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SEISMIC IMPACT ANALYSIS OF INFILL AND WITHOUT INFILL WALL IN MULTI-STOREY BUILDING

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Abstract

The objective of the thesis is to check the applicability of the multiplication factor of 2.5 for the given structure of mid height and to study the effect of infill strength and stiffness in the seismic analysis of mid-rise open ground storey building. An existing RC framed building (G+5) with open ground storey located in Seismic Zone-IV is considered for this study. In this building is analysed for two different cases (a) considering both infill mass and infill stiffness and (b) considering infill mass but without considering infill stiffness by equivalent static and response spectrum analysis methods. Infill weights are modelled through applying static dead load and the infill stiffness is modelled by equivalent diagonal strut approach. The results indicate that the magnification factor of 2.5 is too high to be multiplied to column forces of the ground storey of the given mid-rise open ground storey building. It is found that the infill panels increase the stiffness of the upper storeys of the structure, thereby increasing the forces, displacement, drift and ductility demand in the soft ground storey. This can possibly become the cause of failure for an open ground storey buildings during the earthquake.

Keywords: *Soft storey, Infill wall, Varying infill, Magnification factor, Lateral load, Seismic design principle, Structure model-ling, Non-linear dynamic, Equivalent static analysis, Response spectrum analysis.*

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1. Introduction

Since 1960s, studies have been carried out to study the influence of infill on the moment resisting frames under lateral loads induced by earthquakes, wind and the blast. Various experimental and analytical investigations have been carried out; nevertheless, a comprehensive conclusion has been reached due to the complex nature of material properties, geometrical configuration and the high cost of computation. Though the effect of infill is recognized widely, there is no explicit consideration in the modern codes, thus the practicing/design engineers end up designing the buildings based on judgement.

Infill is normally considered to be the non-structural elements, inspire of its significant contribution of lateral stiffness and strength against the lateral load resistance of the frame structures. Conversely, there is a general misconception among the designers that the infill will increase the overall lateral load carrying capacity. This would lead to undesirable performance of the moment resisting frames because the infill which was not considered during design stage would modify the inherent properties of the reinforced concrete frame members. As a consequence, failure in different forms would be the result due to additional loads on the stiffened members.

The construction of reinforced concrete structures with infill wall is a common method of providing shelter to the ever-increasing population in the developing countries like India, where there is seismic activity. The lack of information on the actual behaviour of such structure in the existing codes of practice is hence an issue. This review presents the modelling techniques of infilled structures, consideration of infill in current seismic codes and recent development in this particular field

2. Literature Review

Stafford Smith (1966) [1] according that the weak frame cannot transmit the forces to the compressive diagonal of infill and so it suffers native crushing at the ends of compressive diagonal. The strong frame can transmit high forces to the compressed diagonal which set infill to initiate cracking from the central region and propagates towards the compressed diagonal ends was reported by Mainstone (1971) in contradiction to that stated above. Zarnic (1985) reported that when the weaker infill is used with the strong frame system then the horizontal sliding failure occurs along the bed joints of the masonry. On the contrary, Parducci(1980) reported that when the stronger infill was used with the weak frame, the frame underwent premature failure of columns before the onset of frame failure, which means that the infilled frame does not reach to its full capacity.

The impact of slip and interface friction between the frame and infill wall was investigated by Mallick and Severn(1967) [2] using finite element analysis. The infill panel were simulated by means of linear elastic rectangular finite elements, with two degrees of freedom at each of the four corner nodes. Interface between frames and infills was modelled and contact length was calculated. The slip between frame and infill was taken into account by considering frictional shear forces in the contact region by using link element. Each node of this element has two translational degree of freedom. The element is able to transfer compressive and bond forces, but incapable of resisting tensile forces.

