Influence of Infills under Lateral Loading in Reinforced Concrete Frame– Review

Deepak Bhati[1], Suresh Singh Sankhla[2], Tarun Gehlot[3]

[1,2]Department of Structural Engineering, MBM University Jodhpur
[3]Department of Civil Engineering, CTAE Jodhpur, Agriculture University Jodhpur

Received: 12.04.2024 Revised : 16.05.2024 Accepted: 22.05.2024

ABSTRACT
High-rise constructions must be developed not just in India, but in most major cities throughout the world, due to socioeconomic challenges caused by industrialisation and the increasing need for space in urban areas. RCC frames are currently being used in the design and construction of high-rise structures, and because of their greater ability to support architectural design, they have become increasingly significant and appealing. Whenever a similar reinforced concrete frame experiences lateral drifts because of dynamic stresses, the behaviour of the infill walls becomes notable. During the static load analysis technique, the interaction of the masonry units as framing components and the adjacent frame members might not be remarkable.This study reviews the methods for addressing the performance of infill walls under lateral loads

Keywords : High Rise Structures , RCC Frame , Infills , lateral Loads , Structural System

1. INTRODUCTION

Many buildings, including those in seismically active areas, use in-filled frame constructions. Unfortunately, there is a lack of sufficient guidance for tackling the modeling, analysis, and design of in-filled frame structures in the current IS-codes and others. This paper describes all theories (i.e., modeling methodologies) for the infill-frame interface and then applies one way to investigate the seismic response of in-filled frame structures. For the sake of analysis, infill walls are treated in this study as an equivalent diagonal strut. An analysis of several infill wall combinations and a variation in the bottom storey height have been conducted for a 20-story infill construction. A basic frame construction has been used to compare each of these models. Based on this work, conclusions have been drawn. The findings demonstrate that infill has a major impact on structural performance. When an infill wall is added, the structural reactions, including the fundamental period, roof displacement, inter-storey drift ratio, stresses, and member forces of the bottom-story column, usually decrease. The comprehension of in-filled frame buildings and earthquake design will benefit from these findings.

The results show that infill significantly affects the performance of the structure. The structural reactions, such as the fundamental period, roof displacement, inter-storey drift ratio, stresses, and member forces of the bottom-story column, often decrease with the addition of an infill wall. These results will aid in the understanding of in-filled frame buildings and earthquake design.

Masonry has been increasingly popular in the building industry, and its primary use are as load-bearing walls in standard projects and as filler material in high-rise reinforced concrete frame structures. Brick units are one of the most often utilized masonry units in Pakistan; they are produced at nearby kilns and have seen a significant increase in production over the past ten years.

A great deal of research has been done on the suitability of using Concrete Masonry Units as masonry units in places that are prone to earthquakes in the aftermath of the tragic October 2005 earthquake. The way that masonry units are used is largely determined by their architectural purpose. Typically, masonry units were only used in structural members for architectural purposes, which led to a reduction in complex modeling scenarios and an overall simplification of the structure's design. An essential part of the structure's design process was played by the architect [1]. Infilled frames are frequently used in the construction of high-rise buildings. Masonry, which includes concrete blocks, brick, and stone, is frequently utilized as filler in construction projects.

When compared to other materials, masonry is a quicker, easier, and less expensive choice for creating infill walls. Tall structures' vertical loads are frequently predictable, which facilitates their analysis and design. On the other hand, lateral loads resulting from earthquakes or wind are concerning. These considerations must be examined while designing tall buildings. Vibrations, excessive lateral sway, and structural stress can all be caused by lateral forces. This is not true because there will definitely be interactions, especially when seismic stresses are present, between the infill panels and the surrounding frame. Infill panels contribute significantly to the resistance of the composite construction. It is evident that a substantial portion of the lateral pressures are always provided by the infill panels, even in cases where the frame may be able to tolerate horizontal stress. This emphasizes how important the in-plane composite movement is between the panel and the frame. In today's construction methods, creating concrete frame structures is one of the most practical solutions for building concrete buildings because it allows the contractors to simply and affordably maintain a flexible work schedule throughout the various stages of development. Bricks, wood, concrete masonry units, cast-in-place concrete, etc. are used to fill the frame's components. Adding infill walls to a reinforced concrete frame can have benefits and drawbacks that are often overlooked in the construction process. The frame elements that are next to the masonry units that are being used as framing components may not be noticeable during the static process for load analysis.

