ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 2,February 2018

Earthquake Resistant Low-Rise Open Ground Storey Framed Building By Pushover Analysis

[1] P.Sudheer Kumar, [2] M.Satish, [3] Rahul Shinde, [4] Dr M.Palanisamy
[1][2][3] Assistant Professor, [4] Professor, Dept of Civil engineering, Balaji Institute of Technology & Science.

Abstract: -- **Presence of infill walls in the frames alters the behaviour of the building under lateral loads. However, it is common industry practice to ignore the stiffness of infill wall for analysis of the framed building. Engineers believe that analysis without considering infill stiffness leads to a conservative design. But this may not be always true, especially for vertically irregular buildings with discontinuous infill walls. Hence, the modeling of infill walls in the seismic analysis of framed buildings is imperative. Indian Standard IS 1893: 2002 allows analysis of open ground storey buildings without considering infill stiffness but with a multiplication factor 2.5 in compensation for the stiffness discontinuity. As per the code, the columns and beams of the open ground storey are to be designed for 2.5 times the storey shears and moments calculated under seismic loads of bare frames (i.e., without considering the infill stiffness). However, as experienced by the engineers at design offices, the multiplication factor of 2.5 is not realistic for low rise buildings. This calls for an assessment and review of the code recommended multiplication factor for low rise open ground storey buildings.**

Index Terms - Infill walls, Open ground storey, Equivalent static analysis, response spectrum analysis, pushover analysis, low rise building.

1. INTRODUCTION

Due to increasing population since the past few years car parking space for residential apartments in populated cities is a matter of major concern. Hence the trend has been to utilize the ground storey of the building itself for parking. These types of buildings having no infill masonry walls in ground storey, but infilled in all upper storeys, are called Open Ground Storey (OGS) buildings. They are also known as 'open first storey building'. The OGS framed building behaves differently as compared to a bare framed building (without any infill) or a fully infilled framed building under lateral load. A 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.

1.1 NEED FOR THE PRESENT STUDY

As experienced by the engineers at design offices the multiplication factor of 2.5 given by IS 1893:2002, for ground storey beams and columns, is not realistic for low rise buildings. This calls for a critical assessment and review of the code recommended multiplication factor. Assessment of the multiplication factor (MF) requires accurate analysis of OGS buildings considering infill stiffness and strength. The presence of infill walls in upper storey's of OGS buildings accounts for the following issues:

Increases the lateral stiffness of the building frame. Decreases the natural period of vibration. Increases the base shear. Increases the shear forces and bending moments in the ground storey columns.

1.2 SCOPE OF THE STUDY

Open ground storey (OGS) buildings are commonly constructed in populated countries like India since they provide much needed parking space in an urban environment. Failures observed in past earthquakes show that the collapse of such buildings is predominantly due to the formation of soft-storey mechanism in the ground storey columns.

1.3 REVIEW OF LITERATURE

A state of the art literature review is carried out as part of the present study. This chapter presents a brief summary of the literature review. The literature review is divided into two parts. The first part deals with the seismic behaviour of the open ground storey buildings whereas the second part of this chapter discusses about the previous work carried out on the linear and nonlinear modelling of infill walls.

Karisiddappa (1986) and ***Rahman (1988***) examined the effect of openings and their location on the behaviour of single storey RC frames with brick infill walls.

Choubey and Sinha (1994) investigated the effect of various parameters such as separation of infill wall from frame, plastic deformation, stiffness and energy dissipation of infilled frames under cyclic loading.

Deodhar and Patel (1998) pointed out that even though the brick masonry in infilled frame are intended to be non-structural, they can have considerable influence on the lateral response of the building.

Davis and Menon (2004) concluded that the presence of masonry infill panels modifies the structural force distribution significantly in an OGS building.

Hashmi and Madan (2008) conducted non-linear time history and pushover analysis of OGS buildings. The study concludes that the MF prescribed by IS 1893(2002) for such buildings is adequate for preventing collapse.

2. STRUCTURAL MODELLING

It is very important to develop a computational model on which linear / non-linear, static/ dynamic analysis is performed. The first part of this chapter presents a summary of various parameters defining the computational models, the basic assumptions and the geometry of the selected building considered for this study. Accurate modelling of the nonlinear properties of various structural elements is very important in nonlinear analysis. In the present study, frame elements were modelled with inelastic flexural hinges using point plastic model.

