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Seismic Analysis of Open Ground Storey Framed Building Using CYPECAD

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ABSTRACT— The presence of the infill material in a building create some resistance against lateral loads in the building. The present study is based on interaction of Open Ground Storey (OGS) Framed Building with different infill conditions against earthquake. Results are compared from Response spectrum analysis. Models are created using CYPECAD-2018 analysis software, as per the suggestions given in Indian earthquake code IS 1893:2002 and 2016. The usefulness of relevant code has been checked in this research work.

Keywords— Open Ground Storey, strength, stiffness, infill material, Response spectrum method.

I. INTRODUCTION

Vertical growth of the city is only solution for requirements of shelter and vehicle parking due to population explosion. This is achieved by constructing high-rise buildings. Among these multi-storey buildings, the soft storey provides the space for parking of the vehicles.

Absence of infill material in any storey(s) of the building is termed as soft storey. If the soft storey is present in ground floor of the building is known as Open Ground Storey (OGS) building.

The failure of OGS building was first observed in 1971 during San Fernando earthquake, OGS of Olive View hospital building was damaged. In India similar kind of failure observed in 2001, during Bhuj earthquake. The existing literature on the collapse of building due to the earthquake proves that the OGS buildings are found to be the weakest to resist the earthquake. 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. The design based on this type of analysis may result in under-estimation of shear forces and bending moments in column of ground storey, and it may also be one of the causes for failure of building.

IS 1893:2016 allows the analysis of OGS RC Framed building with unreinforced masonry infill walls or RC structural walls. Code gives the guidelines that "Lateral stiffness in storey(s) without infill is less than 80% of that in storey with infill wall, and Lateral strength in storey(s) without infill is less than 90% of that in storey with infill walls".

The earthquake of intensity 7.9 was hits to Kuch and Bhuj region of Gujarat in 2001, results in collapse of many OGS buildings including low, medium and high-rise buildings. Also numerous new built soft storey buildings are damaged also in large distance towns from epi-center like Rajkot, Surat and Ahmedabad etc.
Anjani carried out the study on OGS low rise building by equivalent static analysis and pushover analysis and concluded that multiplication factor for low rise building is much lower than 2.5 which is given in IS 1893:2002.

Shruti et.al made the study on retrofitting methods of OGS building with floating columns and concluded that infill material provided in floating column given floors resist lateral loads while comparing floating columns in soft storey.

Aruna Rawat et.al studied on eccentric bracings to reduce the soft storey mechanisms. Analysis was done with considering Indian earthquake Zone-V, for G+6 building (IS 1893:2002) using nonlinear pushover analysis. Results of this research showed that building with eccentric steel bracings had lower drift demand and very less probability of collapse.

In another study, the openings present in masonry infill wall in OGS building was analyzed using a simple performance assessment of low and mid-rise masonry infill RC frame with different infill configuration followed by fatigue analysis. The conclusion of this study was, there is no effect of openings that present in masonry infill walls on earthquake load behavior was observed.

The Fig.1 shows a typical Open Ground Storey building in which the open space of ground floor is used for parking of vehicles. The Fig. 2 shows the failure pattern of OGS building which was collapsed during Bhuj earthquake in 2001.The whole open ground floor was crushed by earthquake and OGS replaced by upper storey(s).

Fig. 1 Ground Storey (OGS) building providing parking.

Fig. 2 Failure of OGS building during Bhuj earthquake.

II. OBJECTIVES

The main objectives0of this study are.as follows;

- To know the importance of strength and stiffness of infill materials in the seismic analysis of OGS buildings.
- To understand the performance of OGS building under lateral load.
- To check the applicability of guidelines given in IS1893:2016 for design of OGS building.