It was observed by Merabi (1994) [3], the brittle shear failure of the column on the windward sides while investigating the in-filled frame structure which had strong infill panels and weak frames. However, the increase in lateral load resistance was found even having the shear failure in column, indicating some ductility due to infill. On the contrary, the formation of hinges in the columns and slip in the bed joints were observed in weak infill frame test specimens. The stronger frame with stronger infill had failed by crushing of infill as the shear failure of column’s was prevented because of enough shear reinforcement and greater sized column. A comprehensive experimental and analytical investigation into the behaviour of infilled structures was conducted by him. It reported that the infill has vital improvement on the lateral strength and stiffness of a bare frame and also considerably improves the energy dissipation capability of the structure. The aspect ratio of the infill panel has very little influence on the behaviour of the frame while the cyclic loadings degrade the structure quicker than the monotonic loadings. He also reported that the increase in vertical loads significantly improves the lateral load carrying capacity of the structure, the distribution of vertical load between beam and column has insignificant influence. He indicated the rise in lateral load carrying capacity by increasing the number of storey, but this could not be true for high rise structures and thus similar study has to be conducted for higher number of storey

Fardis (1996) [4] perform investigation on the seismic response of an infilled frame which had weak frames with strong infill material. It is found that the strong infill which was considered as non-structural is accountable for earthquake resistance of weak reinforced concrete frames. However, since the behaviour of infill is unpredictable, with the likelihood of failing in brittle manner, it was recommended to treat infill as non-structural component by isolating it from frames. On the contrary, since infill is extensively used, it would be cost effective if positive effects of infill is utilised.

The behaviour of reinforced concrete framed open ground storey building when subjected to seismic loads was reported by Arlekar et.al (1997) [5]. A four storied open ground storey (OGS) building was analysed using Equivalent Static Analysis and Response Spectrum Analysis to find the resultant forces and displacements. This paper shows that the behaviour of open ground storey (OGS) frame is quite different from that of the bare frame.

Scarlet (1997) [6] studied the qualification of seismic forces in OGS construction. A multiplication factor for base shear for OGS building was proposed. This procedure requires modelling the stiffness of the infill wall in the analysis. The study proposed a multiplication factor ranging from 1.86 to 3.28 as the number of storey increases from six to twenty.

Al-Chaar (1998) [7] performed study on the behaviour of reinforced concrete frames with masonry infill. The test was conducted on two half scale specimens in which one of the frames was stronger than the other. The stronger frame specimen showed diagonal tension cracking while the weak frame failed because of the diagonal cracking as well as hinging of column at lower end. Both frames were reported to have shown the ductile behaviour, but the extent of ductility was not specific. However, he concluded that infill wall improves the strength, stiffness and energy absorption capacity of the plane structures which are useful for structure created in seismic regions.

Deodhar and Patel (1998) [8] pointed out that even though in infilled frame the brick masonry is intended to be non-structural, they can have considerable influence on the lateral response of the building. Davis and Menon (2004) gave a conclusion that the presence of masonry infill panels modifies the structural force distribution significantly in an open ground storey (OGS) building. As the stiffness of the building increases in the presence of masonry infill at the upper floor of the building the total storey shear force increases. Also, the bending moments in the ground floor columns increase (more than two-fold), and the mode of failure is by soft storey mechanism (formation of hinges in ground floor columns). Das and Murthy (2004) concluded that infill walls, when present in a structure, generally bring down the damage suffered by the reinforced concrete framed members of a fully infilled frame during earthquake shaking. The column beams and infill walls of lower stories are more vulnerable to damage than those in upper stories.

Dominguez (2000) [9] studied the effects on the fundamental period of building of non- structural component. The model was consisted of five storeys, ten storeys and fifteen storeys with diagonal struts as the infill (non-structural component). It was reported that the presence of infill decreases the fundamental period of the structure. When the model was provided with 100mm thick infill, the fundamental period got decreased by 46%, 40% and 34% for five storey, ten storeys and fifteen storeys. When the infill thickness was 200mm, the fundamental period became 53%, 44% and 36% respectively. The trend of increase in thickness with decrease in period is decreasing with the increase in height. However, the effect of thickness is not significant. The effect of masonry strength was reported to be insignificant on the fundamental period of the structure as the difference between 2 models which had 8.6MPa and15.2MPa was 10.4%. The significant difference was observed by increasing the number of bays. The difference in fundamental period was 15%, when the number of bays was increased to 2.

Dukuze (2000) [10] did investigation on the failure modes of infilled structure on single storey specimens with and without opening. In general, three types of failures were observed under an in-plane load such as sliding of bed joints, tensile cracking of infill and local crushing of compressive corners at the loaded corner. The specimen with opening at the centre of panel had suffered shear cracks at the point of contact and severe damages on the lintel beam. The contact length between the infill panel and frame had increased by increasing the stiffness of the confining frame. However, when the aspect ratio (H/L) was increased, the crack pattern spread throughout the panel and the column fails in shear and bending. The failure of fully infilled specimen was dominated with the diagonal cracking along with shear slip along mortar joints. Although, failure occurred at the loaded corners in most cases, the specimen which had strong column, failure occurred mostly near the beam in the loaded corner and conversely failure concentrate near the loaded region of column when their beam is stronger than the column.

