Seismic Analysis of Open Ground Storey framed building

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*Abstract:***The concept of open ground building (OGS) has taken its place in the Indian urban environment because it provides the parking facility in the ground storey of the building. The cost of construction of this type of building is much less than that of a building with basement parking. Surveys of buildings failed in the past earthquakes show that these types of buildings are found to be one of the most vulnerable. The majority of buildings that failed during the Bhuj earthquake (2001) and Gujarat earthquake were of the open ground storey type. The collapse mechanism of such type of building is predominantly due to the formation of soft-storey behaviour in the ground storey of this type of building. Design based on bare frame analysis analysis, results in under-estimation of the bending moments and shear forces in the columns of ground storey, and hence it may be one of the reasons responsible for the failures observed. The prescribed multiplication factor (MF) of 2.5, applicable for all OGS framed buildings, is proved to be fairly higher and suggests that all existing OGS framed buildings (those designed to earlier codes) and are highly vulnerable under seismic loading. Present study deals with various aspects related to the performance of OGS buildings. The values of magnification factor recommended in literatures vary from 1.0 to 4.8 (Kaushik, 2009). The main objective of present study is the study of comparative performance of OGS buildings designed according to various MFs using nonlinear analysis. As the more realistic performance of the OGS building requires the modelling the stiffness and strength of the infill walls, the stiffness and strength of the infill walls also considered. The variations in the type of the infill walls using in Indian constructions are significant. The two extreme cases of infill walls, strong and weak are considered in the study. The behaviour of buildings depends on the type of foundations and soils also. Depending on the foundations resting on soft or hard soils, the displacement boundary conditions at the bottom of foundations can be considered as hinged or fixed. As the modelling of soils is not in the scope of the study, two boundary conditions, fixed and hinged, that represent two extreme conditions are considered.**

Keywords: **Open ground storey buildings, seismic, Multiplication factors**

1. INTRODUCTION

Due to the availability of less space for the construction purposes in the developing countries, buildings are used for various purposes such as car parking, reception lobbies etc. Mostly, these buildings are irregular with different types of irregularity, such as plan irregularity, vertical irregularity etc. Among all the irregularities of the buildings, most vulnerable case is one having stiffness irregularity as observed during the past earthquakes. In some buildings, the ground storey is kept open, i.e. in the ground storey, there are no infills; instead having only columns. This type of construction is always vulnerable to the collapse during earthquake. Such type of open ground storey buildings in which stiffness of the ground storey is less than 70 % of the storey are called soft storey buildings.

The infill material, which is present in the frame, will change the behavior of the building under lateral loads. However, the designer tries to dissemble the stiffness of the infill wall for the analysis of framed building. Buildings with open ground storey have performed poorly during the recent earthquake throughout the world. The failure of OGS building was first observed in 1971 during San Fernando earthquake, OGS of Olive View hospital building was damaged. The earthquake of intensity 7.9 was hits to Kutch and Bhuj region of Gujarat in 2001, resulted in collapse of many OGS buildings including low, medium and high-rise buildings.

The construction of open ground storey is very dangerous if not designed suitably and with proper care. In this paper it has been shown that the behaviour of OGS framed building is totally differently as compared to a bare framed building (without any infill) or a fully infilled framed building under lateral loads. Modern seismic codes just neglect the effects of non-structural infill walls during analysis.

The behavior of OGS framed building is totally differently as compared to a bare framed building (without any infill) or a fully infilled framed building under lateral loads. 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. But when this frame is fully infilled, truss action is introduced. A fully infilled frame shows lesser inter-storey drift, though it attracts higher base shear (due to increased stiffness).

Although infills contribute large lateral strength and stiffness to the building, their influence on lateral load behavior depends greatly on their distribution in the building. One such example, where the influence of infill distribution in the frame is dominant, is an open ground storey (OGS) frame in which the masonry infill walls are present in all storeys except the ground storey.

The presence of infill walls in a framed building not only enhance the lateral stiffness in the building, but also alters the transmission of forces in beams and columns, as compared to the bare frame. In a bare frame, the resistance to lateral force occurs by the development of bending moments and shear forces in the beams and columns through the rigid jointed action of the beam-column joints.

