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Earthquake Resistant Design of Low-Rise Open Ground Storey Framed Building

S. S. Pathan

M.Tech. Student, Department of Civil Engineering, Ballarpur Institute of Technology, Ballarpur, India

***Abstract*: Present study RC framed building (G+10) with open ground storey located in Seismic Zone II, III, IV and V is considered. The main objective of present study is the study of strengthen performance of Open ground storey (OGS) buildings according to various cases such as: (a) bare frame building (b)building with uniform infill in all storey (c) building with OGS (d) OGS with stiffer column (e) OGS with corner shear wall (f) OGS with corner cross bracing (g) OGS with composite columns. The separate models were generated using commercial software ETABS. Infill stiffness was modeled using an equivalent diagonal strut approach. Parametric studies on displacement, storey drift, shear force, bending moment and base shear have been carried out using equivalent static analysis to investigate the influence of this parameter on the behavior of building with OGS.**

***Keywords*: Stiffness, infill wall, equivalent diagonal strut, strengthen of OGS building, seismic analysis.**

1. Introduction

In general, multi-storied Reinforced concrete (RC) frame buildings in metropolitan cities require open taller first storey for parking of vehicles i.e., columns in the ground storey do not have any partition walls (of either masonry or RC) between them and/or for large space for meeting room or a banking hall owing to lack of horizontal space and high cost are becoming increasingly common in India. Such buildings are known as open ground storey buildings or stilts storey building. Open ground storey buildings are inherently poor systems with sudden drop in stiffness and strength in the ground storey. In the current practice, stiff masonry walls are neglected and only bare frames are considered in design calculations. Thus, the inverted pendulum effect is not captured in design.

2. Indian Standard IS 1893-2002

Stiffness Irregularity (soft storey): a soft storey is one in which the later stiffness is less than 70 percent of that in storey above or less than 80 percent of the average lateral stiffness of the three storey above

Stiffness Irregularity (Extreme soft storey): An extreme soft storey is one in which the later stiffness is less than 60 percent of that in storey above or less than 70 percent of the average lateral stiffness of the three storey above. For example, building on STILTS will fall under this category.

Clause 7.10.3: The column and beams of the soft storey are to be designed for 2.5 times the storey shears and moments calculated under seismic loads specified in the other relevant clauses.

3. Objective of the study

Based on the literature review the salient objectives of the present study have been identified as follows:

- The effect of masonry infill stiffness in the seismic analysis of Open ground storey buildings.
- Strengthening of Open Ground Story RC buildings.

4. Structural Modelling

It is very important to develop a computational model on which analysis is performed. In this regard, ETBAS software has been considered as tool to perform. Hence we will discuss the parameters defining the computational models, the basic assumptions and the geometry of the selected building considered for this study. A detailed description on the modeling of RC building frames is discussed. Infill walls are modeled as equivalent diagonal strut elements.

An OGS framed building located at India (Seismic Zone I, II, IV, and V) is selected for the present study. The building is fairly symmetric in plan and in elevation.

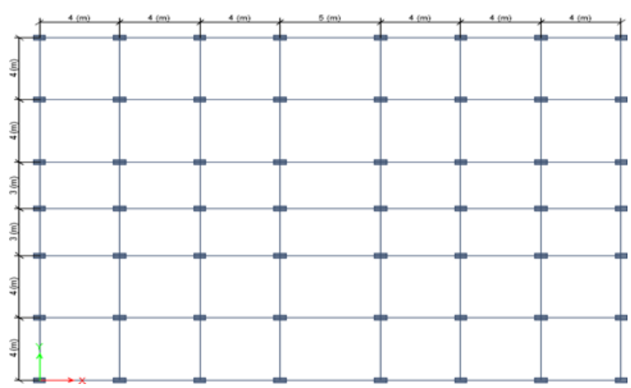
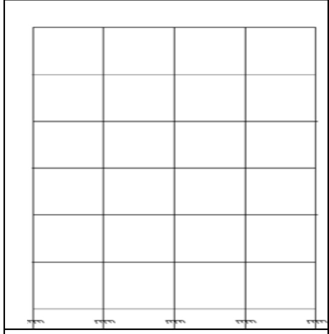
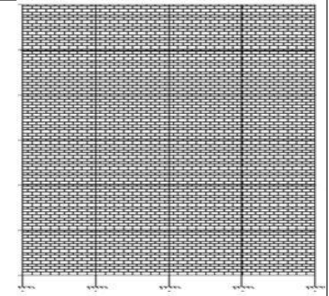


