International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

A Review Paper on Consideration of Stiffness of Masonry in Structure Design

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A B S T R A C T

Masonry has also commonly been used in frame building structures as infill, where it was intended to act as an environmental divider rather than a structural element. The primary function of masonry was either to protect the inside of the structure from the environment (rain, snow, wind, etc.) or to divide inside spaces. In either case, common practice has always been to ignore infill during the design and analysis of steel/reinforced concrete frame structures.

The stiffness of structural elements (columns, beams, and slabs) significantly contributes to the overall stiffness of reinforced concrete (RC) high-rise buildings (H.R.B.s) subjected to earthquake. Contrary to common practice, the presence of masonry infills influences the overall behavior of structures when subjected to lateral forces. When masonry infills are considered to interact with their surrounding frames, the lateral stiffness and the lateral load capacity of the structure largely increase.

Keywords: Infill Walls, Stiffness, Lateral loads.

1. Introduction

When a structure is subjected to ground movement (shaking) in an earthquake, it responds by vibrating. The random motion of the ground caused by an earthquake can be resolved in any three mutually perpendicular directions. Generally, however, the inertia forces generated by the horizontal components of ground motion require greater consideration in seismic design. Structural analysis is mainly used for finding out the behavior of a structure when subjected to some action. This action can be in the form of load due to the weight of things such as people, furniture, wind, snow, etc. or some other kind of excitation such as an earthquake, quivering of the ground due to a blast nearby, etc. since all these loads are dynamic including the self-weight of the structure because at some point in time these loads were not there.

In many countries including those situated in earthquake prone area, most of the multi-story buildings are of moment resisting reinforced concrete frames with unreinforced brick masonry infill. Due to functional demand these infill panels also have openings for doors, windows, etc.The present practice is to treat the masonry infill as non-structural element and the analysis as well as design is carried out by only using the mass but neglecting the strength and stiffness contribution of infill. Therefore, the entire lateral load is assumed to be resisted by the frame only. However, the presence of infill tend to interact with the frame when subjected to earthquake load and have both beneficial as well as unfavourable impact on the performance of the building structure. Since infill panels are not considered, their contributions to the lateral stiffness and strength may invalidate the analysis and the proportioning of structural members for seismic resistance on the basis of its results. In reality, the additional stiffness contributed by these secondary components increases the overall stiffness of the building, which eventually leads to shorter time periods as they are observed during earthquakes, hence induce more lateral force to the structure.
Past earthquakes have shown that buildings with regular masonry infill have a better response than with the irregular ones. Masonry infills have a very high initial stiffness and low deformability thus, making infill wall a constituent part of a structural system. This changes the lateral load transfer mechanism of the framed structure form predominant frame action to predominant truss action, which is responsible for reduction in bending moments

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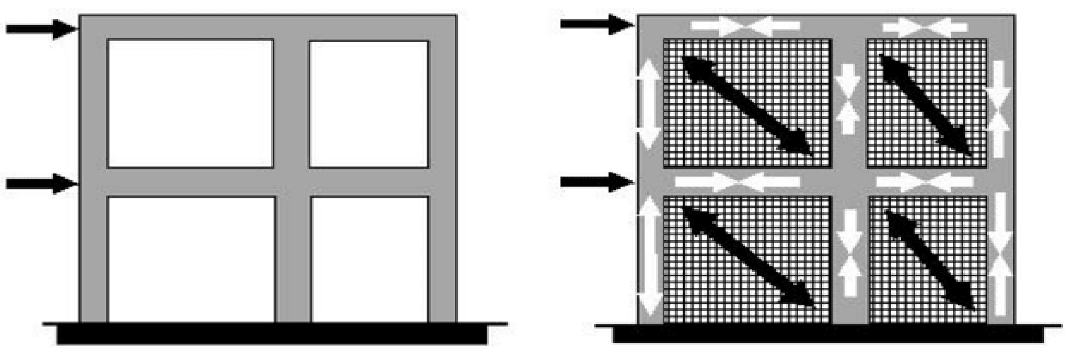
and increase in axial forces in the frame members. The presence of infill also increases damping of the structures due to the propagation of cracks with increasing lateral drift. However, behavior of masonry infill is difficult to predict because of significant variations in material properties and failure modes that are brittle in nature.

Masonry infills in reinforced concrete buildings cause several undesirable effects under seismic loading: short-column effect, soft-storey effect, torsion, and out-ofplane collapse. Hence, seismic codes tend to discourage such constructions in high seismic regions. However, in several moderate earthquakes, such buildings have shown excellent performance even though many such buildings were not designed and detailed for earthquake forces. The influence of infills on overall behavior of the structure has been found to change with the direction in which the load is applied.



(a) Frame action in bare frame (b) Predominant truss action in infilled frame

Figure 1: Change in the lateral load transfer mechanism owing to inclusion of masonry infill walls.