2. METHODOLOGY

The methodology carried out to meet the objective of this study was based on reviewing and analysis. Initially the review of the existing literatures by different researchers and also by the Indian design code provision for designing the OGS building was carried out. Later part consisted of selecting the building models for the case study. Once the building selection was done, the modelling of the selected buildings with and without considering their infill strength and stiffness was considered. Nonlinear analysis of the selected building models and a comparative study on the results obtained from the analyses was performed to meet the objective. Finally, the observations of results and discussions were studied and a conclusion was drawn.

Overall, the different types of building frames are modelled given below:

1. Bare frame
2. OGS building considering different MF as suggested by various codes.
3. Fixed support
4. Hinged support
5. Weak infill
6. Strong infill

All the above building frames were first designed in the software E-tabs. After designing in the software, necessary data such as shear forces, bending moment, axial load, reinforcement detailing of each beam and column were imported to another software called SAP for modelling purpose.

Altogether, we have modelled 76 building frames with several variations like that in type of support (fixed & hinged), type of infill wall (weak &strong), MF values (1, 2.5 & 3) and finally bare frame. The number of storeys of the building chosen was 4, 6, 8 &10 with number of bays remaining constant i.e. six. In addition, we discussed about the magnification factor suggested by various codes.

The most important topic discussed above was the modelling and analysis of the building frames. In course of modelling, we have gone through the modelling of both beams & columns with material properties and parameters.

Table 1 – Seismic data assumed for the analysis

Sr. No.	Design Parameter	Value
1	Seismic Zone	V
2	Zone factor (Z)	0.36
3	Response reduction factor (R)	5
4	Importance factor (I)	1
5	Soil type	Medium soil
6	Damping ratio	5%
7	Frame Type	Special Moment Resisting Frame

Table 2 – Material Properties and parameters

Sr. No.	Design Parameter	Value
1	Unit weight of concrete	25 kN/m3
2	Unit weight of Infill walls	18kN/m3
3	Characteristic Strength of concrete	25 MPa
4	Characteristic Strength of steel	415 MPa
5	Damping ratio	5%
6	Frame Type	SMRF
7	Slab thickness	150 mm
8	Wall thickness	230 mm

The dimensions of the elements of the structure were:
1. Beam: 230 mm x 350 mm
2. Column: 300 mm x 300 mm
3. Slab thickness: 150 mm
4. Wall thickness: 230 mm

5. Parapet height: 1.2 m

The most important topic discussed above was the modelling and analysis of the building frames. In course of modelling we have gone through the modelling of both beams & columns and that of infill wall individually along their hinge's property during modelling. The various performance levels (immediate occupancy, life safety and collapse prevention) were defined on the proposed curve. Based on the performance levels, simplified piece-wise linear relationship was proposed for the axial hinge property of a strut. The nonlinearity in the strut is incorporated by the changes in slope of the linear segments. The proposed hinge property was modified to incorporate the diagonal compression failure in the strut. All of the above proposed model was modelled and finally non-linear analysis that is pushover analysis was performed from where we were able to get the curves (the curve between base shear of the building versus roof displacement). After that all the building frames were compared with respect to their aspects like in terms of support, infill wall and MF values from those curves obtained at the time of analysis which are shown in the graphs above. The Indian Code which suggests the MF 35 value to be 2.5 and the other one we have accounted is UBC code or Bulgarian Code which suggests the value of 3.0 is considered in this study.

