EARTHQUAKE RESISTANT DESIGN OF OPEN GROUND STOREY BUILDING

Athira Baiju[1], Amrutha.M[2]

[1]PG Student (M.Tech), Civil Engineering Department, The Oxford Engineering College, Bengaluru, India
[2]Assistant Professor, Civil Engineering Department, The Oxford Engineering College, Bengaluru, India

***

Abstract-*Open ground storey building has infill wall in all the storey except the ground storey of the building. For the designing of the building, the engineer ignores the stiffness and strength of the infill wall because it is believed that it is a conservative design. And for the open ground storey buildings multiplication factor of 2.5 is recommended by Indian standered code IS1893:2002 to all the beams and columns for a ground storey. Therefore, the objective of this study is to check the applicability of the multiplication factor of 2.5. Two different models of symmetrically regular building with open ground storey located in Seismic Zone V is considered for the study using commercial Etabs Software. Infill Stiffness with openings was modelled using a Diagonal Strut approach. Response spectrum method is carried out for these models and results were compared.*

Key Words: **open ground storey, Infill wall, Equivalent diagonal strut, Response spectrum method.**

1. INTRODUCTION

Open ground storey buildings have gained popularity in recent years especially in metropolitan cities as it provides ample parking space on the ground floor. This helps to increase the utilization of available land area (fig.1). this building has a lot of advantages mainly parking area at the same time disadvantages is there. Important issues arise when these buildings come under the seismic zone area. Open ground storey buildings are more vulnerable to earthquakes. A clear idea about the failure of these types of buildings will get from the past few earthquakes, major failure of these kind of buildings occurring in the ground storey is because of effect soft storey. In normal design practices, infill wall stiffness in the higher floor of the open ground storey structure is not considered in the modelling. In densely populated cities constructions mainly happen in such a way to utilize the available land, this leads to the construction of many high-rise buildings including skyscrapers. Availability of parking area is a major concern in such an environment as multiple houses or offices are present in high-rise buildings whereas the total covered area would be insufficient to accommodate all vehicles, the open ground storey is gaining popularity in this context. Open ground storey buildings is a special type of building in which there is no infill wall at a ground storey, only frames as columns and beams are there. When there is an earthquake occurring, lateral loads are coming to the ground storey, due to this ground storey is stressed heavily. When open storey at the basement of building having infill wall in the upper storey makes it stiffer than the ground story. Normally during design practice engineers are considering framed structure, infill strength and stiffness are completely rejected.

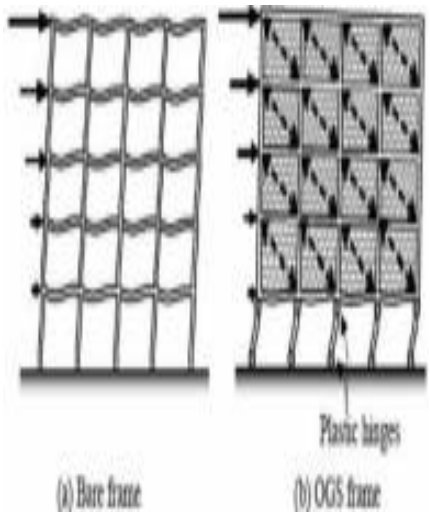


Fig.1:Open Ground Storey

2. OBJECTIVE

- To investigate the seismic behaviour of a G+14 and G+3 model with infill and without infill by using response spectrum analysis
- To calculate the multiplication factor of low rise building and high rise by comparing the base shear value with infill and without infill.
- Comparison of G+14 and G+3 open ground storey building with multiplication factor 2.5 from IS 1893 2016 part-1.

3. METHODOLOGY

There are several methods used to examine and design buildings. For this study, the response spectrum method is used to analyze the concrete structure. The approach used for the study and analysis is listed below.

- Select the symmetrically regular building having G+3 and G+14 with the open ground story buildings with infill wall and bare frame.
- Analysis of the previous research on the result of the earthquake on buildings with infill walls and bare frame buildings.
- Develop the model with infill masonry and without infill masonry.
- Analysis of the model by the Response spectrum method.
- Analysis of observation and results.

