SUITABILITY OF MAJOR INTERNATIONAL CODAL PROVISIONS FOR OPEN GROUND STOREY BUILDINGS

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ABSTRACT: In the present study, a typical OGS framed building is considered and the building considered is located in Seismic Zone-V. The design forces for the ground storey columns are evaluated based on various codes such as Indian, Euro, Israel, Bulgarian codes and Kaushik et. al (2009) suggested approach. Various OGS frames will design considering MF as 1.0, 2.1 (Israel), 2.5 (Indian), 3.0 (Bulgarian), 3.79 (Kaushik et. al, 2009) and 4.68 (Euro). The performance of each building will studied using the fragility analysis method introduced by Cornell et. al (2002). In the present study, fragility curves are generated for each building, by developing a Probabilistic Seismic Demand Model (PSDM) according to power law. The relative performances of each building designed as per various codes will be compared using fragility curves.

Keywords: Open Ground Storey (OGS), Multiplication factor (MF), Probabilistic Seismic Demand Model (PSDM)

1. INTRODUCTION

The OGS framed building behaves differently as compared to that of a bare framed building (without any infill) or a fully infilled framed building under lateral load. Global lateral stiffness of a bare frame is much less than that of a fully infilled frame; it resists the applied lateral load through frame action and shows well-distributed plastic hinges at failure. When the frame is fully infilled, truss action is introduced. A fully infilled frame shows less inter-storey drift, although it attracts higher base shear (due to increased stiffness). The OGS framed building behaves differently as compared to that of a bare framed building (without any infill) or a fully infilled framed building under lateral load. Global lateral stiffness of a bare frame is much less than that of a fully infilled frame; it resists the applied lateral load through frame action and shows well-distributed plastic hinges at failure. When the frame is fully infilled, truss action is introduced. A fully infilled frame shows less inter-storey drift, although it attracts higher base shear (due to increased stiffness).

1.1 Multiplication Factor (MF) provisions in various codes

The OGS buildings can be considered as extreme soft-storey type of buildings in most of the practical situations, and shall be designed considering special provisions to increase the lateral stiffness or strength of the soft/open storey. Here we are ignoring the infill strength and stiffness of infill walls. The various code recommendations are to magnify the bending moments and shear forces of bare frame for the columns in the soft/open storey by MF.

1.1.1 Indian standards IS-1893:2002

After the incident of the Bhuj earthquake, the IS 1893 code has been revised in 2002, incorporating new design recommendations to improve OGS buildings As per IS 1893 (2002), a storey is called *soft-storey* (a type of vertical irregularity) if the lateral stiffness of a particular storey is less than 70% of stiffness of adjacent storey or less than 80% of the average lateral stiffness of three storeys above the storey under consideration. A storey is called *extreme soft-storey* if the lateral stiffness is less than 60% of that in the storey above or less than 70% of the average stiffness of the three storeys above. Stilts or open ground storey buildings fall under extreme soft-storey type of vertically irregular buildings.

1.1.2 Euro Code 8 EN 1998-1:2003

Euro Code has not suggested checking criteria of vertical irregularity, as in of other codes. *Eurocode 8* (2003) recommends increasing the resistance of columns in the less infilled storey in proportion to the amount of deficit in strength of masonry infill (MI). If there is a drastic reduction of infill walls in any storey compared to the adjoining storeys, seismic forces in the less infilled storey (ground storey of OGS building) shall be increased by a multiplication factor (MF). However, further research (Fardis and Panagiotakos 1997) has shown that increasing the beam resistance would further increase the seismic demands on the columns, thus seismic design forces in only columns are increased by a factor as follows,

$$\left[1 + \frac{\Delta V_{RW}}{\Sigma V_{Ed}}\right] \leq q$$

where ΔV_{RW} is the total reduction of the lateral resistance of MI in the ground storey compared to that in the upper storey, As there is no infill wall in the ground storey of an OGS building, ΔV_{RW} is equal to the resistance of masonry in the first storey itself and ΣV_{Ed} is the sum of seismic shear forces acting on all structural vertical elements of the storey concerned The term q is called behaviour factor, which accounts for energy dissipation capacity of the structure and the value varies from 1.5 to 4.68 depending upon the type of building systems, ductility classes, and plan regularity in the building.

1.1.3 Bulgarian Code (1987)

According to the Bulgarian code (1987), members of the soft stories (story stiffness less than half the stiffness of the adjacent stories) are required to be designed for increased forces by introducing a coefficient while calculating the design forces. The value of coefficient for *regular* RC frames with MI is 0.3 as compared to a value of 0.2 for the bare frames, and the coefficient for the RC frames with a soft story is 0.6. Therefore, it recommends the seismic design forces for soft storey in MI-RC frames are required to be increased by two times the corresponding design forces for a regularly infilled frame, and by three times the design seismic forces for a regular bare frame.