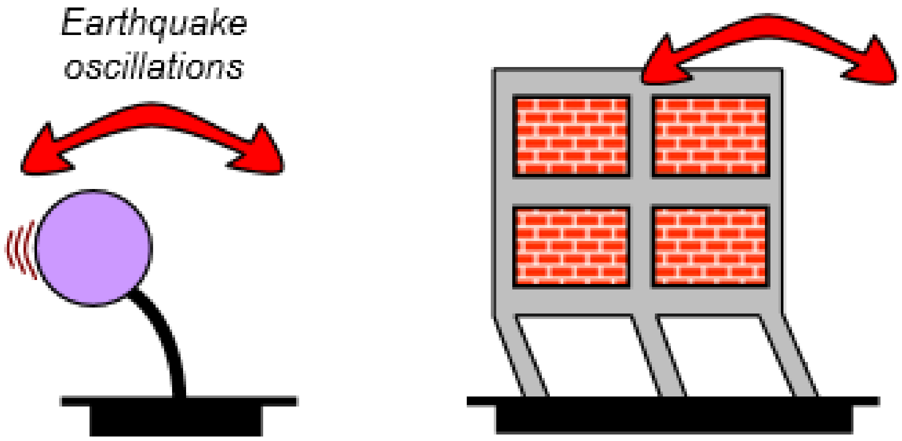

Fig. 3 Behavior of OGS building as vibration in inverted pendulum.

III. METHODOLOGY

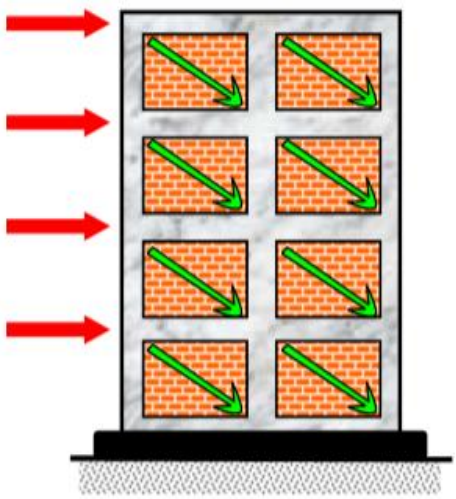

Fig.4 Infill transfer the lateral load through diagonal struct.

The Fig. 3 showing the response of OGS building against earthquake is like inverted pendulum.

The pendulum is vibrated, support is getting stressed due to lateral load. In OGS building, due to earthquake load the above storey(s) are moving forth and back, while columns in ground storey are getting stressed. Fig.4 showing behavior of infill material whish transfer lateral load through diagonal struct.

For the comparative study on the OGS building model, following steps are followed;

i) Selection of OGS buildings for case study
ii) Study on present literature for OGS building.
iii) The OGS model is created for different infill conditions.
iv) Response spectrum analysis was carried out using CYPECAD-18 analysis software.
v) Comparative discussion on results.

Description of building:

G+10, OGS framed building located in Karwar which is in Indian seismic zone V is used for modeling. This is an apartment consists of 2BHK six flats in each floor. The OGS provide the parking of vehicles for above flat’s owners. The building is triangular in plan and rectangular elevation. Height of OGS is 3.5m and height of other storey is 3.05m. Total height of building is 34m and is made up of Ordinary Moment Resistance Frame (OMRF).

The thickness of slab is 125mm. External and internal masonry infill wall thickness is 230mm and 150mm respectively. Size of column is 300 × 900 mm in ground and first storeys and for 2^{nd} to 10^{th} storey column size is 300 × 750 mm and that of beam is 300 × 525 mm,300× 450 mm and 200× 450 mm.

Design considerations:

Live load is taken as 2.5kN/m^2. Grade of concrete and steel is assumed as M_{25} and Fe_{500} respectively. Considered Seismic zone is V and corresponding Zone factor is 0.36. Response reduction factor is 5(SMRF) and Importance factor is 1.0. 5% damping of structure is assumed. Type of soil is considered as II. Dead load is taken as self -weight of different components of structure. Live load on floor is 2.5kN/m^2 and 1.5kN/m^2 on the roof.