4. MODELING AND ANALYSIS OF STRUCTURE

To analyze the usefulness of the multiplication factor of 2.5 which is recommended by IS Code 1893-2016, four building models with the same material properties are created using ETABS version 18.1.1. Regular concrete buildings consisting of G+3 and G+14 are chosen for the modelling considering that it represents the low rise and high-rise categories respectively, also for each of these, with infill wall and without infill wall structure is modelled. The first step for creating a model is to create the plan of the structure with the required input parameters such as material properties and sectional properties. The variable used for the model in this analysis are added in table-4.1. After creating the plan, for buildings with infill walls equivalent diagonal strut is modelled to compensate infill wall. Calculation of width of the equivalent diagonal strut is added in section 1.1. For performing the seismic analysis following parameters are required, damping of structure, seismic zone, analysis mode, live load, dead load, load factor, earthquake load, type of soil, etc. The values of this parameter are shown in the table-4.1. From the result of the response spectrum analysis storey shear, storey displacement, storey drift, and storey stiffness values can be obtained. Comparing these values for all four models will give an idea about the effect of the infill wall during an earthquake.

Table. 1.2 Details of Building Models

1.	Number of Floors	G+14, G+3
2.	Level Height	Ground Floor=4m, Intermediate Floors=3m
3.	Infill Wall	405x230mm
4.	Category of soil	Medium
5.	Dimensions of Column	(800x600) mm
6.	Dimensions of Beam	230mm x 700 mm
7.	Depth of Slab	140 mm
8.	Materials properties of Concrete	Column and Beam: M30 Slab: M30
9.	Damping of Structure	5%
10.	Seismic zone	5
11.	Modulus of Elasticity of Concrete	M30-27386 N/mm2
12.	Grade of steel	Fe415
13.	Modulus of Elasticity of Brick	550*fm
14.	Zone factor	0.36
15.	Live load	3KN/mm^2
16.	Dead load	1 KN/mm^2
17.	Earthquake load	As per IS 1893 2016 (part 1)
18.	Analysis mode	Response spectrum
19.	strut	Masonry

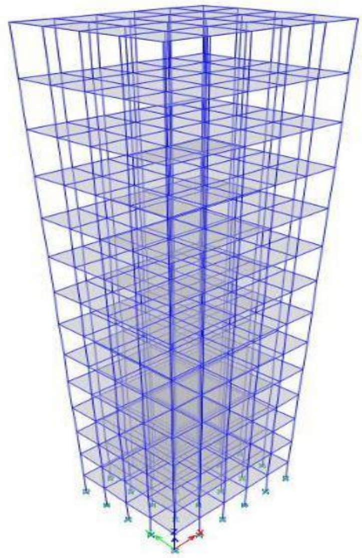


Fig-2: 3D view of G+14 without Strut

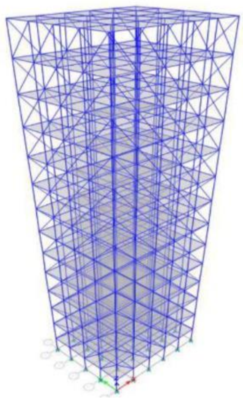


Fig-3:3D view of G+14 with Strut

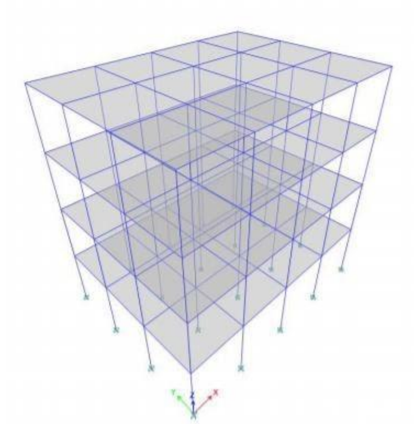


Fig-4: 3D view of G+3 building without strut

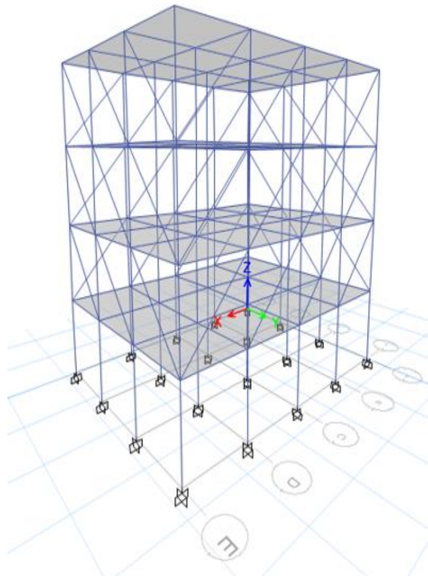


Fig-5:3D view of G+3 building with strut

5. DESIGN OF INFILL WALL

F_{ck} = 30N/mm^2

E_f = 25000N/mm^2

column size = 800x600

beam = 230x700

f_m Compressive strength of masonry = 6N/mm^2

so,

E_m (Modulus of elasticity of masonry infill wall)

= $550f_m$ = 3300N/mm^2

Storey height = 3000mm

Height of infill = 3000 - 600 = 2400mm

Length of infill = 3000 – 230 = 2770mm

Thickness of infill = 230m

$\theta = \tan^{-1} h/l = \tan^{-1}(2400/2770)$ = 40.89 degree

$L_{ds} = h/\sin\theta = 2400/\sin 40.89 = 3666$

As per IS 1893-2016, putting the above value in the equation,

“Em = modulus of elasticity of materials of infill

Ef = modulus of elasticity of materials of RC frame.