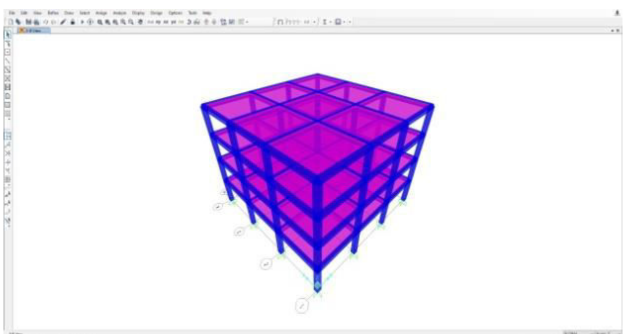

Fig 1 – Structural modeling of Four storey building

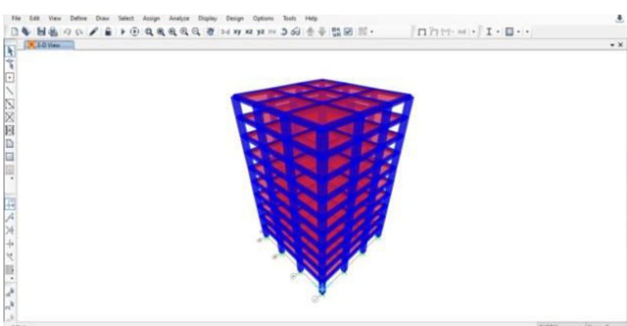

Fig 2 – Structural modeling of 10 storey building

3. RESULTS AND DISCUSSION

In fig 2 and fig 3 it can be seen that the base shear increases linearly with the roof displacement initially but, after reaching a certain base shear the building yields. The bare frame designed with MF =1 fail at a base shear of 180kN while other buildings designed with MF =2.5 and 3.0 exhibit a higher capacity of 230kN. Thus, the increase in strength being 1.3 times more than that with MF 2.5 while the buildings designed with MFs = 2.5 and 3.0 undergo a higher value of displacements as compared to that of MF =1.0. It is also seen that the base shear capacity of a 10 storeyed building designed with MF of 3.0 & 2.5 is more than that designed with MF 1.0 whereas the deflection varies by note more than 15 mm between them. For 10 storeyed bare frame the curves for fixed and hinged support condition are same.

In fig 4 and fig 5 it can be seen that the buildings designed with fixed support has more strength than that with hinged support. Also, the fixed one can undergo deflection up to 11 mm whereas the hinged goes only up to 8.5 mm. The building frames of 4S that with fixed and hinged support have the same nature of curves for fully case. The only difference is that the one with fixed support condition gives the higher performance than that of the hinged one. Also, the fixed support can take high amount of load and undergo higher deflection than that of the hinged one. The behaviour of fixed & hinged supported frame with full infill is almost same only the difference being in the base shear. For fixed support the strength is more than that of the hinged support and the deflection of the fixed supported frame can go up to 31 mm whereas hinged up to 22 mm.

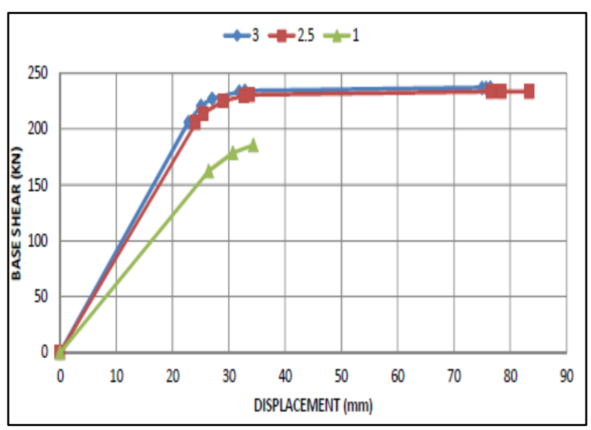

Fig 3 – Curves of 4 storey bare frames

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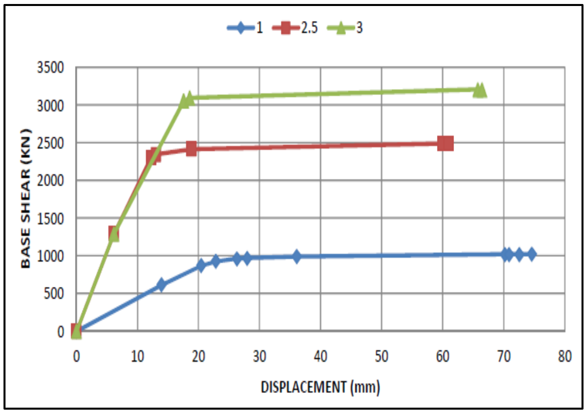