The typical floor plan and beam column orientation is as shown in Fig 5& Fig 6. In this study, the bare frame elements with and without infill were modelled using CYPECAD2018 analysis software. Seismic analysis is estimation of response of building against lateral force (Earthquake load). The earthquake analysis includes calculation of earthquake loads at different storey level and effect of these loads on performance of entire building. The building model is analyzed by static and dynamic method.

In this study, the bare frame elements with and without infill were modelled using CYPECAD-2018 software.

The load combinations for this work are considered as per the IS 1893:2016 which are as follows.

i) 0.9 DL + 1.5 (ELx + 0.3Ely + 0.3ELz)
ii) 0.9 DL + 1.5 (Ely + 0.3Elx + 0.3ELz)
iii) 0.9 DL - 1.5 (ELx + 0.3Ely + 0.3ELz)
iv) 0.9 DL - 1.5 (Ely +00.3ELx0+00 .3ELz)
v) 1.2 (DL + LL - (ELx + 0.3Ely + 0.3ELz))
vi) 1.2 (DL + LL - (Ely + 0.3Elx + 0.3ELz))
vii) 1.2 (D L + LL + (ELx + 3Ely +03ELz))
viii) 1.2 (DL + LL + (Ely +00.3Elx + 0.3ELz))
ix) 1.5 ((DL - (ELx + 0.3Ely + 0.3ELz))
x) 1.5 ((DL - (Ely + 0.3Elx + 0.3ELz))
xi) 1.5 ((DL + (ELx + 0.3Ely + 0.3ELz))
xii) 1.5 ((DL + (Ely + 0.3Elx + 0.3ELz))

The following types of general building models with different configuration of plan are considered for comparison.

1) Existing building with OGS.
2) Normal infill building with OGS.
3) Normal infill building without OGS.
4) Building with shear wall in ground storey.

Existing building has earthquake resisting structural design. The columns in OGS are made stronger than columns of storey above. OGS and 1^{st} floor column size is 300 X 900 mm, 2^{nd} to 10^{th} floor column size is 300 X 750 mm. Fig 7 shows the model of existing building.

For model of building with wall in all storey, ordinary design is considered. From ground floor to top floor the column sizes are same. Size of column is taken as 300 X 750 mm in all floors. Fig 8 shows typical building model. Since it is not OGS building, to understand the behavior of strength and stiffness of infill material, this type of model is used.

Building model with OGS is common type with OGS with same design for all storeys. The size of column is 300 X 750 mm in all floors. Fig 9 shows the typical building model.

Model of building with shear wall, is the special kind of model as suggested in Indian earthquake code IS 1893:2016. Ground storey is surrounded by shear wall in this model. Fig 10 shows typical building model. Column size in all floor is 300 X 750 mm and thickness of shear wall is 200mm in Ground storey.

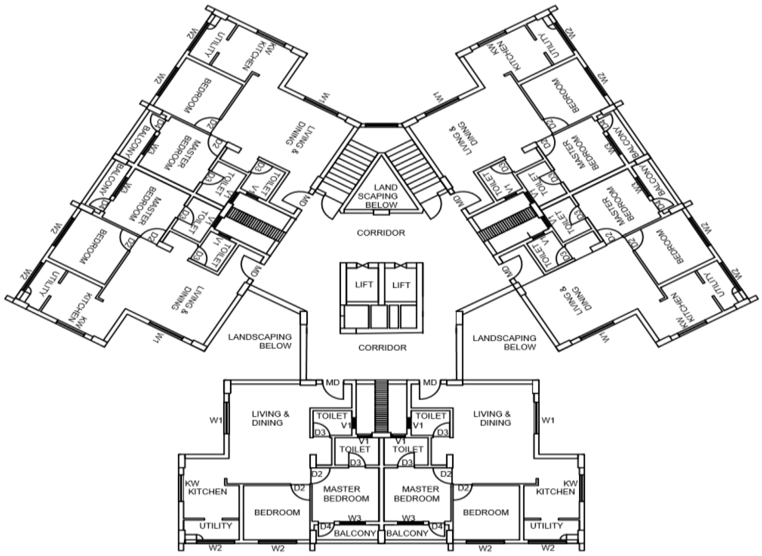

Fig. 5 Typical Floor plan of upper stories of selected building.

