"Evaluation of Design Factor for Partially Open Ground Story Reinforced Concrete Buildings."

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Abstract - *Though multistoried buildings with open ground floor are inherently at risk to collapse due to earthquake load, their construction is still prevalent in the developing nations. Social and functional need to provide car parking space at ground level far out-weighs the warning against such buildings from engineering community. An investigation has been performed to study the behavior of the columns at ground level of multistoried buildings with soft ground floor subjected to dynamic earthquake loading. The structural action of masonry infill panels of upper floors has been considered by modeling them as diagonal struts. Finite element models of six, nine and storied buildings are subjected to earthquake load in accordance with equivalent static force method as well as response spectrum method. It has been found that when infill is incorporated in the model, modal analysis shows different mode shapes indicating that dynamic behavior of buildings changes when infill is incorporated in the model. Natural period of the buildings obtained from modal analysis are close to values obtained from code equations when infill is present in the model. This indicates that for better dynamic analysis of RC frame buildings with masonry walls, infill should be present in the model as well. Equivalent static force method produces same magnitude of earthquake force regardless of the infill present in the model. However, when the same buildings are subjected to response spectrum method, significant increase in column shear and moment as well as total base shear has been observed in presence of infill. In general, a two-fold increase in base shear has been observed when infill is present on upper floors with ground floor open when compared to the base shear given by equivalent static force method. The study suggests that the design of the columns of the open ground floor would be safer if these are design for shear and moment twice the magnitude obtained from conventional equivalent static force method.*

***Key Words*: concrete, earthquake, infill, multistore, response spectrum, soft story**

1. INTRODUCTION

Reinforced concrete frame buildings are becoming increasingly common in world. Many such buildings constructed in recent times have special features such as the ground story is left open for the purpose of parking. Such buildings are often called open ground story buildings. Open ground story (OGS) buildings have consistently shown poor performance during past earthquakes across the world. The reason is total horizontal displacement at ground story due to lateral loading is much larger than story's above it.

Owing to high land cost, small sizes of plot, buildings with open parking floor is a need & after the collapses of number of RC buildings in 2001 Bhuj earthquake, the Indian seismic code IS 1893-2002 has included special design provisions related to soft story buildings. The IS code suggests that the forces in the columns, beams & shear wall under the action of seismic loads specified in the code, may be obtained by bare frame analysis. However, beams & columns in open ground story are required to be designed for 2.5 times the forces obtained from this bare frame analysis.

2. LITERATURE REVIEW:

Raghvendra deshpande, Surekha Bhalchandra [1]

Investigation has been performed to examine the behavior of various alternative models of R.C. moment resisting frame building with an open first storey & unreinforced masonry infills in the upper storeys. Various parameters based on equivalent static analysis, such as drift, lateral displacement, stiffness has been discussed.

Nikhil Agrawal, Prof. P. B. Kulkarni, Pooja Raut [2]

Attempt is made to assess the seismic performance of soft story structure through computer-based models. Various computer-based models were created, such as bare frames, frames with solid infill walls, frames with infill walls having central & corner openings. Attempt has been made to demonstrate the effect of open ground story on drift profiles, displacement profiles, stiffness ratio & damage pattern in model.

R. Davis, D. Menon , A. M. Prasad[3]

Attempt is made to assess the evaluation of Magnification factor for only open ground storey using Response Spectrum Analysis (RSA) and Nonlinear Dynamic Analysis (NDA) are carried out on a four storeyed and a seven storeyed building, for various infill wall Arrangements to find out magnification factor.

J.Prakshavel, C. Uma Rani, MUthumani, N. Gopalkrishnan [4]

Attempt is made to assess the seismic performance of soft story reinforced concrete building using shake table test. During test it is found that, damages are predominantly spread in the ground story of the tested model. Attempt has been made to demonstrate the effect of open ground story on drift profiles, displacement profiles, stiffness ratio & damage pattern in model.