1.1.4 Israel Code SII-413 (1995)

This code allows soft or weak storey, including open ground storey, only in buildings with low or medium ductility levels. The design forces for flexible or weak storey members, and for the members in the storey above and below, are required to be increased by a factor 0.6R, where R is the response reduction factor. For masonry infilled RC frame buildings, R is 3.5 for low ductility level, and 5.0 for medium ductility level. Therefore, the beams and columns of the soft/weak storey, and also the adjacent

storeys are required to be designed for at least 2.1-3.0 times the design forces for regular storey, depending upon the level of ductility.

Here we have considered the building as a low ductility level therefore the beams and columns of the ground and first storey are increased by a factor 2.1.

1.1.5 Kaushik et. al (2009)

Kaushik et. al (2009) has specified a formula for ground storey columns to strengthen by increasing the amount can be calculated as

$$\eta = \frac{H_S + \Sigma V_{col}}{\Sigma V_{col}}$$

Where η = factor by which design forces for open ground-storey columns are required to be increased and ΣV_{col} = summation of shear strength, in N, of all columns in the ground storey by considering concrete contribution and over-strength in the reinforcing bars and *Hs* is the lateral resistance offered by infills in the ground storey. *Hs* is deficit in lateral strength of the ground storey. The same type and thickness of infills present in the upper stories shall be considered in the ground storey also, and the deficit in the lateral strength shall be calculated accordingly.

Table 2.1: Multiplication factors (MF) as per various codes

Code	MF considered
Indian	2.5
Euro	4.68
Bulgarian	3.0
Israel	2.1(This factor shall be applied to both ground and first storey)

2. LITERATURE REVIEW

2.1 Genral

Various research works and experiments have been carried out since a long time all over the world to understand or to ascertain the stability of the RC building in various zones. The concept of modelling and analysis technique used for this purpose has also been getting improved with advancement of engineering and technology as well as with past experience.

2.2 Reviews

[1]Implications Of Major International Codal Design Provisions For Open Ground Storey Buildings by Jerripotula Nageswarrao(2017,Jan)14jp1d8704,M.Tech.(Structural)represents that,

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. "Open Ground Storey" (OGS) buildings are those types of buildings in which the ground storey is free of any infill masonry walls. These types of buildings are very common in India for parking provisions.

[2]Analytical Review of Soft Storey by Ghalimath.A.G1, Hatti M.A2(Volume: 02 Issue: 06 | Sep-2015) Represents That,

Soft storeys in a high rise building play an important role on its seismic performance. At the soft storey level, there is a discontinuity in the rigidity of the structure due to lack of infill walls or due to variation in floor height. It is this continuity which is the cause of structural failure of multi stored buildings under earthquake loads.

[3]Comparative Analysis of Soft Storey Mechanism using Different Codal Standards

K.Indumathi1 Mr.G.Saravanan2(Vol. 4, Issue 01, 2016) Represents That,

The present study is to evaluate the behavior of G+9 reinforced concrete frame structure subjected to earthquake forces in severe condition. The reinforced concrete structures are analyzed by nonlinear static analysis using ETABS 2013 V 13.1.1 software. To analyse and compare results of soft storey mechanism of modeled 2D frame structure with different conditions as follows and also to compare results of maximum storey displacement and maximum storey drift of Indian and American Standards.

3. SCOPE OF THE STUDY

- The present study is limited to reinforced concrete multi-storey framed buildings that are regular in plan.
- The present study is based on a case study of ten storey six bays and the buildings with basement, shear wall and stiff plinth beams are not considered in this study.
- The infill walls are assumed to be non-integral, non-load bearing and made of brick masonry.
- Asymmetric arrangement of infill walls is ignored and window and door openings infill panels are neglected in the modeling.

4. OBJECTIVE OF THE STUDY

1. To study the seismic performance of typical OGS buildings designed as per applicable provisions in international codes in a Probabilistic Frame Work
    - Indian
    - Euro
    - Bulgarian
    - Israel
2. To develop Probabilistic Seismic Demand Model for the designed buildings
3. To develop fragility curves for the designed OGS buildings

5. METHODOLOGY

Various steps to be followed to achieve the objectives are given below.

Step 1: Select a frame

Step 2: Design the frame as per IS 456 and IS 1893

Step 3: Develop Fragility curves for the designed frames as per Cornell et. al (2002)

Step 4: Building performance levels are considered using FEMA – 356

Step 5: Analyse the fragility curves obtained to draw the conclusions

6. CONCLUSIONS

Followings are the salient conclusions obtained from the present study:

- The performance of typical OGS buildings designed considering various magnification factors according to different codes are studied using fragility curves.
- Uncertainties in concrete, steel and masonry are incorporated using LHS scheme. It is found that the performances of the OGS frames, in terms of ground storey drift is increasing in the increasing order of magnification factors used by various codes for all the performance levels.
- In all the cases of the buildings designed using various codes, the first storey is about 80% more vulnerable than the ground storey except for Israel code.
- It is found that relative vulnerability of first storey increases due to strengthening of the ground storey.

7. REFERENCES

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[2] Analytical Review of Soft Storey by Ghalimath.A.G1, Hatti M.A2(Volume: 02 Issue: 06 | Sep-2015)

[3] Comparative Analysis of Soft Storey Mechanism using Different Codal Standards K.Indumathi1 Mr.G.Saravanan2(Vol. 4, Issue 01, 2016)