Fig. 1. Typical floor plan of the selected building

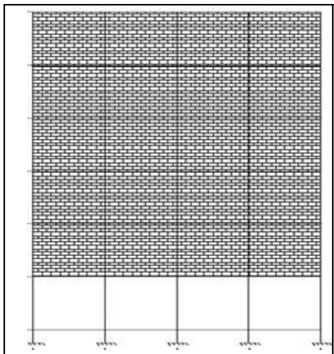
In the present study different building components are modeled as described below Using Software. In this study the seven models are studied as described below.



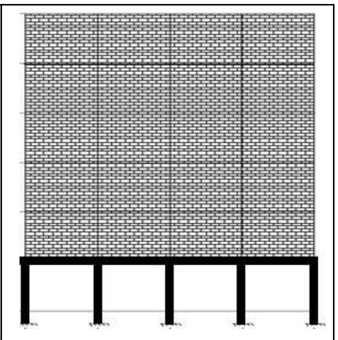
Case1- Bare Frame Building



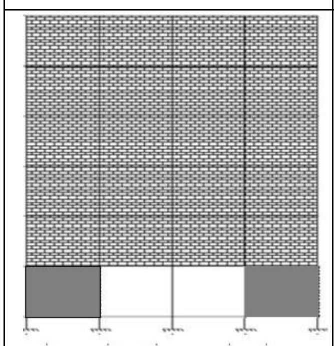
Case2- Building with Uniform Infill in All Storey



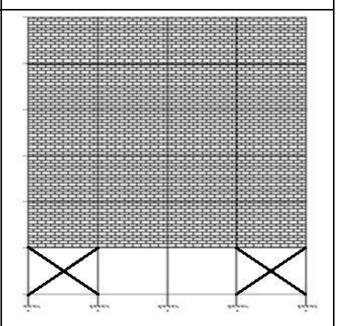
Case3- Building with Open Ground Story



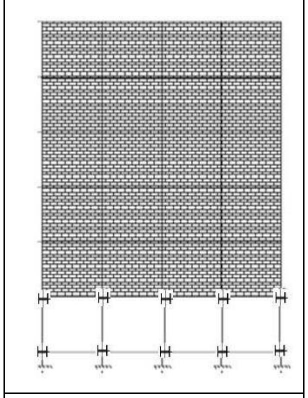
Case4- Open First Story with Stiffer Column (MF 2.5)



Case 5- Open First Story with Corner Shear Wall



Case 6- Open First Story with Corner Cross Bracing



Case7- Open First Story with Composite Column and Beam in Ground Story

5. Building Description

Plan dimensions : 31 m x22m
Number of Storey : G+10
Total height of building: 33 m
Floor height : 3 m
Beam sizes : 300 x 500 mm
Column sizes : 300 x 600 mm
Slab thickness : 150 mm
Floor Live Load : 3 kN/m2
Roof live load : 1.5 kN/m2
Floor Finish Load : 0.5 kN/m2
Concrete grade : M25
Steel: Fe415

Earthquake parameters

Seismic zone : II, III, IV and V
Response Reduction Factor: 5
Importance Factor : 1
Type of soil : Medium
Damping of structure. : 5%

Modeling of Infill Walls

In present study, in fills wall in stories are modeled as equivalent diagonal strut (Proposed by Hendry in 1998) and its equivalent width (W) of a strut is given as,

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

To determine αh and αl which depends on the relative stiffness of the frame and on the geometry of the panel.

$$\alpha_h=\frac{\pi}{2}\left[\frac{4E_f I_c h}{E_m t \sin 2\theta}\right]^{\frac{1}{4}}$$

