iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: XII Month of publication: December 2025

DOI: https://doi.org/10.22214/ijraset.2025.76493

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue XII Dec 2025- Available at www.ijraset.com

Retrofitting of Soft Storey Building Using Different Structural Systems: Software Based Study

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Abstract: After the Bhuj earthquake took place, the IS 1893 code was revised in 2002, incorporating new design recommendations to address OGS framed buildings. According to this clause 7.10.3(a) of the same code states: "The columns and beams of the soft-storey are to be designed for the multiplication factor of 2.5 times the storey shears and moments calculated under seismic loads of bare frame". The prescribed multiplication factor (MF) of 2.5, applicable for all OGS framed buildings, is proved to be fairly higher and suggests that all existing OGS framed buildings (those designed to earlier codes) are highly vulnerable under seismic loading. This MF value however does not account for number of storeys, number of bays, type and number of infill walls present, etc and hence it is independent of all of the above factors. Present study deals with various aspects related to the performance of OGS buildings. The values of magnification factor recommended in literatures vary from 1.0 to 4.8 (Kaushik, 2009). The main objective of present study is the study of comparative performance of OGS buildings designed according to various configuration using seismic analysis. As the more realistic performance of the OGS building requires the modelling the stiffness and strength of the infill walls, the stiffness and strength of the infill walls also considered. The variations in the type of the infill walls using in Indian constructions are significant. Depending on the modulus of elasticity and the strength, it can be classified as strong or weak. The two extreme cases of infill walls, strong and weak are considered in the study. The behavior of buildings depends on the type of foundations and soils also. Depending on the foundations resting on soft or hard soils, the displacement boundary conditions at the bottom of foundations can be considered as hinged or fixed. As the modeling of soils is not in the scope of the study, boundary conditions, fixed, that represent extreme condition is considered. It can be pointed out that the maximum storey drift is occurring in the case of open ground storey building. As the height of the building increases, the storey drift is considerably reducing, i.e. there is a larger drift at bottom storey as compared to other storey of the open ground storey building. It can be seen that the addition of shear wall greatly reduces the ground storey drift. As compared to the provision of diagonal steel bracing, the cross-steel bracing reduces the storey drift to a greater extent. The time period taken for first mode shape is 1.54 seconds for bare model. For OGS model, the time is 0.93. Thus, for OGS model, the time period is less by while compared to the normal model because of the OGS model has more stiffness.
IndexTerms: Base Shear, Boundary conditions, Infill walls, Maximum story drift, Soft storey, Seismic analysis.

I. INTRODUCTION

The collapse mechanism of such type of building is predominantly due to the formation of soft-storey behavior in the ground storey of this type of building. The sudden reduction in lateral stiffness and mass in the ground storey results in higher stresses in the columns of ground storey under seismic loading. In conventional design practice, the contribution of stiffness of infill walls present in upper storeys of OGS framed buildings are ignored in the structural modelling (commonly called bare frame analysis). Design based on such analysis, results in under-estimation of the bending moments and shear forces in the columns of ground storey, and hence it may be one of the reasons responsible for the failures observed.

After the Bhuj earthquake took place, the IS 1893 code was revised in 2002, incorporating new design recommendations to address OGS framed buildings. According to this clause 7.10.3(a) of the same code states: "The columns and beams of the soft-storey are to be designed for the multiplication factor of 2.5 times the storey shears and moments calculated under seismic loads of bare frame". The prescribed multiplication factor (MF) of 2.5, applicable for all OGS framed buildings, is proved to be fairly higher and suggests that all existing OGS framed buildings (those designed to earlier codes) are highly vulnerable under seismic loading. This MF value however does not account for number of storeys, number of bays, type and number of infill walls present, etc and hence it is independent of all of the above factors.

Need of space became very important in urban areas due to increase in population especially in developing countries like India. Need of parking space takes important vital role while planning a building. To provide adequate parking spaces, ground storey of the building is utilised.

These types of buildings (Figure 1.1) having no infilled walls in ground storey, but in-filled in all upper storeys, are called Open Ground Storey (OGS) buildings. The majority of apartments are of this type and the infill walls used are of mainly brick masonry.

In developing countries like India there is increasing need of high-rise buildings. High-rise building is a solution of land scarcity in developing cities and due to scarcity of land commercial utilization of high-rise buildings and their construction is enhanced. Around the business section of cities wide office space is needed which is easily be available in high-rise buildings and tall buildings. All these demands, necessity of large space, is easily be fulfilled by the high-rise building. Economical and efficiently designed high-rise buildings will easily incorporate all these necessities. Technological and scientific progress in the high-rise buildings results in the socio-economic development. Modern urbanization and development of large cities give birth to the several problems like shortage of land in cities, rising in the prices of land which in turn results in the development of high-rise building and a magnificent high-rise building effectively serves the purpose. In present world of increasing intense business competition high-rise buildings are the symbol of economic strength and have an important propaganda effect therefore they play an important role and best suited in present scenario.

In multi-storied framed building, damages from earthquake generally initiate at locations of structural weaknesses present in the lateral load resisting frames. This behavior of multi-story framed buildings during strong earthquake motions depends on the distribution of mass, stiffness, strength in both the horizontal and vertical planes of buildings. In few cases, these weaknesses may be created by discontinuities in stiffness, strength or mass along the diaphragm. Such discontinuities between diaphragms are often associated with sudden variations in the frame geometry along the length of the building. Structural engineers have developed confidence in the design of buildings in which the distributions of mass, stiffness and strength are more or less uniform. There is a less confidence about the design of structures having irregular geometrical configurations and diaphragm discontinuities (J.Sreenath and Dr.H.Sudharsana Rao, 2018).