However, lateral drifts in the same reinforced concrete frame happen when dynamic forces cause the behavior of the infill walls to become noteworthy. This paper reviews the various approaches that have been put out in order to discuss how well masonry infill walls perform when subjected to lateral loads or dynamic forces. A routine-based design process would only consider the structural elements of the structure, such as the columns, beams, footings, etc., and would not take into account the existence of masonry units inside the structure's frame components [2]. As research on concrete elements exposed to lateral load analysis advanced, a fresh discussion about the effectiveness of incorporating these masonry units in the frame members as shown in Fig. 1 emerged. The fact that the performance levels of a building are affected when masonry units are used as infill material, particularly when masonry infill is placed in the spaces between two columns, was gradually accepted by the structural engineers in charge of building design [3].

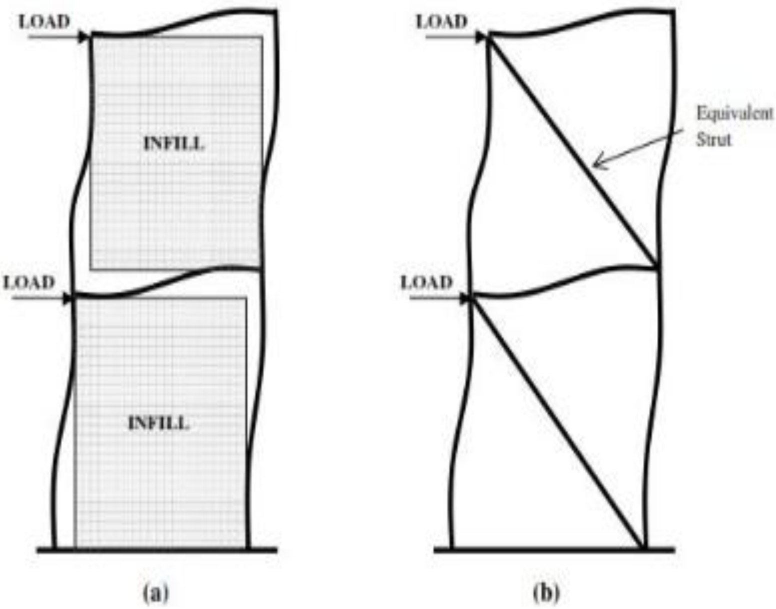

Figure 1. Laterally loaded infilled frame

The characteristics of the frame and the masonry infill material employed in reinforced concrete (RC) frame buildings have a significant impact on the failure modes of the infilled material [4]. The adjacent masonry pieces collectively or the frame component itself may fail [5]. Studying the various types of failure that occur in the frame-masonry interface as a result of lateral stresses is crucial in order to measure the degree of augmentation of lateral stiffness of frame members [6]. According to observations made by [7], [8], tension failure in the column member or shear failure of the beams or columns are the most frequent types of failure that occur under lateral loads.