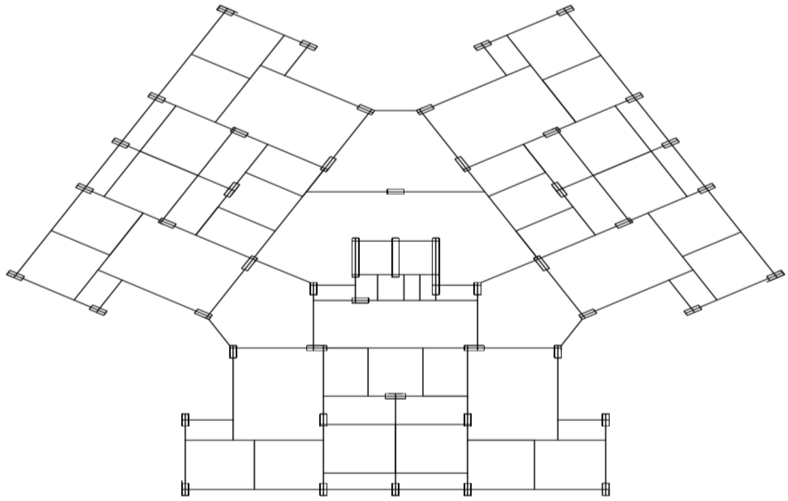

Fig. 6 Column-Beam layout of selected building

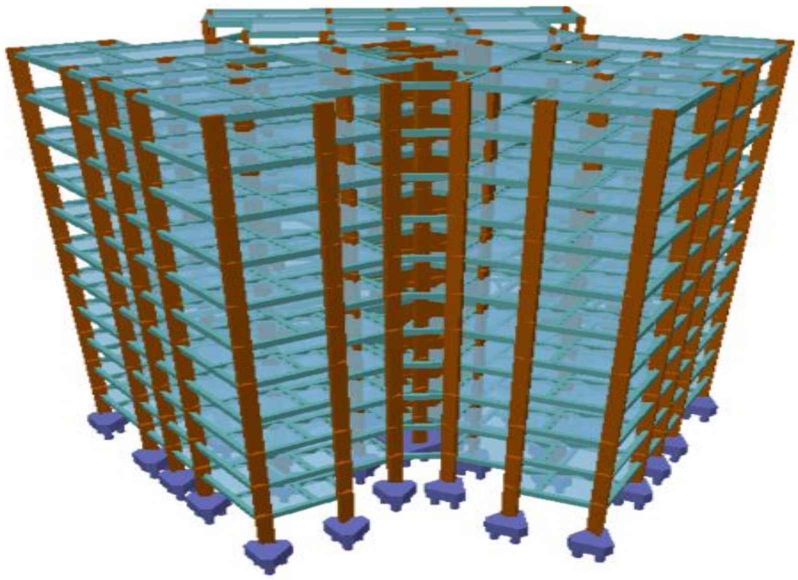

Fig. 7 Existing OGS building Model

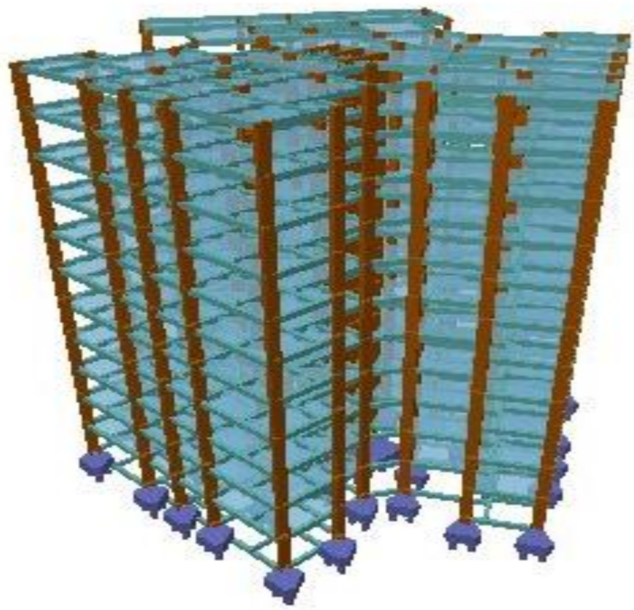

Fig. 8 Building Model with wall in all storey

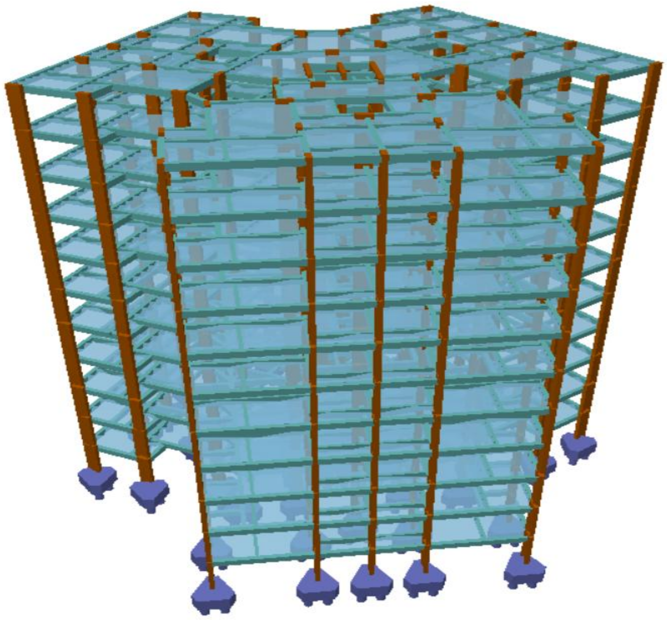

Fig. 9 Normal Building Model with OGS

Fig. 10 Building Model with Shear wall in OGS storey

IV. RESULTS AND DISCUSSIONS

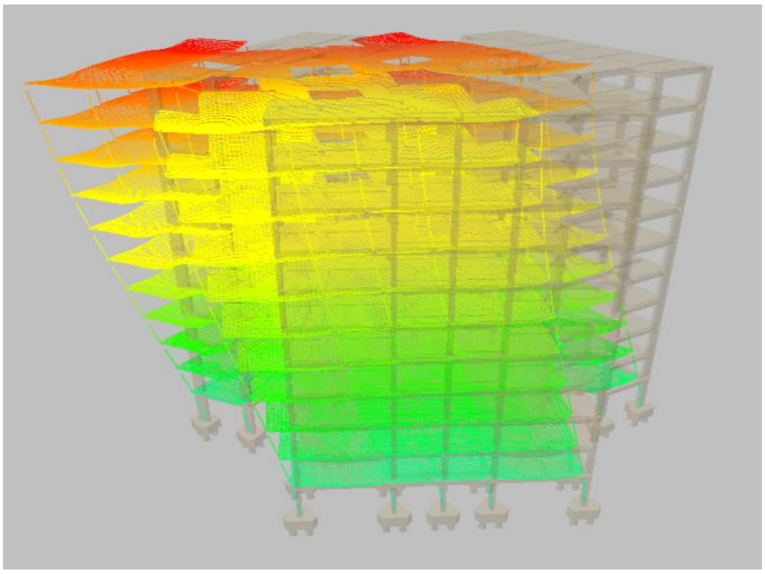

Fig. 11 Deflection pattern of typical model

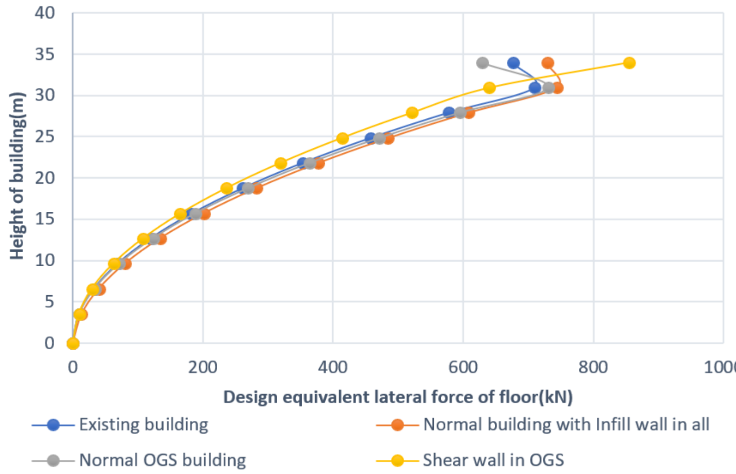

Fig.12 Graph showing equivalent lateral force V/S height of building

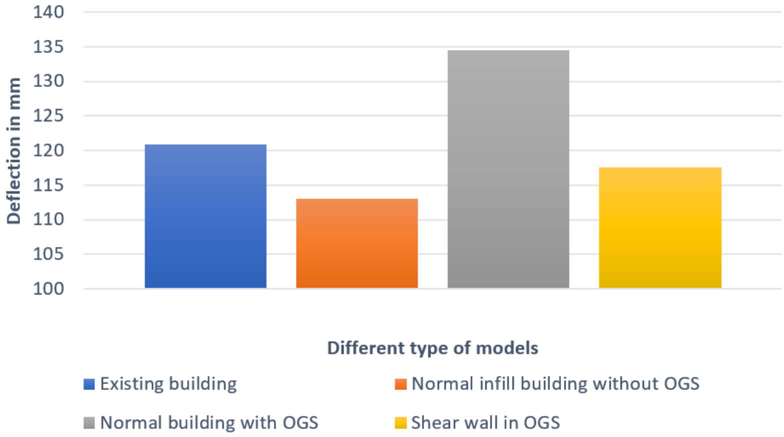

Fig.13 Graph showing variation in deflection of different models.