Fig 4 – Curve of 10 storey bare frames

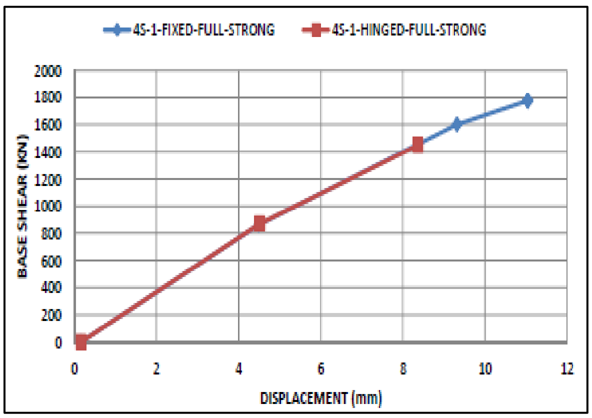

Fig 5 Curves of fixed and hinged support for 4 storey building

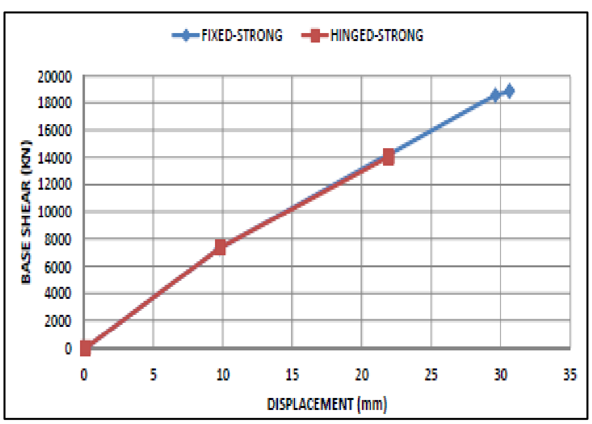

Fig 6 – Curve of fixed and hinged support for 10 storey building

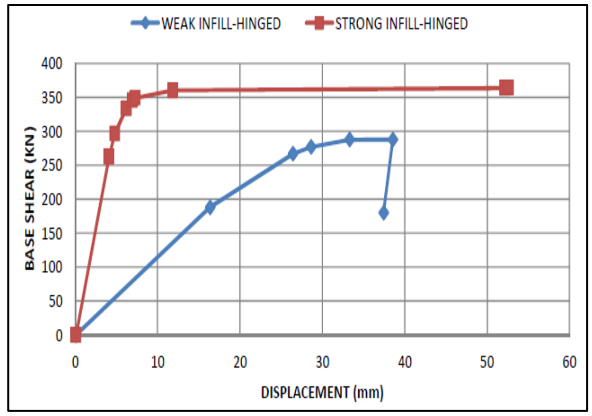

Fig 7– Curves of infill walls for 4 storey building

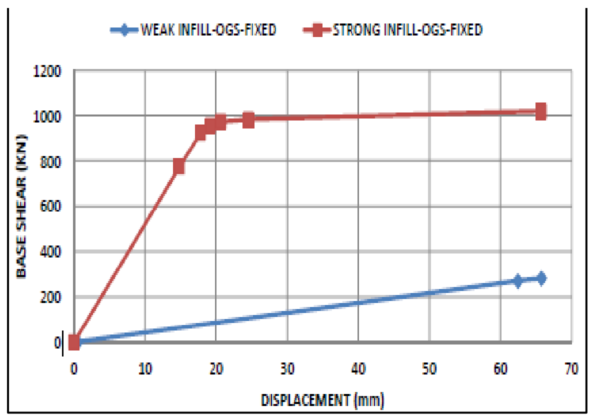

Fig 8 – Curves of infill walls for 10 storey building

4. CONCLUSION

Ground storey in large number of multi-storey buildings is left open (i.e., without infill walls), even in seismically active regions, in order to accommodate shopping or parking facilities or for other functional purposes. Such buildings have performed poorly during several past earthquakes. In such a scenario, it is extremely important that seismic vulnerability of such buildings be quantified using simple scientific methods that can remove the conceived misperception about safety of such buildings when opening is present in infill walls.

Following major conclusions can be drawn from the study:

The base shear capacity of bare frame is the lowest.

- Strong infill 4S6B frame with hinged support has almost 25 % more shear strength than that of weak infill also former can withstand 53 mm of
- Deflection when loaded whereas later can take only 38 mm.
- Strong infill 10s frame with fixed support can take three times more load than that with weak infill whereas the deflection being almost same about 66 mm for both the cases.
- Both 4S6B frame almost follows the same path but that designed with fixed support has 24% more strength than that with hinged support also the former one can undergo deflection up to 11 mm whereas the later only up to 8.5 mm.
- 10S OGS-2.5 frame with fixed support possesses 3 times higher strength than that with hinged support whereas in deflection point of view hinged has higher ability of deforming than fixed by 10 mm.

Lateral load behaviour of OGS buildings remains unaffected by the number of openings in infill walls primarily because infill walls are not present in the ground storey

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