Sharany Haque, Khan Mahmud Amanat [5]

In present study an investigation has been performed to study the behavior of the columns at ground level of multi storied buildings with soft ground floor subjected to dynamic earthquake loading. The structural action of masonry infill in upper floors has been considered. FE models of six, nine & twelve storied buildings are subjected to earthquake loads in accordance with equivalent static force method as well as response spectrum method. It has been found that calculation of earthquake forces by treating them as ordinary frames results in underestimation of base shear. It is suggested that base shear calculated by equivalent static method may at least be doubled for the safer design of columns at soft ground floor.

A.S. Kasnale, S. S. Jamkar[6]

In present work an investigation has been made to study the behavior of RC frames with various arrangements of infill wall when subjected to dynamic earthquake loading. The result of bare frame, frame with infill, soft ground floor are compared & conclusions are made in view of IS 1893-2002.

3. ANALYTICAL MODELING – STAAD PRO

For the modeling of the Three, six and nine story structure, line element was used for beams and columns and concrete element was used for slabs. The base of structure was fully fixed by constraining all the degrees of freedom. A six story RC building in Zone III on medium soil was analyzed and the shear forces, bending moment's axial forces, mode shapes around the structure due to different load combinations were obtained. Seismic analysis was performed using Equivalent lateral force method and response spectrum method given in IS 1893:2002. The structural model and the building plan shown in figure 3.1 and 3.2.

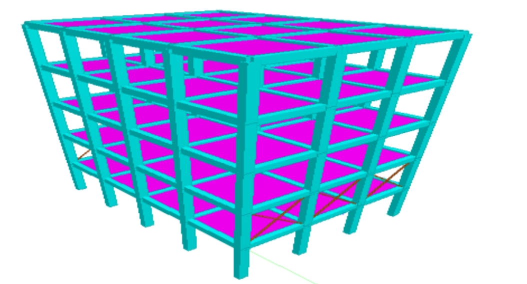


Figure 3.1: Structural Model

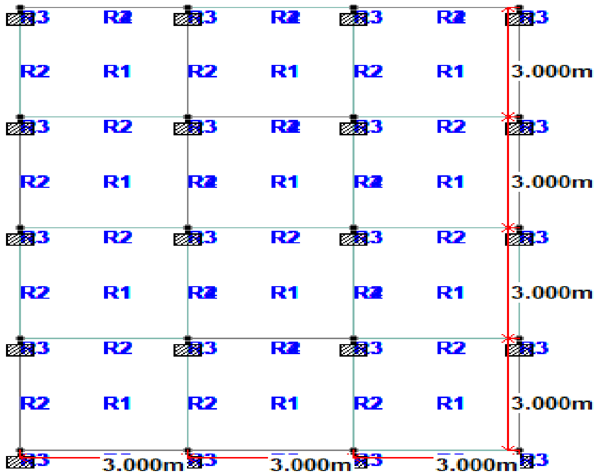


Figure 3.2: The Building in Plan

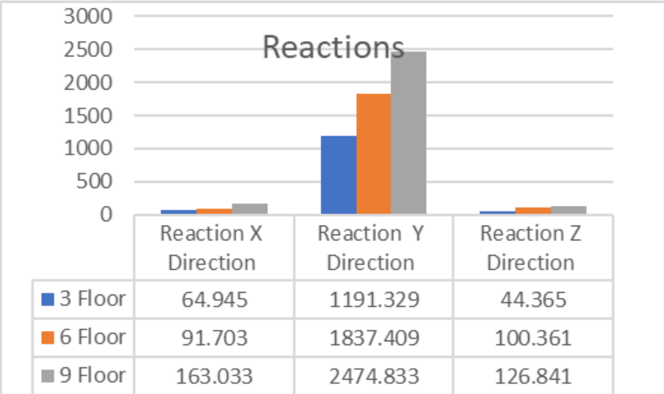
Rc Frame Model Number of span and bays = 3× 3.
Thickness of slab = 125 mm
Width of each bay = 3000 mm
Story height = 3.0 m
Size of corner column (mm × mm) = 600 x 230,
Size of beam (mm x mm) = 450 x 300.
Density of concrete = 25 kN/m3
Grade of concrete: M30,
Grade of steel = Fe 415
Live load on roof = 1.5 kN/m^2
Live load on floors = 3 kN/m ^{2}
Thickness of Brick wall = 230 mm
Density of brick wall including plaster = 20 kN/m^3
Amount of infill = with infill, 50% & 75 % infill, without infill