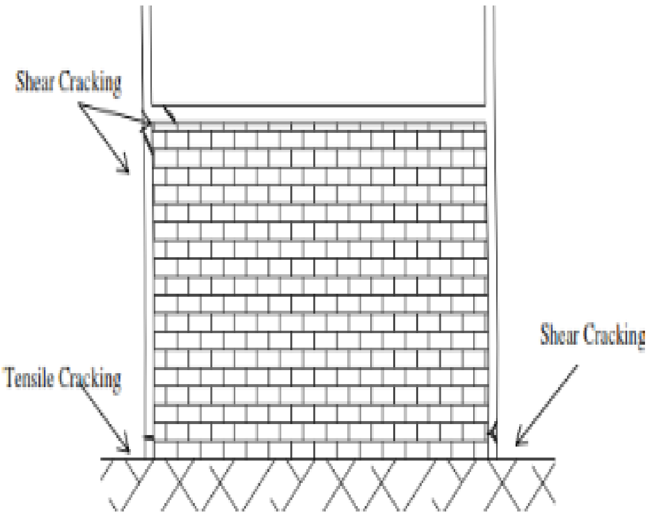

Figure 2. Failure mode of RC frame

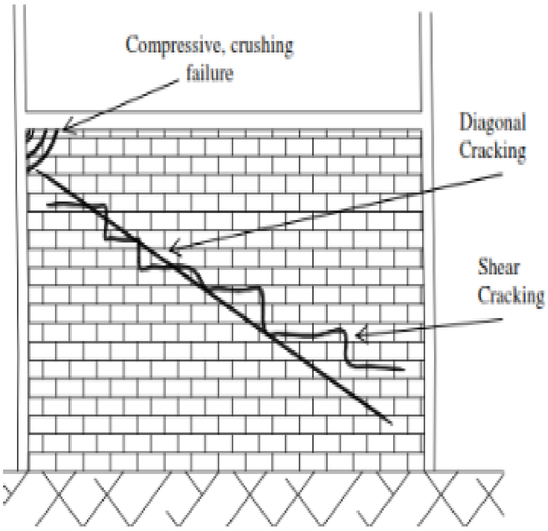

Figure 3. Failure mode of Infill

Figs. 2 and 3 depict the masonry units' and the adjacent concrete frame member's mechanisms of failure. The applied overturning moments cause a tension failure that is the main cause of the frame's column failure. The designers may have serious concerns about this mechanism of failure [9]. Shear and flexure failures of the columns and beams are the most common modes of failure in the event that the frame components are weak [10]. The primary areas of this mechanism of failure are where the structure's plastic hinges have formed [11].
The shear generated at the infill panel in the frame from the horizontal direction is directly related to the failure of the masonry infill in shear [14]. The stability of the structure under lateral stresses is significantly influenced by the shear resistance of the masonry infill material [15]. The frictional forces present in the masonry and mortar material, as well as the bond shear strength, add up to the total shearing stress that the masonry infill material provides to the external loads [16].

2. Role and Effect of Infill in Structure
Flexible frames don't offer much defense against lateral forces on their own. The joints commonly twist and deflect noticeably as a result of this. Parallel to this, lateral stress panels or walls shear primarily at low loads and during shifts. If the infills are carefully designed and implemented, the composite system's overall motion as a result of the frame and panel working together differs from that of the frame or wall offered in that frame alone. Greater lateral stability, greater lateral load resistance, and less distortions may be seen in a larger frame. When shear loads and distortions are reduced, high diagonal forces are produced by infill panels made of concrete that are combined with RC frames. They function as elements of the framework.

2.1 Infilled Frames

An infilled frame is essentially a composite construction consisting of filler walls and a moment-resisting plane frame. An infilled frame is usually composed of RCC or steel, with gaps filled in with masonry or concrete. The purpose and effect on the primary of the masonry infill. The structure is determined by the connection between the infill and the frame.

2.2 The benefits of infills

1.Th addition of infills significantly strengthens the building frame's overall strength and lateral resistance. As a result, the structure's sideways swing is lessened.
2.The ability of structures to dissipate energy is increased by the addition of infills by infill cracking and friction between the infill and the surrounding frame.
3.Properly built infill barriers might lessen the likelihood that construction, even in the event that the frames are poorly made.
4.Shear force and bending moment are significantly reduced by the insertion of infill in members of the frame.
5.Considering the infill in design and analysis lowers the cross-sectional dimensions of the components, lowering the structural system's total cost framework.

2.3 Negative Effects of Neglecting Infills

Designers often simplify their designs by ignoring the structural role of infills, even though they can be designed as shear panels that interact with the frames to improve the structure's lateral strength and stiffness. There is a common misconception that these exclusions are prudent and secure. Due to increased forces of inertia and the unequal distribution of lateral shears between the frames, this technique may provide inaccurate designs (Smith and Carter, 1969).
The problems with infills are as follows:

- The presence of infills can enhance stiffness, which can shorten a structure's natural lifespan and raise seismic forces;
- Infills in the frames may significantly alter the intended structural response by drawing pressures to areas of the structures that aren't meant to withstand them.
- The center of rigidity of the structure may shift if infilled frames are not positioned symmetrically, leading to torsional effects.
- Localized damage to frame sections around beam-column connections or at column mid-heights may arise from the frame-infill interaction.
- Infill collapse and early failure can result from strong but poor infills combined with reduced lateral rigidity in frames.

The failure modes of the infilled material in reinforced concrete (RC) frame constructions are determined by the properties of both the frame and the infilled masonry material. The material that is filled in masonry. Failure is possible. either in the neighboring brickwork units or the frame component. It is necessary to investigate the many forms of probable failure in the frame-masonry interface due to the influence of lateral loads in order to quantify the need for improving the lateral stiffness of the frame components. It has been observed that the most common type of failure is shearing failure in beams or columns or tension failure on the underside that occurs under lateral loads in column members.
The processes of failure of the neighboring concrete frame member and the masonry units. The primary cause of the frame's columns collapsing is a tension breakdown brought on by the applied overturning moments. Designers may be quite worried about this approach failing. if there are any weak areas in the frame members. Shear failure and column and beam flexure are the most frequent types of failure.The places where the plastic hinges in the structure have evolved are the main sites of failure for this mechanism of failure. The adjacent will result from the degree of applied lateral stress on the frame that the frame quickly resists membership.
The components of the framework are bits of masonry. This kind of failure could happen sequentially as a result of the masonry members' failure plus the failure of the frame. The shear caused by the horizontal direction at the infill panel of the frame is directly related to the shear-related masonry infill failure.