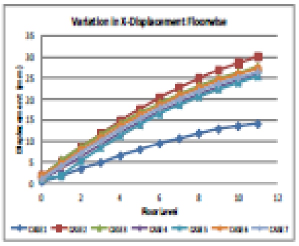
Where,

$$\alpha_l=\pi\left[\frac{4E_f I_b l}{E_m t \sin 2\theta}\right]^{\frac{1}{4}}$$

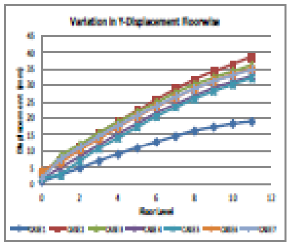
Em and Ef = Elastic modulus of the masonry wall and frame material, respectively t, h, l = Thickness, height and length of the infill wall, respectively Ic, Ib = Moment of inertia of the column and the beam of the frame, respectively Θ = tan-1(h/L)

6. Result and discussion

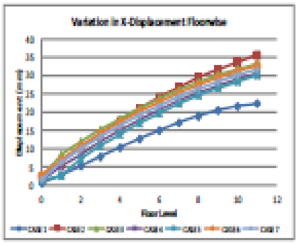
Later Displacement: The later displacement in columns in X-direction and Y-direction direction is considered for analysis in seismic zone II, III, IV, and V shown in graphical representation of data is shown in Graph no. 1 to 8.



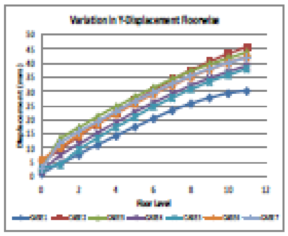
Graph 1 : Zone II, X-direction



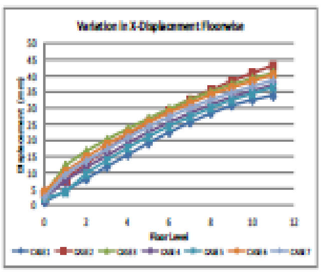
Graph 1: Zone II, X-direction



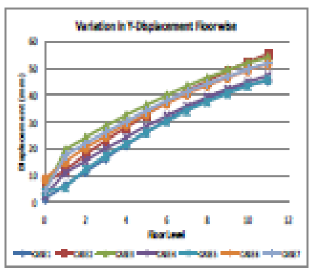
Graph 3 : Zone III, X-direction



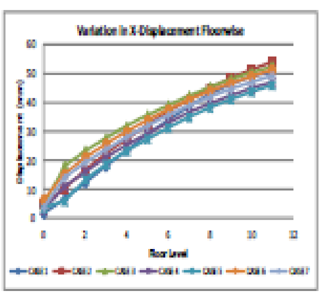
Graph 4 : Zone III, Y-direction



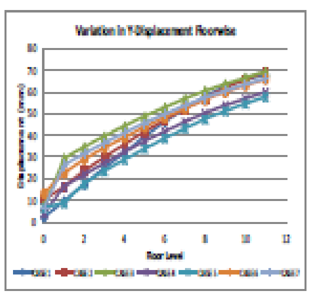
Graph 5 : Zone IV, X-direction



Graph 6: Zone IV, Y-direction



Graph 7 : Zone V, X-direction



Graph 8 : Zone V, Y-direction

For comparison of the later displacement of the selected building, plots of the storey level displacement in X-direction or Y-direction versus height are made for the seven cases, all imposed on the same graph. The displacement is inversely proportional to the stiffness.

From the graphs it is observed that the displacements are large occurs in case of open ground storey building (case 3).In case 2, case 4, case 5, case 6 and case 7 displacement are reduced as compared to case 3 (open ground storey).

Percentage reduction in displacement with respect to case 3 (OGS).

Percentage reduction of displacement is more in Case 5 as compared to other Cases. So the best model of OGS building with corner shear wall (case 5).