4. RESULTS AND DISCUSSION

4.1 Forces and Moment in Column

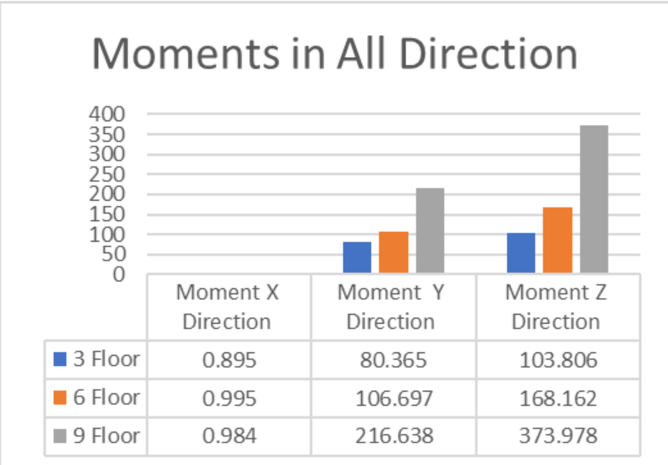
The increase in shear is about twofold compared to the no infill condition or equivalent static condition. Thus, the building frame behaves in a flexible manner causing distribution of horizontal shear across floors. In presence of infill, the relative drift between adjacent floors is restricted causing mass of the upper floors to act together as a single mass. In such a case, the total inertia of the all upper floors causes a significant increase in the horizontal shear at base or in the ground floor columns.

In the present study, infill is modeled as diagonal struts which develop axial force while resisting the relative lateral drift across floors. The vertical component of this axial force gives rise to axial force in interior columns



	Reaction X Direction	Reaction Y Direction	Reaction Z Direction
3 Floor	64.945	1191.329	44.365
6 Floor	91.703	1837.409	100.361
9 Floor	163.033	2474.833	126.841

Figure 4.1. Reaction of building at 50% opening

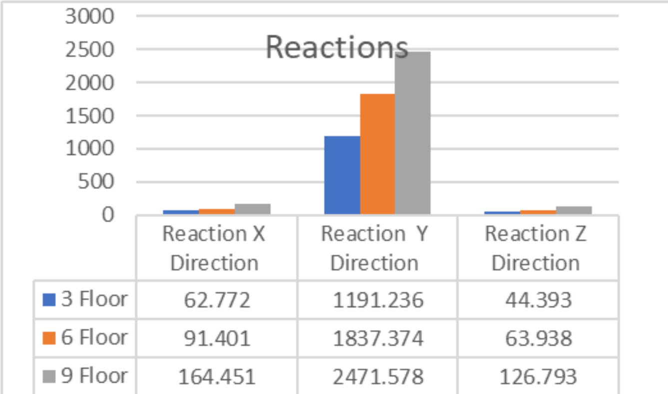


	Moment X Direction	Moment Y Direction	Moment Z Direction
3 Floor	0.895	80.365	103.806
6 Floor	0.995	106.697	168.162
9 Floor	0.984	216.638	373.978

Figure 4.2. Moments of building at 50% opening

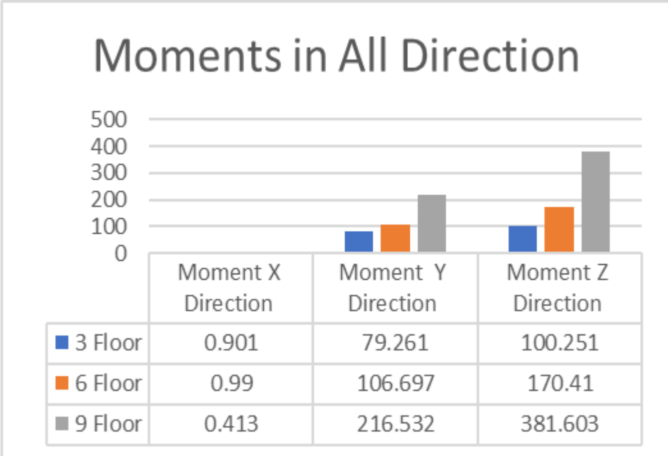
	Displacement X Direction	Displacement Y Direction	Displacement Z Direction
3 Floor	24.652	3.69	29.254
6 Floor	29.687	5.396	38.962
9 Floor	36.19	14.205	42.392