CONCLUSION

The shear resistance lateral weights of the masonry infill material have a major impact on the stability of the building under stress. The masonry infill material, which is a combination of the frictional forces occurring in the mortar material and the shear strength of the brickwork, supports the overall shearing force provided by the outside loads.

The brick infill material finally splits in diagonal tension as a result of the fundamental tensile stress generated by the diagonal pressures. The structural member's deflection increases immediately when infill material breaks down under compression pressures.
The behavior of a structure under lateral loads is mostly determined by the existence of columns. It is clear that the main elements of a frame design that can support side loads are columns. The method by which masonry-filled frame building units' fractures seem to be necessary to replicate a frame-infill-wall construction. When modeling a frame infill-wall system, understanding the mechanism of crack development in a frame structure filled with masonry units appears to be essential.

REFERENCES

[1] Sucuoğlu, H. and McNiven, H. D. “Seismic Shear Capacity of Reinforced Masonry Piers”, Journal of Structural Engineering, Vol. 117, No. 7, pp. 2166-2187, July 1991.
[2] Sucuoğlu, H. and Erberik, A., “Performance Evaluation of a Three-Storey Unreinforced Masonry Building During the 1992 Erzincan Earthquake, Earthquake Engineering and Structural Dynamics, Vol. 26, pp. 319-336, 1997.
[3] Paulay, T. and Priestley, M. J. N, Seismic Design of Reinforced Concrete and Masonry Buildings”, John Wiley & Sons, Inc., 1992.
[4] Smith, B. S. and Coull, A., “Tall Building Structures: Analysis and Design”, John Wiley & Sons, Inc., 1991.
[5] EERI, 2006, AT RISK: The Seismic Performance of Reinforced Concrete Frame Buildings with Masonry Infill Walls, A Tutorial Developed by a committee of the World Housing Encyclopedia, a project of the Earthquake Engineering Research Institute and the International Association for Earthquake Engineering.
[6] Alcocer, S.M, Flores, L., Duran, R.1996. Recent Experimental Evidence On The Seismic Performance Of Rehabilitation Techniques In Mexico. Advances in Earthquake Engineering for Urban Risk Reduction 261-274.
[7] Almusallam, T.H., Al-Salloum, Y.A., 2006. Behavior of FRP Strengthened Infill Walls under In-Plane Seismic Loading. Journal of Composites for Construction 11:3(308).
[8] Altin, S., Anil, Ö., Kara, M.E., Kaya, M., 2007. An experimental study on strengthening of masonry infilled RC frames using diagonal CFRP strips. Composites: Part B 39:680-693.
[9] Altin, S., Anil, Ö., Kara, M.E., 2007. Strengthening of RC nonductile frames with RC infills: An Experimental Study. Cement & Concrete Composites 10:1016/j.
[10] Binici, B., Özcebe, G., Özçelik, R., 2007. Analysis and design of FRP composites for seismic retrofit of infill walls in reinforced concrete frames.Composites: Part B 10:1016/j.
[11] Canbay, E., U., Ersoy, Özcebe, G., 2003. Contribution of Reinforced Concrete Infills to Seismic Behavior of Structural Systems. ACI Structural Journal 100-S66
[12] Erdem, I., Akyüz, U., Ersoy, U., Özcebe, G., 2006. An experimental study on two different strengthening techniques for RC frames. Engineering Structures 28:1843-1851.
[13] Saatçioglu, M., 2006. Seismic Risk Mitigation Through Retrofitting Nonductile Concrete Frame Systems. Advances in Earthquake Engineering for Urban Risk Reduction 179-194
[14] Borah, B., Naik, S., Abhishek, V., Kaushik, H. B., & Singhal, V. (2024). Influence of wall openings on nonlinear lateral load response of reinforced concrete frames with masonry infills: A finite element study. International Journal of Civil Engineering, 22(4), 619-637.
[15] Sivanantham, P., Selvan, S. S., Srinivasan, S. K., Gurupatham, B. G. A., & Roy, K. (2023). Influence of infill on reinforced concrete frame resting on slopes under lateral loading. Buildings, 13(2), 289.
[16] Kim, M., & Yu, E. (2021). Experimental study on lateral-load-resisting capacity of masonry-infilled reinforced concrete frames. Applied sciences, 11(21), 9950.