Asokan (2006) [11] studied that how the presence of masonry infill walls within the frames of a building changes the lateral stiffness and strength of the structure. This analysis projected a plastic hinge model for infill wall to be employed in nonlinear performance primarily based analysis of a building and concluded that the ultimate load (UL) approach along with the proposed hinge property provides a better estimate of the inelastic drift of the building.

Doudoumis (2006) [12] studied the importance of contact condition between the infill and frame members on a single storey finite element model. He reported that the interface condition, friction coefficient, size of mesh, relative stiffness of beam to column, relative size of infill wall have significant influence of the response of infilled frame, whereas the effect of orthotropy of infill material was reported to be insignificant. That means that the infill can be treated as homogeneous material. When the mesh density was made finer the stress pattern among the infill was conjointly improved, with the maximum values of stresses at the compressive corners. The existence of friction coefficient at the interface was reported to increase the lateral stiffness of the system. However, friction coefficient is dependent on the quality of material and workmanship, which is difficult to define accurately. The response parameters were also exaggerated with the stiffness of frame and infill and therefore the relative size of frame and infill plane. However, this study was conducted for a single storey model under monotonic loading, thus, it is necessary to conduct similar studies for more number of stories under earthquake load.

Kaushik (2006) [13] conducted a comparative study of the seismic codes particularly on the design of infilled framed structures. The study concealed that the most of the modern seismic codes lack the vital information required for the design of such buildings. Moreover, the relevant clauses of codes are not consistent and vary from country to country. Such variations were attributed to the absence of an adequate research information on important structural parameters like determination of natural period of vibration of infilled structures, soft storey phenomenon associated with the presence of infill, exclusion of strength and stiffness of infill and considerations of openings. The main reason of not considering the beneficial effects of the infill is due to variation in material property as well as brittle nature of failure.

Hashmi and Madan (2008) [14] conducted non-linear time history and pushover analysis of OGS buildings. The study concluded that the MF prescribed by IS 1893(2002) for such buildings is adequate for preventing collapse. D Menon et. al. (2008) concluded that the MF increases with the height of the building, primarily due to the higher shift in the time period. Also when large openings are present and thickness of infills is less, there is a reduction in MF. The study proposed a multiplication factor starting from 1.04 to 2.39 as the number of storey will increases from four to seven.

J. Dorji and D.P. Thambiratnam (2009) [15] concludes that the strength of infill in term of its Young's Modulus (E) has significant influence on global performanceof the structures. The stresses in the infill wall decreases with increase in (E) values due toincrease in stiffness of the models. The stresses varies with building height for a given E and seismic hazard.

Sattar and Abbie (in 2010) [16] in their study concluded that the pushover analysis has showed an increase in initial stiffness, strength, and energy dissipation of the infilled frames, in comparison to the bare frames, despite the wall's brittle failure modes. Similarly, dynamic analysis results indicates that fully-infilled frames has the lowest collapse risks and the bare frames were found to be the most vulnerable to earthquake-induced collapses. The better collapse performance of fully-infilled frame was associated with the larger strength and energy dissipation of the systems, associated with the added wall

3. Summary

Literature review discusses briefly the previous work done on the area of seismic behaviour of open ground storey reinforced concrete buildings and modelling of infill walls as equivalent diagonal strut. From published work it can be concluded that even though the brick masonry in infilled frame are intends to be non-structural, yet they can have considerable influence on the lateral response of the building. Multiplication factor to increase the design forces of ground storey columns and beams of open ground storey (OGS) buildings is a function of storey numbers. IS 1893:2016 (Part-1) proposal for multiplication factor of 2.5 may not be appropriate for mid-rise building. The four different approaches namely (a) Finite element method of analysis (b) Elastic analysis approach (c) Ultimate load approach (d) Plastic analysis approach to understand the behaviour of infilled frames and to model the infill walls is described in detail in literature review. Also, the codal provisions have been discussed here.

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