Figure 4.2. Displacement of building at 50% opening



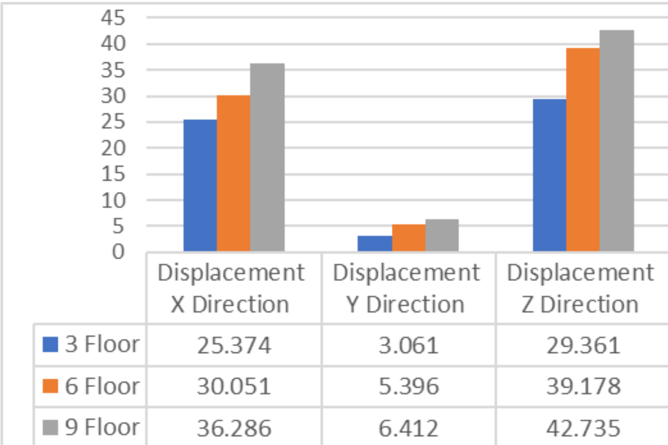
	Reaction X Direction	Reaction Y Direction	Reaction Z Direction
3 Floor	62.772	1191.236	44.393
6 Floor	91.401	1837.374	63.938
9 Floor	164.451	2471.578	126.793

Figure 4.4. Reaction of building at 75 % opening



	Moment X Direction	Moment Y Direction	Moment Z Direction
3 Floor	0.901	79.261	100.251
6 Floor	0.99	106.697	170.41
9 Floor	0.413	216.532	381.603

Figure 4.5. Moments of building at 75% opening



	Displacement X Direction	Displacement Y Direction	Displacement Z Direction
3 Floor	25.374	3.061	29.361
6 Floor	30.051	5.396	39.178
9 Floor	36.286	6.412	42.735

