry Unit, Lateral Loads, Dynamic Forces

1. Introduction

The use of masonry in construction industry has gained much popularity and the prime areas of its usage is, by far, as load-bearing walls in ordinary constructions and as infill material in high-rise reinforced concrete frame structures. One of the widely used masonry units in Pakistan is the Brick units that are manufactured in local kilns and their production has gained tremendous increase during the last decade. In recent years, due to the post-earthquake scenario of the catastrophic earthquake of October 2005, the use of Concrete Masonry Units has undergone a lot of research for their suitability as masonry unit in earthquake-prone areas. The use of masonry units depends greatly on their architectural function. Usually, the use of masonry units in structural members was only for architectural purpose as a result of which the overall design of the structure got simplified and complex modeling situations reduced. The architect had an important role in this design procedure of the structure [1].

In a routine based design procedure, the structure would be designed only for the structural members i.e. columns, beams, footings etc. whereas ignoring the presence of masonry units within the framing members of the structure [2]. With the advancement in research in concrete members subjected to lateral load analysis, there ascended a new debate on the performance of the incorporation of these masonry units in the frame members as in Fig. 1. Gradually the engineers responsible for the design of structures adopted this fact that the use of masonry units as infill material influences the performance levels of the overall building especially whenever a masonry infill is provided in spaces present in between two columns [3].

![Figure 1. Laterally loaded infilled frame](image)

2. Failure Modes

The failure modes of masonry infilled material in reinforced concrete (RC) frame structures depends greatly on the properties of the frame and the masonry infill material used [4]. Failure may occur in the frame member or in the adjoining masonry units as a whole [5]. In order to quantify the amount of enhancement of lateral stiffness of frame members is of utmost importance to study the various modes of failure occurring in frame-masonry interface as a result of lateral loads [6]. It has been observed by [7], [8] that the most common type of failure occurring under lateral loads is tension failure in the...
column member or the shear failure of the beams or of the columns.

![Figure 2. Failure mode of RC frame](image)

The modes of failure of the masonry units and that of the adjoining concrete frame member are presented in Fig. 2 and 3. The failure of columns in the frame is primarily a tension failure that initiates as a result of the applied overturning moments. This mode of failure can be of a great concern for the designers [9].

In case of weak elements of the frame members, the modes of failure that are dominant are the failure in flexure and shear of the columns and beams [10]. This mode of failure is primarily occurring at the locations where plastic hinges have been formed in the structure [11]. An amount of lateral load applied on the frame that is resisted easily by the frame members will result in the failure of the adjoining masonry units present in the framing members [12].

This kind of failure can be sequential as a combination of the failure occurring in the frame as well as that of the masonry members [13]. The failure of masonry infill in shear possesses a direct linkage with the shear induced from the horizontal direction at the infill panel in the frame [14]. The shear resistance of the masonry infill material has an important role in the stability of the structure under lateral loads [15]. The total shearing stress provided by the masonry infill material to the external loads is a combined contribution of the frictional forces occurring in the masonry and the mortar material and also the bond shear strength [16].

A principle tensile stress is introduced as a result of the diagonal forces which gives way to the cracking of the masonry infill material in diagonal tension [17]. The failure of infill material under compressive loads is escorted by the prompt increase in the deflection of the structural member [18].

3. Mechanical Model

A modeling technique, presented by [18], of the frame-infill-wall comprises of an equivalent diagonal strut model and a finite element method. The equivalent strut model provides interaction between the frame members and the adjoining masonry infill material [19] wherein the strut model is greatly dependent on the finite element method as a whole.

![Figure 3. Failure mode of Infill](image)

By adopting the equivalent strut model, the designer can attain simplicity in the design of the frame members [20]. Moreover, it does not compel the designer to increase the number of degrees of freedom of the overall structure used in the analysis of the members [21].

On the other hand the finite element technique can facilitate the designers by overcoming the drawbacks of the equivalent-strut model [22]. The versatility obtained by the incorporation of the finite element method may be overshadowed by the requirement of the greater amount of degree of freedoms in the structural design and analysis procedure [23]. The model development can be broadly subdivided into two distinct areas for further discussion. As a preliminary area, the topological development along with the configuration of the structural members and secondly the material model development in order to describe the characteristics and performance levels of the materials is of prime importance to understand [24].
4. Material Model
The material modelling technique has been broadly subdivided into the areas of frame material model, masonry material model, gap model and the joint material model [25]. The behaviour of the columns and beams of the framing members can be assumed to possess a bilinear rotation behaviour that is focussed in the regions where non-linear hinges are formed [26].

Figure 5. Bilinear moment rotation relation for the columns and beams

Figure 5 shows a typical behaviour of the rotation curve that has been formed as a result of moment variation in the framing members. On the contrary to reinforced concrete structures, this type of relationship is best suited for steel structures [27]. However, the provision of such a model will boost the understanding the behaviour of the material model itself.

The modelling of a frame and wall problem requires the subdivision of the column and beam members into smaller fragments [28]. The segmentation should be done in such a manner that the individual segment depicts the realistic behaviour scenarios when subjected to external force application [29]. It is not suitable to assume any sort of interaction to exist between the columns in terms of inelastic behaviour and the axial load on the column is modelled as an elasto-plastic material [30] which, by far, is free from the influences of the bilinear moment rotation relationship that exists in figure 5.

5. Conclusions
The behaviour of frame structures under lateral loads is mainly dominated by the presence of columns in the structure. It can be seen that columns are the primary members of a frame structure that resists the lateral loads. The mechanism of development of cracks in a frame structure infilled with masonry units seems indispensable in modelling a frame-infill-wall system. A further systematic work is needed to be carried out to develop design adjustments in the form of numerical.