3. BUILDING DESCRIPTION

An existing OGS framed building located at Guwahati, India (Seismic Zone V) is selected for the present study. The building is fairly symmetric in plan and in elevation. This building is a G+3 storey building (12m high) and is made of Reinforced Concrete (RC) Ordinary Moment Resisting Frames (OMRF). The concrete slab is 150mm thick at each floor level. The brick wall thicknesses are 230 mm for external walls and 120 mm. for internal walls. Imposed load is taken as 2 kN/ m2 for all floors. Fig. 3.1 presents typical floor plans showing different column and beam locations. The cross sections of the structural members (columns and beams 300 mm×600 mm) are equal in all frames and all stories. Storey masses to 295 and 237 tonnes in the bottom storyes and at the roof level, respectively. The design base shear was equal to 0.15 times the total weight.

3.1 MATERIAL PROPERTIES

M-20 grade of concrete and Fe-415 grade of reinforcing steel are used for all the frame models used in this study. Elastic material properties of these materials are taken as per Indian Standard IS 456: 2000. The short-term modulus of elasticity(Ec) of concrete is $E_c = 5000 fck$ is the characteristic compressive strength ofconcrete cube in MPa at 28-day (20 MPa in this case). For the steel rebar, yield stress (*fy*) and modulus of elasticity (*Es*) is taken as per IS 456:2000. The material chosen for the infill walls was masonry whose compressive strength (*fm'*) from the literature was found out to be 1.5 MPa and the modulus of elasticity was stated as:
Em = 350 to 800 MPa for table moulded brick.

3.2 STRUCTURAL ELEMENTS

Beams and columns are modelled by 3D frame elements. The beam-column joints are modelled by giving end-offsets to the frame elements, to obtain the bending moments and forces at the beam and column faces. The beam-column joints are assumed to be rigid.The rigid beam-column joints were modelled by using end offsets at the joints (Fig. 3.2). The floor slabs were assumed to act as diaphragms, which ensure integral action of all the vertical lateral load-resisting elements. The weight of the slab was distributed as triangular and trapezoidal load to the surrounding beams.

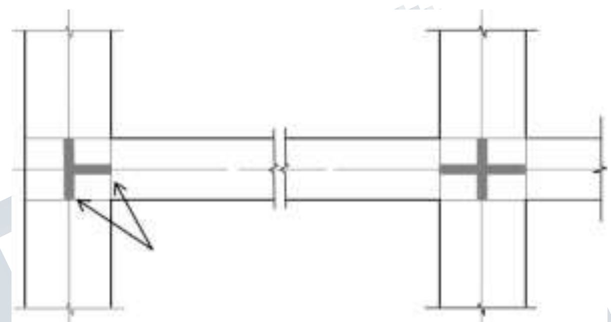
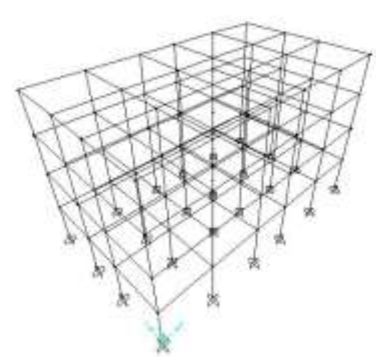


Fig. 3.2.1: Use of end offsets at beam-column joint

3.3 Modelling Infill Walls

Infill walls are two dimensional elements that can be modelled with orthotropic plate element for linear analysis of buildings with infill wall. But the nonlinear modelling of a two dimensional plate element is not understood well. Therefore infill wall has to be modelled with a one-dimensional line element for nonlinear analysis of the buildings. Same building model with infill walls modelled as one-dimensional line element is used in the present study for both linear and nonlinear analyses. Infill walls are modelled here as equivalent diagonal strut elements.



ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 3, Issue 2, February 2018

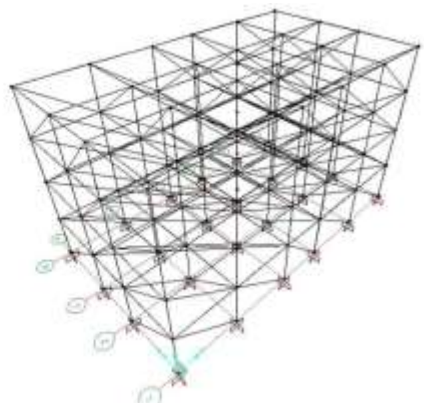


Fig. 3.1 3D Computer model of building without and with considering infill stiffness respectively.