Ic = the moment of inertia of the adjoining column.

T = the thickness of the infill wall.

Θ = the angle of the diagonal strut with the horizontal.

H = the height of infill wall" [1]

$$\alpha_h = h\left(\sqrt[4]{\frac{E_m t \sin 2\theta}{4E_f I_c h}}\right)$$

By applying the above values in the equation 1.1,

$\alpha_h = 3.207$

$$w_{ds} = 0.175\alpha_h^{-0.4} L_{ds}$$

Where Lds is the length of the diagonal strut,

By applying the above values in the above equation 1.2,

W_{ds} = 404.67 = 405mm

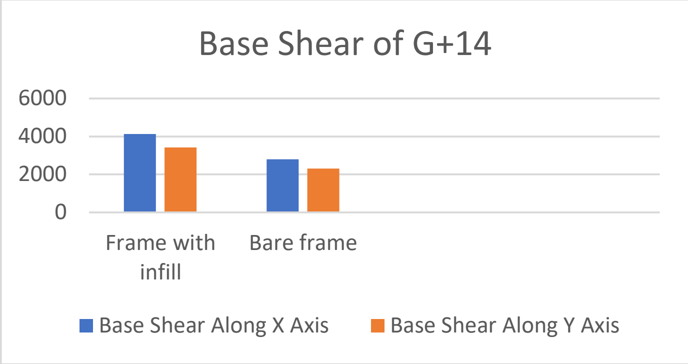
6. RESULTS

6.1 Comparison of Base Shear

Base shear is one of the main measures that is used for the analysis of the seismic behavior of a building. It is defined as the maximum lateral force on the base of the structure due to seismic activity. In Response Spectrum analysis, base shear of the structures of both the G+3 and G+14 category is compared between the bare frame model and infill model to see the variation of multiplication factor. Table no.4.5 shows base shear values of 14 storey building having infill and bare frame.

Table. Error! No text of specified style in document.**.1**
Base Shear of G+14 Building

G+14 STOREY		With infill	Bare frame	M.F
Base shear	X-axis	4123	2798	1.47
	Y-axis	3416	2309	1.48



Chat-6.1:Comparison of Base Shear G+14 Building

1.1

From the observed result in table 5.1, it has been found that the infill model gives higher values of base shear when compared to the bare frame. So, it concludes that the infill model is more effective against earthquake forces.

Table. Error! No text of specified style in document.**.2**
Base shear for G+3 storey Building

1.2

G+3 STOREY		With infill	Bare frame	M.F
Base shear	X-axis	469.42	465.42	1.00
	Y-axis	469.91	465.4	1.00

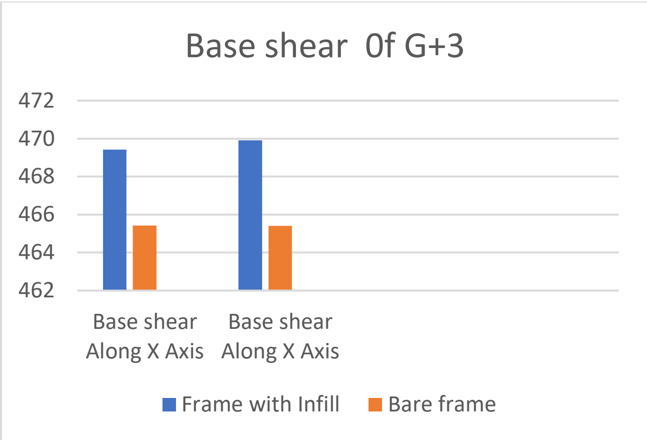


Chart-6.2:Comparison of Base Shear for G+3 Build

The observed result from table 6.2 it has been found that there is no considerable difference between multiplication factor for infill model and bare frame model.

7. CONCLUSION

In this paper analysis of open ground storey building has been done. The structures under study are modelled using ETABS software version 18.1.1, structures of G+3 category and G+14 category including open ground storey frame and infilled frame are modelled and analyzed.

