Effect of Infill Walls in Performance of Reinforced Concrete Building Structures

Prakash Paudel

MTech Structural Engineering, Graphic Era University, Dehradun, India

Paudel257@gmail.com

Abstract: In open ground story buildings, sudden change of stiffness takes place along the building height which makes the story more flexible than the adjacent story. Hence columns and beams in those storeys got heavily stressed. Presence of infill walls in the frame alters the behavior of the building under lateral loads. However, it is a common industry practice to ignore the stiffness of infill wall for analysis of framed building. Engineers believe that analysis without considering infill stiffness leads to a conservative design. But this may not be always true, especially for vertically irregular buildings with discontinuous infill walls. Hence, the modelling of infill walls in the seismic analysis of framed buildings is imperative. Indian Standard IS 1893: 2002 allows analysis of open ground story buildings without considering infill stiffness but with a multiplication factor 2.5 in compensation for the stiffness discontinuity. However, as experienced by the engineers at design offices, the multiplication factor of 2.5 is not realistic for low rise buildings. This calls for an assessment and review of the code recommended multiplication factor for low rise open ground story buildings.

Keywords- Stiffness, Story, infill, multiplication factor, Strut, Drift, Ductility, Model

INTRODUCTION

The building in which the ground story consists of open space is known as stilt building or soft story building. That open story is called as stilt Floor or Soft-Story and such space is used for recreational use such as parking or for retail and commercial purpose. In these buildings, sudden change of stiffness takes place along the building height which makes the story more flexible than the adjacent story. In other words, story of which significant reduction of stiffness is observed is known as soft story. Hence columns and beams in those storeys got heavily stressed. Therefore, it is required that the ground story columns must have sufficient strength and adequate ductility. These types of buildings are commonly used in the urban area nowadays since they provide parking area which is most required. Performance of these buildings is found to be poor in the recent earthquakes. Under earthquake load their deformations are greater than other floors so design of these stories should be different from upper storeys. Soft story can be existing at any story level but generally exist at the ground story. major type of failures that occurred during past earthquake in soft story building are snapping of lateral ties, crushing of core concrete, buckling of longitudinal reinforcement bars etc. As per IS-1893:2002 (part I), A Soft Story is one in which the lateral stiffness is less than 70 percent of that in the story above or less than 80 percent of the average lateral stiffness of the three storeys above. An extreme soft story is one in which the lateral stiffness is less than 60 percent of that in the story above or less than70 percent of the average stiffness of the three storeys above. After the Bhuj earthquake, the IS 1893 code was revised in 2002, incorporating new design recommendations for soft story buildings. Clause 7.10.3(a) states: “The columns and beams of the soft story are to be designed for 2.5 times the story shears and moments calculated under seismic loads of bare frames.” The factor 2.5 is a multiplication factor (MF). This multiplication factor (MF) is used in the compensation for the stiffness discontinuity.

An appropriate way to analyze the soft story buildings is to model the infill walls. But due to lack of guidelines in IS 1893: 2002 (Part-1) for modeling the infill walls it is difficult to model. Alternatively, bare frame analysis is widely used that ignores the strength and stiffness of the infill walls. Since we are dealing with lateral loading, ductility of the structural members should be considered such that structure can sustain lateral load by its ductile behavior. structures are designed on the basis of strength and serviceability criteria. The strength is related to ultimate limit state, which assures that the forces developed in the structure remain in elastic range. The serviceability limit state stiffness is related to stiffness which assures that the structural displacements remains within the permissible limits.

In case of lateral forces the demand is for ductility. Ductility is an essential attribute of a structure that must respond to strong ground motions. Ductility is the ability of the structure to undergo distortion or deformation without damage or failure which results in dissipation of energy. Larger is the capacity of the structure to deform plastically without collapse, more is the resulting ductility and the energy dissipation. This causes reduction in effective forces. The seismic force generated at each floor levels are transferred through the various structural members to the ground. The building components need to be made ductile. The failure of a column can affect the stability of the whole building, but the failure of a beam causes localized effect. Therefore, strong column weak beam combination is desirable. In soft story buildings, energy developed during earthquake is transferred through columns which are of reduced stiffness due to lack of infill walls. The bare frame is much less stiff than a fully infilled frame; it resists the applied lateral load through frame action and shows well-distributed plastic hinges at failure condition.