4. RESULTS FROM LINEAR ANALYSIS

This is a linear static analysis. This approach defines a way to represent the effect of earthquake ground motion when series of forces are act on a building, through a seismic design response spectrum. This method assumes that the building responds in its fundamental mode. The applicability of this method is extended in many building codes by applying factors to account for higher buildings with some higher modes, and for low levels of twisting. To account for effects due to "yielding" of the structure, many codes apply modification factors that reduce the design forces. In the equivalent static method, the lateral force equivalent to the design basis earthquake is applied statically. The equivalent lateral forces at each storey level are applied at the design ‘centre of mass’ locations. It is located at the design eccentricity from the calculated ‘centre of rigidity (or stiffness)’. The base dimension of the building at the plinth level along the direction of lateral forces is represented as d (in meters) and height of the building from the support is represented as h (in meters). The response spectra functions can be calculated as follows:

For Type I soil (rock or hard soil sites):

$$S_a/g=\{1+15T \quad 0.00\le T\le 0.10$$
$$2.5 \quad 0.10\le T\le 0.40$$
$$1/T \quad 0.40\le T\le 4.00$$

For Type II soil (medium soil):

$$SS_{aa}gg=\{1+15T \quad 0.00\le T\le 0.10$$
$$2.5 \quad 0.10\le T\le 0.55$$
$$1.36T \quad 0.55\le T\le 4.00$$

For Type III soil (soft soil):

$$S_ag=\{1+15T \quad 0.00\le T\le 0.10$$
$$2.5 \quad 0.10\le T\le 0.67$$
$$1.67T \quad 0.67\le T\le 4.00$$

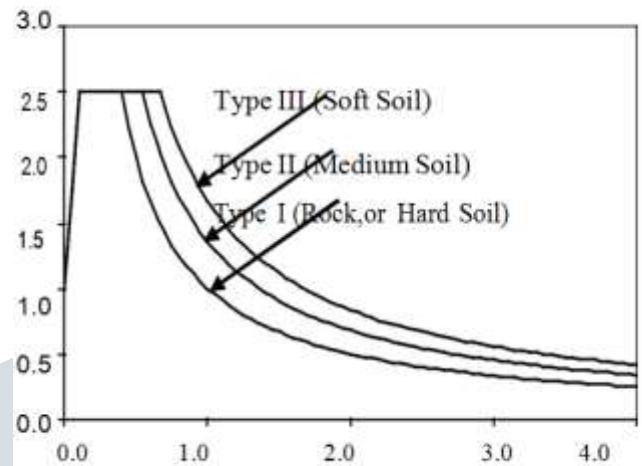


Fig. 4.1: Response spectra for 5 percent damping (IS 1893: 2002)

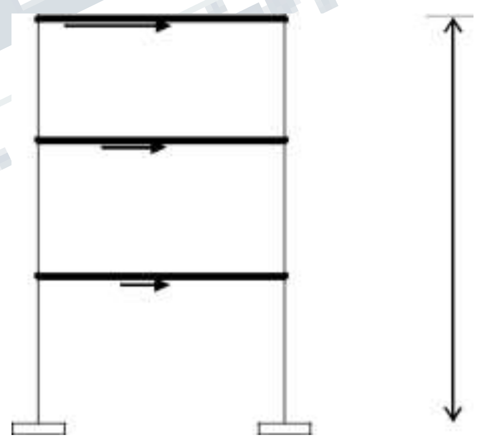


Fig. 4.2: Building model under seismic load

5. RESULTS FROM PUSHOVER ANALYSIS

Pushover analysis is carried out for both of the two building models. First pushover analysis is done for the gravity loads (DL+0.25LL) incrementally under load control. The lateral pushover analysis (PUSH-X and PUSH-Y) is followed after the gravity pushover, under displacement control.

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 2, February 2018

The capacity curve (base shear versus roof displacement) is obtained in X- and Y- directions and presented in Figs. 5.3(a) and 5.3(b). These figures clearly show that global stiffness of an open ground storey building hardly changes even if the stiffness of the infill walls is ignored.