Figure 4.6. Displacement of building at 75% opening

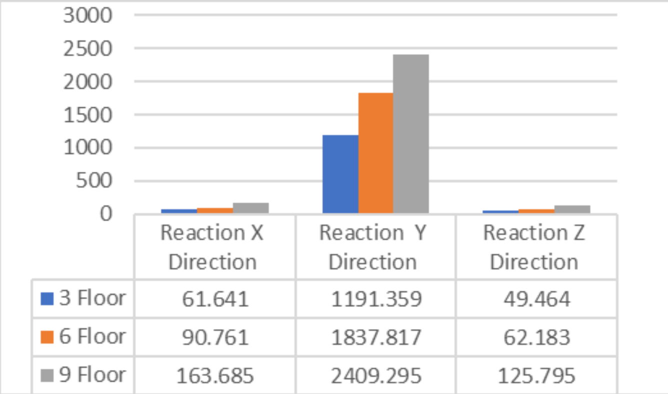


Figure 4.7. Reaction of building at 100% opening

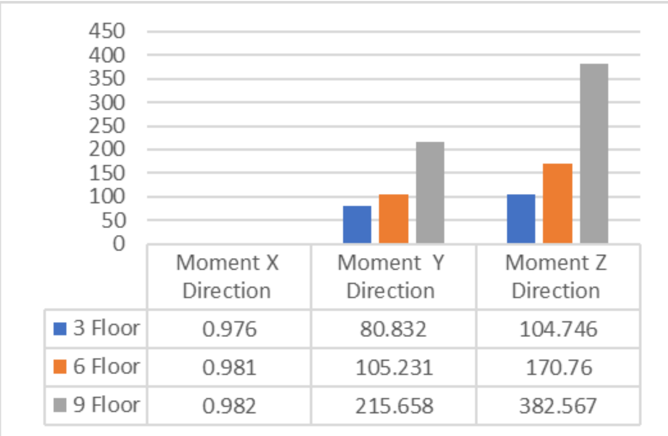


Figure 4.8. Moments of building at 100% opening

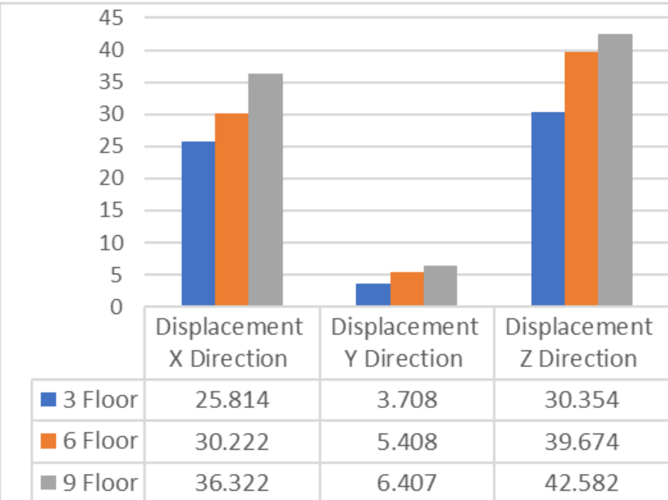


Figure 4.9. Displacement of building at 100% opening

4.2 Mode Shapes

As a part of the study mode shapes of different modes of vibration of the building are determined. Though higher mode shapes are more of a theoretical topic, these do indicate the dynamic characteristics of a building. Mode of the building are visually compared below.