Table 1
In zone II

Displacement	Case 2	Case 4	Case 5	Case 6	Case 7
% reduction	25	47	58	22	25

Table 2
In zone III

Displacement	Case 2	Case 4	Case 5	Case 6	Case 7
% reduction	40	48	71	23	25

Table 3
In zone IV

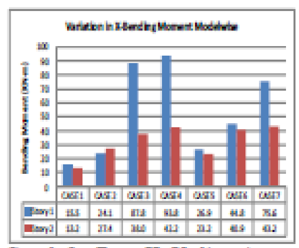
Displacement	Case 2	Case 4	Case 5	Case 6	Case 7
% reduction	48	48	71	24	25

Table 4
In zone V

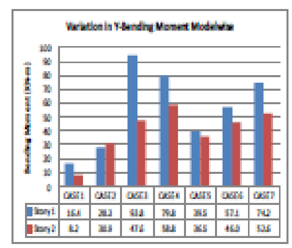
Displacement	Case 2	Case 4	Case 5	Case 6	Case 7
% reduction	52	50	71	26	30

A. *Bending Moment*

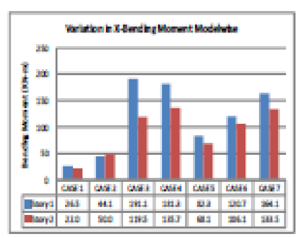
The bending moment in columns in X-direction and Y-direction direction is considered for analysis in seismic zone II, III, IV, and V shown in graphical representation of data is shown in Graph no. 9 to16.



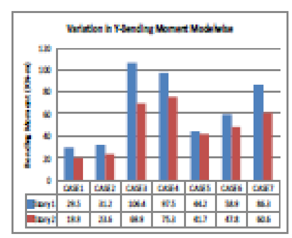
Graph 9 : Zone II, X-direction



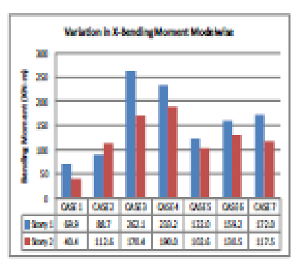
Graph 10 : Zone II,Y-direction



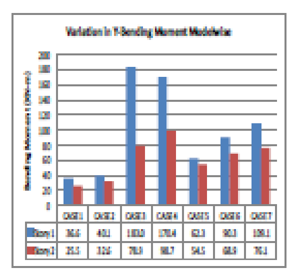
Graph 11: Zone III, X-direction



Graph 12: Zone III,Y-direction



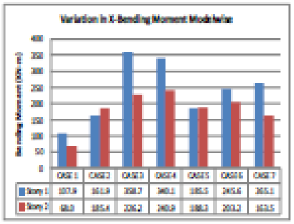
Graph 13 : Zone IV, X-direction



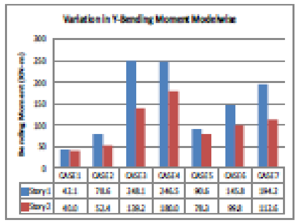
Graph 14 : Zone IV, Y-direction

The bending moment is maximum in ground storey columns as compared to above storeys in case of OGS building (case 3).

In open ground story with corner shear wall and open ground story with corner cross bracing the moment are reduces by approximate 50-70% as compare to open ground storey building and very effective from strength point of view these cases.



Graph 15 : Zone V, X-direction

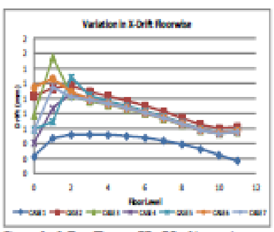


Graph 16 : Zone V, Y-direction

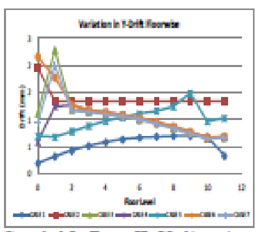
From the graphs it is observed that stiffer column and composite column (case 4 and case 7) increases the bending moment in the ground storey column.