Infill wall is the key factor for the analysis of open ground storey building. In this study, response of infill wall against seismic force is mainly considered. For modelling the infill wall, an equivalent diagonal strut method was used.

- Effective earthquake force acting on the ground storey of the building is more in case of OGS building. This is evident from the comparison of Linear static analysis results of OGS buildings and bare frame buildings.
- IS code recommended multiplication factor value of 2.5 does not match with the results obtained by analysis done on G+3 storey building. For the design of low-rise buildings in general the multiplication factor value should be considered as a lesser number than 2.5.
- Multiplication factor for Maximum bending moment obtained for G+3 building is 41.6 % less for the column and 58 % less for beam.
- The multiplication factor for base shear obtained for the G+3 building is 60 % less for both x and y axes.
- IS code recommended multiplication factor value of 2.5 does not match with the results obtained by analysis done on G+14 storey building also. For the design of a high-rise building in general the multiplication factor value should be considered as a lesser number than 2.5. But the MF for high rise buildings is higher than low rise buildings.
- The occurrence of an infill wall can influence the earthquake behavior of a structure to a huge range and stiffness and strength also increased because of infill in the higher floor.
- When bare frames are used for the analysis, underestimation of the base shear will cause the structure to fail during an earthquake. It is therefore very significant during the study of the infill wall in the analysis.

REFERENCES

[1] IS 1893 Part 1 (2002) "Design of earthquake resisting structure"

[2] IS 1893 Part 1 (2016) "Design of earthquake resisting structure"

[3] Ramesh et al "Earthquake Resistant of RCC" International Journal of Trend in Scientific Research and Development (IJTSRD) Volume 4 Issue 5, July-August 2020 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

[4] Dandu Sivaramaraju and Dr. Dumpa Venkateswarlu, "Earthquake Analysis of Multistoried Residential Building – A Case Study using ETABS" International Journal for Modern Trends in Science and Technology, 7(04): 47-54, 2021

[5] P. Rajeswari1, Mr. A. Koti Neelakantam, "Seismic Analysis and Design Of Multistorey Building In Different Seismic Zones By Using ETABS" International Research Journal of Engineering and Technology (IRJET), Volume: 06 Issue: 09, Sep 2019

[6] Dr. M Rame Gowda1, Techi Tata2Rao, " Study of seismic Behavior of Building with Flat Slab" International Research Journal of Engineering and Technology (IRJET), Volume: 03 Issue: 09 Sep-2016

[7] Karisiddappa, (1986) Effect of position of openings on the behaviour of infilled frames. M. Tech Thesis. Indian Institute of Technology Madras, Chennai.

[8] Rahman "Influence of openings on the behaviour of infilled frames" Ph. D. Thesis. Indian Institute of Technology Madras. Chennai.

[9] Akshay Paidalwar and G.D. Awchat, "Seismic Analysis of Open Ground Storey Building", International Journal of Civil Engineering Research (IJCER) Volume 8, Number 2, 2017.

[10] Piyush Tiwari1, P.J. Salunke, "Earthquake Resistant Design of Open Ground Storey Building" International Research Journal of Engineering and Technology (IRJET) Volume: 02 Issue: 07 Oct-2015.

[11] Akhilesh Yadav1, Dr A.K. Mishra, "Earthquake Resistant Design of Open Ground Storey Low Rise Building" International Journal of Science of Technology and Management Volume. No.6, Issue No.05, May 05.

[12] Somani Kishangopal J, Sangave Prakarsh A, "Seismic Response of RC Framed Buildings with Open Ground Storey" Int. Journal of Engineering Research and Applications ISSN: 2248-9622, Vol. 5, Issue 2, (Part -5) February 2015.

[13] Amit kumar1, Mohd. Adnan2, "Earthquake Resistance Design Of Open Ground Story Building" International Research Journal of Engineering and Technology (IRJET) Volume: 06 Issue: 03 Mar 2019.

[14] **Kapil Verma,** "Comparative Study of Seismic Behavior of Open Ground Storey Buildings After Replacing Rectangular Columns with Circular Columns" International Journal of Advance Research, Ideas and Innovations in Technology Volume3, Issue3.

[15] **S R Satish Kumar & J L Srinivasan,** "Performance-Based Design of Reinforced Concrete Open Ground Storey Buildings" Department of Civil Engineering, Indian Institute of Technology Madras, Chennai 600 036, India.

[16] **Sivakumar et al** "Seismic Vulnerability of Open Ground Floor Columns in Multi-Storey Buildings" International Journal of Scientific Engineering and Research (IJSER) www.ijser.in ISSN (Online): 2347-3878 Volume 1 Issue 3, November 2013