MODELLING

Beams and columns in this study are modelled by using 3D frame element by creating rectangular cross section in SAP2000. The floor slabs were assumed to act as diaphragms, which ensure integral action of all the vertical lateral load-resisting elements. Building is considered to be in isolated foundation. Column ends are fixed at the top of the isolated foundation. Three different models are used to study the effect of infill wall in RC framed building structure. First is without infills, another with open ground story and third is completely infilled. Infill walls are modelled by using diagonal struts pinned at the both ends. As self-weight of wall is considered already in the model, density of the strut material is taken as 0.so diagonal struts are modelled to provide stiffness only.

The geometric properties are of effective width and thickness of the strut. The thickness and material properties of strut are similar to the infill wall. many investigators have proposed various approximations for the width of equivalent diagonal strut. Originally proposed by polyakov and subsequently developed by many investigators, the width of strut depends on the length of contact between the walls and columns,α_h, and between the wall and beams , α_l.The proposed range of contact length is between one forth and one tenth of the length of the panel. Stafford Smith developed the formulations for α_h and α_l on the basis of beam on an elastic foundation. The following equations are proposed to determine $\alpha_h$and α_l,which depends on the relative stiffness of the frame and infill, and on the geometry of the panel.

$$\alpha_h = \frac{\pi}{2}\sqrt[4]{\frac{4E_f I_c h}{E_m t \sin 2\theta}}$$

$$\alpha_l = \pi\sqrt[4]{\frac{4E_f I_b h}{E_m t \sin 2\theta}}$$

Where,

E_m and E_f = Elastic modulus of the masonry wall and frame material, respectively
t, h, L = Thickness, height and length of the infill wall, respectively
I_c, I_b = moment of inertia of the column and the beam of the frame, respectively
$\theta = \tan^{-1}\frac{h}{L}$

Hendry has proposed the following equation to determine the equivalent strut width w, where the strut is assumed to be subjected to uniform compressive stress

$$W=\frac{1}{2}\sqrt{\alpha_h{}^2 + \alpha_l{}^2}$$

Holmes recommended a width of the diagonal strut equal to one third of the diagonal length of the panel, whereas New Zealand Code (NZS 4230) specifies a width equal to one quarter of its length.

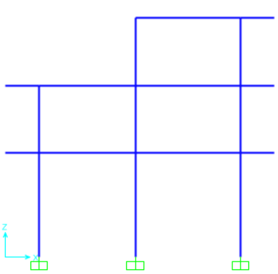

Figure 1. Model 1.

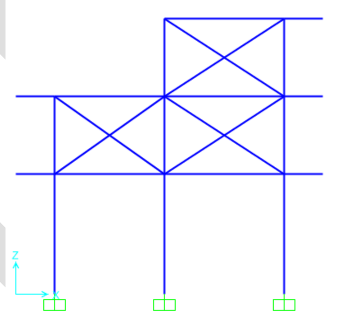

Figure 2. Model 2.

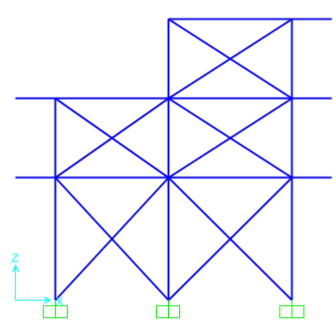

Figure 3. Model 3.

LOADING AND ANALYSIS

Nominal dead load and live loads are provided as static loads. Equivalent lateral load method is used to apply seismic loads in both the directions. Analysis of the three different models is carried out by using SAP2000 software.

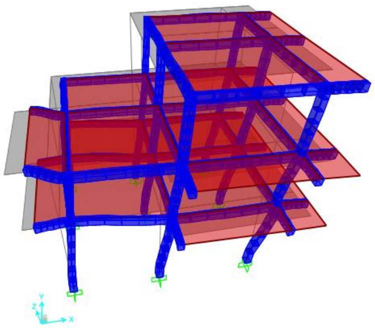

Figure 4. Deflected shape of model 2 building after analysis

4. Results

Time period is maximum in first model, decreases slightly in the second model which then decreases drastically in the third model. Reduction in time period means increase in earthquake response. So, structure should be designed for that increased earthquake force.

Table 1. Comparison of time periods of three models.