B. *Storey Drift*

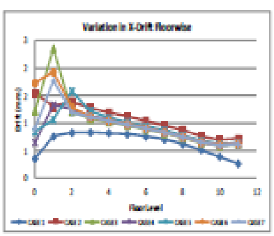
The storey drift in columns in X-direction and Y-direction direction is considered for analysis in seismic zone II, III, IV, and V shown in graphical representation of data is shown in Graph no. 17 to 24



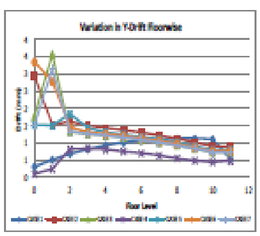
Graph 17 : Zone II, X-direction



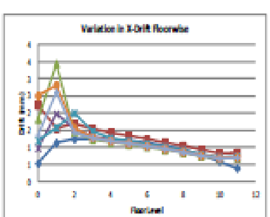
Graph 18: Zone II, Y-direction



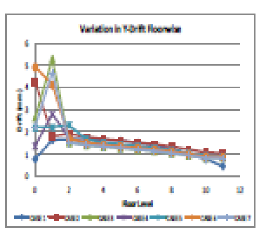
Graph 19 : Zone III, X-direction



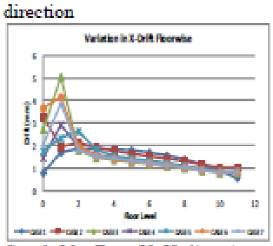
Graph 20 : Zone III, Y-direction



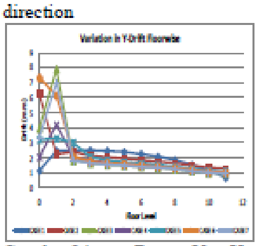
Graph 21 : Zone IV, X-direction



Graph 22 : Zone IV, Y-direction



Graph 23 : Zone V, X-direction



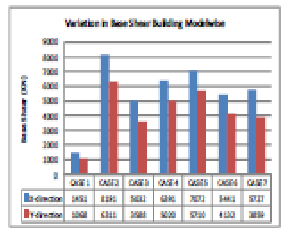
Graph 24 : Zone V, X-direction

From the graphs it is observed that the storey drift is large for open ground storey (case 3).

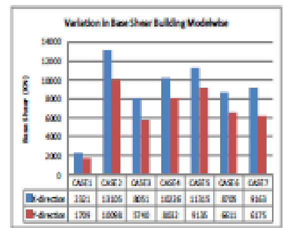
Storey drift profile becomes smooth from case 4 to case 7 indicating more stiffness. Stiffer columns (case 4) and composite column (case 7) reduces the storey drift at first floor level.

C. *Base Shear*

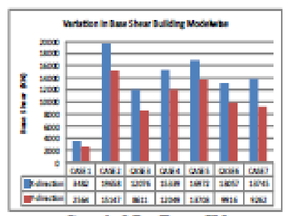
The base shear in columns in X-direction and Y-direction direction is considered for analysis in seismic zone II, III, IV, and V shown in graphical representation of data is shown in Graph no. 25 to 28.



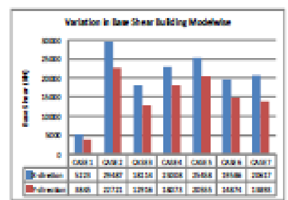
Graph 25 : Zone II



Graph 26 : Zone III



Graph 27 : Zone IV



Graph 28 : Zone V

The base shear is directly proportional to weight of structure. From the graphs base shear profiles it is observed that minimum shear occurs in open ground storey building (case 3). It is observed that the use of uniform infill in all storeys in the first storey increase the base shear up to 68% as compared with case3. Stiffer column and beam (case 4) increase the base shear to 33% of case 3. By introducing Corner shear wall (case 5) increase the base shear to 45% of case 3. Corner cross bracing (case 6) increase the base shear to 12% of case 3. Composite column and beam (case 7) increase the base shear to10% of case 3.

7. Concluding remarks

1. Underestimation of design base shear in case of bare frame models as compared to the infill models the design base shear increases with increase in mass and stiffness of masonry infill wall and vice versa.
2. Infill panel increases the later stiffness of the building, measured in terms of first story displacement there by reducing displacement in all storey levels compared to open ground story building cases.
3. Open ground story with shear wall and cross bracing are found to be very effective in reducing the stiffness irregularity and bending moment in the column.
4. Open ground story with stiffer column and composite columns are effective in reducing the stiffness irregularity

and drift, but there is increase in the shear force and bending moment in the first story.

5. Ductility if found more in the infill frame panel compare to the open ground story building models.

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