The Fig.11 showing typical deflection pattern of building model. The graph of equivalent lateral force v/s height of the building is plotted for different models as shown in Fig.12. This graph highlighting the code suggestion of IS 1893:2016. The curve representing the shear wall in OGS building model shows better performance comparing to other models. The existing building model next highest performance. Normal buildings with and without OGS showing poor performance.

Deflection variation of different models are shown in Fig.13 The normal building model with OGS is showing maximum deflection While building model with shear wall in OGS showing least deflection.

For lateral loads 10 modes in both X and Y direction were given. The maximum response observed was in seismic mode X_1 for all type of models. The corresponding modification factors and maximum roof displacement are tabulated as shown in the Table1.

TABLE I. MODIFICATION FACTOR AND MAXIMUM ROOF DISPLACEMENT

Model type	Earthquake Load Case	Modification Factor	Roof Displacement(mm)
Existing building	Seismic X_1	2.35	120.89
Normal infill building with OGS	Seismic X_1	2.48	134.443
Normal infill building without OGS	Seismic X_1	2.24	113.01
Building with shearwall in ground storey	Seismic X_1	2.30	117.52

V. CONCLUSION

- Modification factor required for selected building is 2.3 instead of 2.5 as mentioned in IS 1893:2002.
- The shear wall provided in OGS is taking up to 80% of seismic loads in both X and Y directions, it satisfies the provision given in IS 1893:2016.
- Analysis confirms that OGS building fails through a soft storey mechanism at ground storey, due to comparatively low base shear and displacement. And the mode of failure is found to be brittle.

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