2. Literature Review

The typical multi-storey construction in India comprises reinforced concrete (RC) frames with brick masonry infills. Unreinforced masonry infill wall panels may not contribute towards resisting gravity loads, but contribute significantly, in terms of enhanced stiffness and strength under earthquake (or wind) induced lateral loading. However, in practice, the infill stiffness is commonly ignored in frame analysis, resulting in an under-estimation of stiffness and natural frequency. Also, the infills have energy dissipation characteristics that contribute to improved seismic resistance. It is instructive to study the implications of the common practice of ignoring the infill stiffness with regard to performance under seismic loading

The infill wall is the supported wall that closes the perimeter of a building constructed with a three-dimensional framework structure (generally made of steel or reinforced concrete). Therefore, the structural frame ensures the bearing function, whereas the infill wall serves to separate inner and outer space, filling up the boxes of the outer frames. The infill wall has the unique static function to bear its own weight.

The infill wall is an external vertical opaque type of closure. With respect to other categories of wall, the infill wall differs from the partition that serves to separate two interior spaces, yet also non-load bearing, and from the load bearing wall. The latter performs the same functions of the infill wall. Infill walls have following Characteristics – fire safety, thermal comfort, acoustic comfort, durability and water leakage. Infills interfere with the lateral deformations of the RC frame; separation of frame and infill takes place along one diagonal and a compression strut forms along the other. Thus, infills add lateral stiffness to the building. The structural load transfer mechanism is changed from frame action to predominant truss action (Given in figure below) the frame columns now experience increased axial forces but with reduced bending moments and shear forces.

When infills are non-uniformly placed in plan or in elevation of the building, a hybrid structural load transfer mechanism with both frame action and truss action, may develop. In such structures, there is a large concentration of ductility demand in a few members of the structure. For instance, the soft-storey effect (when a storey has no or relatively lesser infills than the adjacent storey's), the shortcolumn effect (when infills are raised only up to a partial height of the columns), and plan-torsion effect (when infills are unsymmetrically located in plan), cause excessive ductility demands on frame columns and significantly alter the collapse mechanism.

Another serious concern with such buildings is the out-of-plane collapse of the infills which can be life threatening. Even when the infills are structurally separated from the RC frame, the separation may not be adequate to prevent the frame from coming in contact with the infills after some lateral displacement; the compression struts may be formed and the stiffness of the building may increase. Infills possess large lateral stiffness and hence draw a significant share of the lateral force. When infills are strong, strength contributed by the infills may be comparable to the strength of the bare frame itself.

Masonry infill wall panels increase strength, stiffness, overall ductility and energy dissipation of the building. More importantly, they help in drastically reducing the deformation and ductility demand on RC frame members [Murty and Nagar, 1996]. This explains the excellent performance of many such buildings in moderate earthquakes even when the buildings were not designed or detailed for earthquake forces. The reinforcement in the infills does not contribute significantly towards stiffness and strength; in fact, it may lead to reduction in stiffness and strength due to increased mortar thickness in the layers containing the reinforcement. However, the reinforcement helps in improving the post-cracking behaviour of the masonry and in preventing out-of-plane collapse.

Most multistorey building constructions in the developing countries consist of RC frames with URM infills. Often the RC frame is not even formally designed for seismic loading even in severe seismic zones. This situation is not likely to change significantly in the near future. Such buildings are commonly used as residential or office buildings which typically have a fairly large number of infills placed more or less uniformly and have small to moderate panel size. It should be possible to develop suitable detailing schemes for anchoring masonry reinforcement into the frames and thereby improve the out-of-plane behaviour of the infills. In such situations, the infills could be relied upon to ensure good seismic performance.

The detrimental effects of infills, e.g., short column effect, soft-storey effect and torsion, however, remain and could be a serious concern. For instance, in the Jabalpur earthquake of 1997 in India [Jain et al., 1997], the only RC frame buildings that sustained damage were those with soft-first storey created by the absence of infills in the ground storey to facilitate parking. It is not reasonable to expect that the developing countries will be able to adopt a significantly different structural system in the short run. Extensive research is needed with a view to develop robust seismic design methodologies for such buildings. The seismic design provisions addressing such buildings in the European and the Nepalese codes are an excellent beginning.

3. Outlining Scope

In above study, we can underline that after consideration that stiffness of infill walls in building contribute towards the large lateral stiffness and hence draw a significant share of the lateral force. When infills are strong, strength contributed by the infills may be comparable to the strength of the bare frame itself and ignorance of infill leads to uneconomical and inaccurate design of structure.

4. Conclusion

The study is focused on the study of seismic behavior of RC buildings using analytical techniques for the building of Indian medium soil. The performance of the building is studied in terms of Base shear, Lateral displacement in Linear static and linear Dynamic (Time-History) analysis for with and without the effect of infill wall G+10 storey building.Influence of Base Shear and Lateral Displacement will be compared and impact of infill walls will be observed with the help of graphs and Charts.

Base Shear - Base shear is an estimate of the maximum expected lateral force on the base of the structure due to seismic activity. It is calculated using the seismic zone, soil material, and building code lateral force equations.

Lateral Displacement - Lateral displacement is important when structures are subjected to lateral loads like earthquake and wind loads. Lateral displacement depends on height of structure and slenderness of the structure because structures are more vulnerable as height of building increases by becoming more flexible to lateral loads.

Energy dissipation - Energy dissipation is used in the structure to determine the consumption of the vibration energy of the structure under the earthquake, reduction of the vibration response of the structure, and achieve the purpose of earthquake resistance of the structure.

Stiffness - The term 'stiffness' refers to the rigidity of a structural element. In general terms, this means the extent to which the element is able to resist deformation or deflection under the action of an applied force.

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