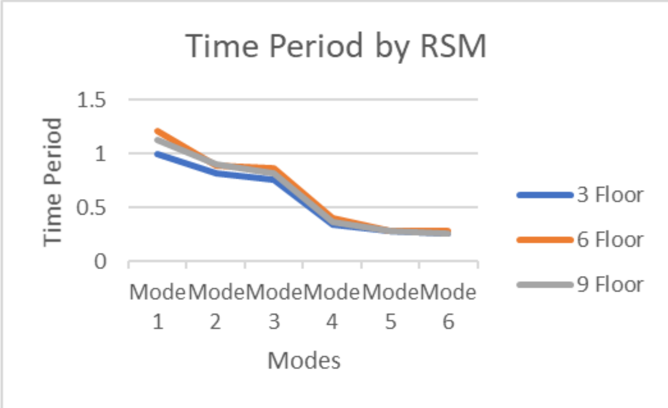


Figure 4.10. Mode shape of building at 50 % opening

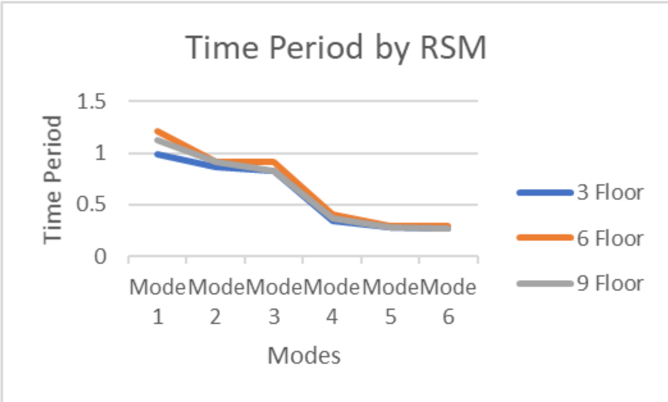


Figure 4.11. Mode shape of building at 75 % opening

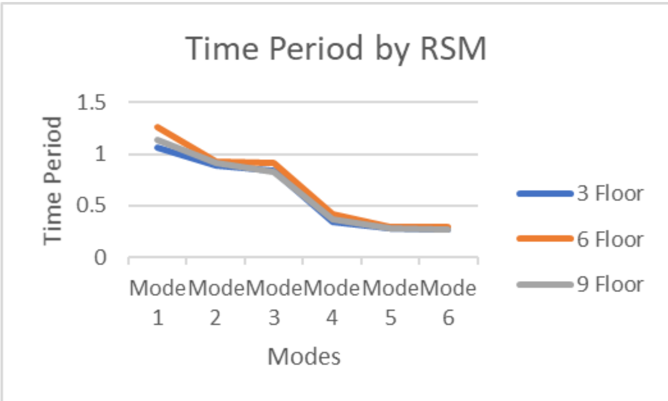
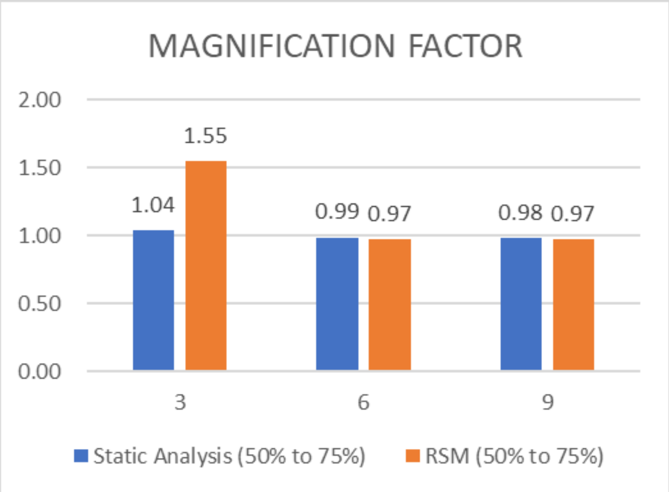


Figure 4.12. Mode shape of building at 100 % opening

4.3 Magnification Factor

The MF is applied to OGS buildings to compensate the stiffness irregularity in ground storey due to absence of infills. The Indian seismic code IS 1893- 2002 recommends that the members of the soft story to be designed for 2.5 times the seismic story shears and moments, obtained without considering the effects of masonry infill in any story. The factor of 2.5 is specified for all the buildings with soft stories irrespective of the extent of irregularities and the method is quite empirical and may be too conservative and thus have further scope for improvement.



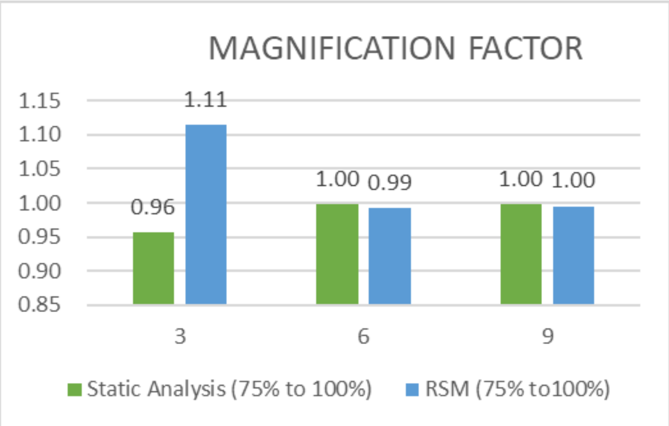


Figure 4.13. Magnification Factor

5. CONCLUSIONS

The base shear obtained for infilled frame was much greater than bare. The increase in base shear is due to stiffness of infill walls, which proves that when OGS building are analyzed as bare frame Base shear are underestimated.

In infilled frame upper stories moves as a monolithic structure and the bottom story moves separately inducing large bending Moment and shear forces in ground columns

MF 2.5 in case of low-rise building, cannot be considered conservative as columns designed for such a high MF will be less ductile due to heavy reinforcement leading to uneconomical design consideration.

MF 2.5 in case of high-rise buildings, is also not conservative as columns designed for less MF 2.5 will be unsafe due to insufficient strength and total collapse of ground columns occurs

There is no need for applying any Magnification Factor to beams of soft story, when stiffness of infill is considered in Open ground story building

Calculation shows that, when RC framed buildings having brick masonry infill on upper floor with soft ground floor is subjected to earthquake loading, base shear can be more than twice to that predicted by equivalent earthquake force method with or without infill or even by response spectrum method when no infill in the analysis model.

The possible schemes to achieve the above are:

(i) Provision of stiffer columns in the first story, and
(ii) Provision of a concrete service core in the building.

The former is effective only in reducing the lateral drift demand on the first story columns. However, the latter is effective in reducing the drift as well as the strength demands on the first story columns

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