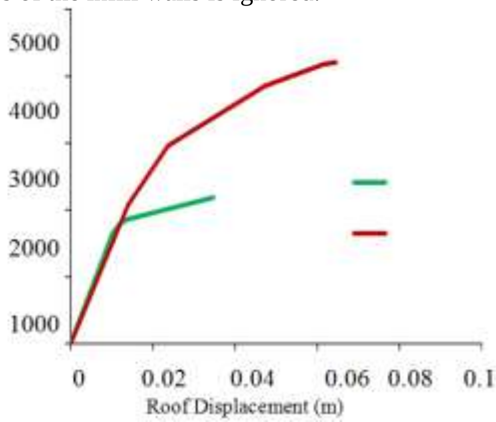


Fig. 5.1 (a) X-direction Push

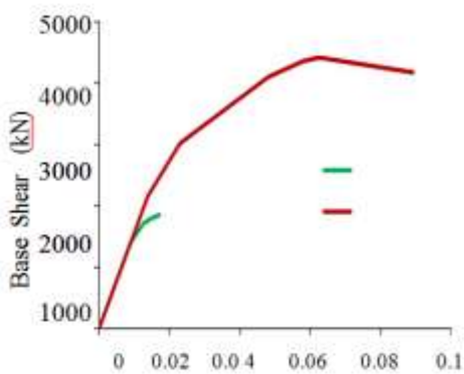


Fig. 5.2 (b) Y-direction Push

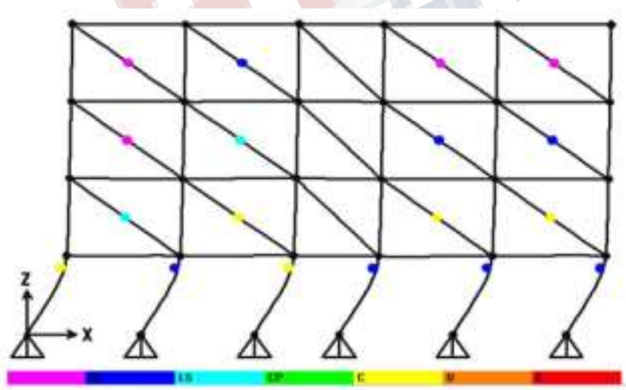


Fig 5.3 Distribution of plastic hinges for WI building model

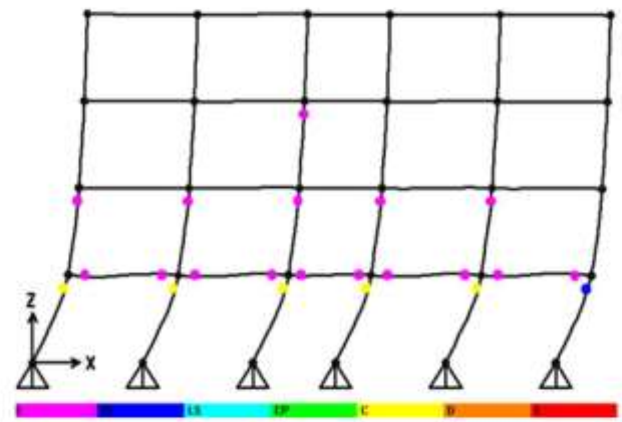


Fig 5.4 Distribution of plastic hinges for WOI building model

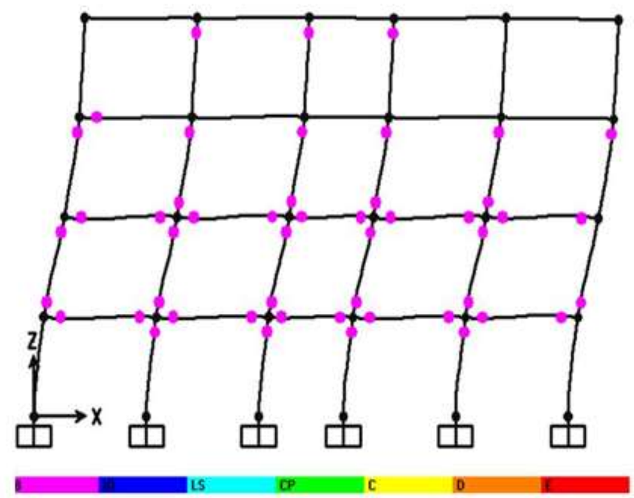


Fig 5.4 Modelled without infill stiffness

6. CONCLUSIONS

IS code gives a value of 2.5 to be multiplied to the ground storey beam and column forces when a building has to be designed as open ground storey building or stilt building. The ratio of IR values for columns and DCR values of beams for both the support conditions and building models were found out using ESA and RSA and both the analyses supports that a factor of 2.5 is too high to be multiplied to the beam and column forces of the ground storey. This is particularly true for low-rise OGS buildings.

The linear (static/dynamic) analyses show that Column forces at the ground storey increases for the presence of infill wall in the upper storeys. But design force amplification factor found to be much lesser than 2.5.

Nonlinear analysis reveals that OGS building fails through a ground storey mechanism at a comparatively low base shear and displacement. And the mode of failure is found to be brittle.

REFERENCES

[1] Asokan, (2006) Modelling of Masonry Infill Walls for Nonlinear Static Analysis of Buildings under Seismic Loads. M. S. Thesis, Indian Institute of Technology Madras, Chennai.

[2] Agarwal P. and Shrikhande M. (2006) Earthquake resistant design of structures, PHI Learning Pvt. Ltd., New Delhi.

[3] Chopra A. K. (1973) Earthquake resistance of buildings with a soft first storey. Earthquake and Structural Dynamics.

[4] Asteris P. G. (2003) Lateral stiffness of brick masonry infilled plane frames. Journal of Structural Engineering