Modes	Model 1 (sec)	Model 2 (sec)	Model 3 (sec)
1^{st}	0.885119	0.763663	0.088502
2^{nd}	0.809937	0.701948	0.076088
3^{rd}	0.670112	0.596686	0.067101
4^{th}	0.271312	0.074745	0.059711
5^{th}	0.248055	0.066062	0.058058
6^{th}	0.208171	0.064401	0.056126
7^{th}	0.171019	0.060411	0.053035
8^{th}	0.160291	0.059215	0.05267
9^{th}	0.153167	0.053573	0.051351
10^{th}	0.075578	0.052887	0.050584
11^{th}	0.069347	0.05249	0.049208
12^{th}	0.061464	0.050801	0.048532

Story drift decreases as amount of infill increases in the building. We can also see that ground story drift in 2^{nd} model is larger, it is because upper storeys with higher stiffness causes the ground story to be flexible one so that its displacement is larger than that of the upper storeys. Also drifts in ground floor of 3^{rd} models are negligible due to increased stiffness by the infill walls.

Table 2. Drifts along x direction

Story	Model 1 (mm)	Model 2 (mm)	Model 3 (mm)
1st story	2.1	2.2	0.0486
2nd story	1.68	0.109	0.039
3rd story	0.99	0.1	0.073

Table 3. Drifts along Y direction

Story	Model 1 (mm)	Model 2 (mm)	Model 3 (mm)
1st story	2.13	3.22	0.014
2nd story	1.66	0.036	0.036
3rd story	0.7	0.062	0.058

Comparing the element forces, it is found that there is no significant change in moments in beams but every column of the infilled model is subjected to larger moments than that of the previous analysis. So, some modification should be applied for the moments obtained from the model without infills in the design procedure.

5. Conclusion

Analysis result shows that Column forces at the ground story increases for the presence of infills in upper storeys, but design load multiplication factor 2.5 is found to be much higher, it is actually found to be 1.15. Not significant change in beam forces of the first-floor beams was obtained after the consideration of infills too. Time periods decreases with the increase of amount of infill in the buildings (highest for without infills and lowest for the fully infilled case). This results in the attraction of more earthquake force for the lower time periods. Story drift is found to be lowest for fully infilled and highest for without infills but drift of first story is highest for the building with infills above ground floor (i.e. open ground story).

REFERENCES:

[1] Agarwal P. and Shrikhande M, "Earthquake resistant design of structures", PHI Learning Pvt. Ltd., New Delhi, 2006.

[2] Chopra A. K, Earthquake resistance of buildings with a soft first story. "Earthquake and Structural Dynamics", 1. 347-355, 1973.

[3] Das S, "Seismic design of vertically irregular reinforced concrete structures". Ph.D. Thesis. North Carolina State University. Raleigh. NC, 2000.

[4] Deodhar S. V. and A. N. Patel, "Ultimate strength of masonry infilled steel frames under horizontal load". Journal of Structural Engineering. Structural Engineering Research Centre, 24. 237, 1998.

[5] Dhansekar M. and A.W. Page "The influence of brick masonry infill properties on the behavior of infilled frames". Proceedings of Institution of Civil Engineers, Part 2. 81. 593-605,1986.

[6] Dolsek M and P. Fajfar, "Soft story effects in uniformly infilled reinforced concrete frames". Journal of Earthquake Engineering, 5(1). 1-12, 2001.

[7] Holmes M. "Steel frames with brick and concrete infilling". Proceedings of Institution of Civil Engineers, 19. 473-478, 1961.

[8] I.S 13920, "Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces-Code of Practice", Bureau of Indian Standards, 1993.

[9] Mehrabi A. B.; P. B. Shing; M. P. Schuller and J. L. Noland "Experimental evaluation of masonry – infilled RC frames". ASCE Journal of Structural Engineering, 122. 228-237,1996.

[10] Murthy C.V.R. and S.K. Jain. "Beneficial influence of masonry infill on Seismic performance of RC frames buildings". Proceedings of 12th World Conference on Earthquake Engineering, New Zealand, Paper No. 1790, 2000.

[11] Rahman, S. S. Influence of openings on the behavior of infilled frames. Ph. D. Thesis. Indian Institute of Technology Madras. Chennai, 1988.

[12] Sattar S and Abbie B. L "Seismic Performance of Reinforced Concrete Frame Structures with and without Masonry Infill Walls", 9th U.S. National and 10th Canadian Conference on Earthquake Engineering, Toronto, Canada, July 2010.