The recent earthquake including the last Nepal earthquake (2015) in which many reinforced concrete structures have been severely damaged or collapsed, have indicated the need for evaluating the seismic adequacy of existing buildings. In multi-storied framed building, damages from earthquake generally initiate at locations of structural weaknesses present in the lateral load resisting frames. This behavior of multi-storied framed buildings during strong earthquake motions depends on the distribution of mass, stiffness, strength in both horizontal and vertical planes of buildings. In few cases, these weaknesses may be created by discontinuities in stiffness, strength or mass along the diaphragm.

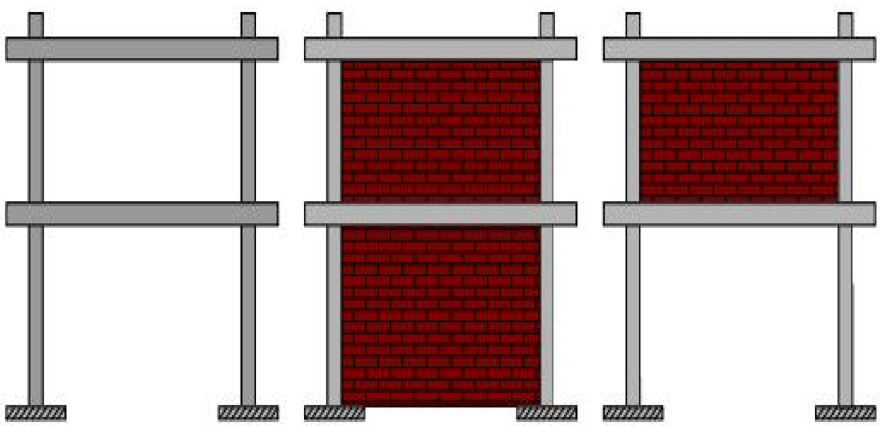

Figure 1: Typical Model of soft storey building

II. OBJECTIVES OF THE STUDY

1) To create 3D G+9 storey Ordinary Moment Resisting Frame structure as per IS 1893:2016 with different configurations (Bare frame model, Infills model, Bracings frame model, Shear wall frame model).
2) To study the behaviour of ground and first storey as soft storey building with different models in high seismic zones.
3) Analyse the different model by using Etabs software.
4) To calculate the responses in terms of maximum bending moment, shear force and displacement and to carry out the comparison of these responses for building models.

III. METHODOLOGY

This project work is carried out using ETABS that is a very powerful tool which is widely used for design and analysis of multistory buildings. It is used to evaluate basic and advanced systems under static or dynamic conditions. For a refined assessment of seismic performance, modal and direct integration time-history analysis, may couple with p-delta and large displacement effects. The modeling of various regular and building is very easy in ETABS.

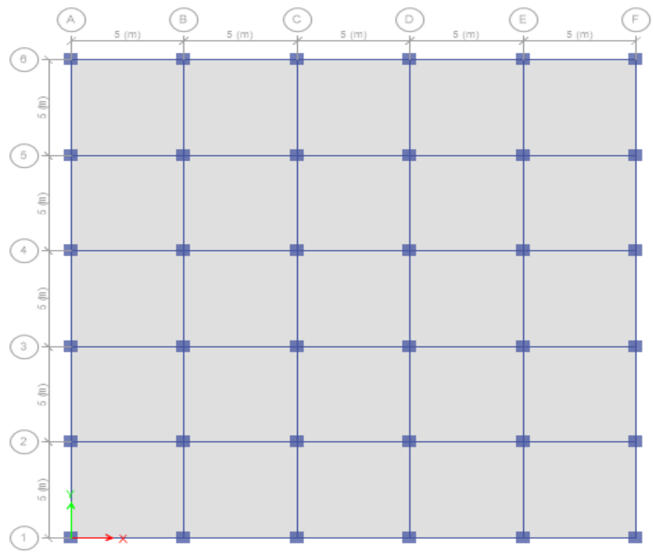

Figure 3: Plan view of the structure

Table 1: Cases Considered for the Study

Specifications	Data
Typical Storey Height	3 m
Base Storey Height	1.5 m
No. of Bays alongX-Direction	5
No. of Bays alongY-Direction	5
Bay Length alongX-Direction	5 m
Bay Length alongY-Direction	5 m
Concrete Grade	M-30
Density of R.C.C.	25 KN/m^3
Density of Masonry	21 KN/m^3
Columns	600 mm x 600 mm
Beams	300 mm x 600 mm
Slab Thickness	150 mm
Bottom Support Conditions	Fixed
Shear wall Thickness (Set II)	230 mm
Section property used as bracings	ISLB 600
Live Load- Roof Rest of the structure	 2 KN/m^2 4 KN/m^2
Soil Conditions	Type 2(Medium Soil)
Damping Ratio	0.05(asper IS-1893: 2002)
Poisson Ratio	0.2
Response Reduction Factor	3(OMRF)
Importance Factor	1
Zone Factor	0.36 (as per IS 1893)

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IV. RESULTS

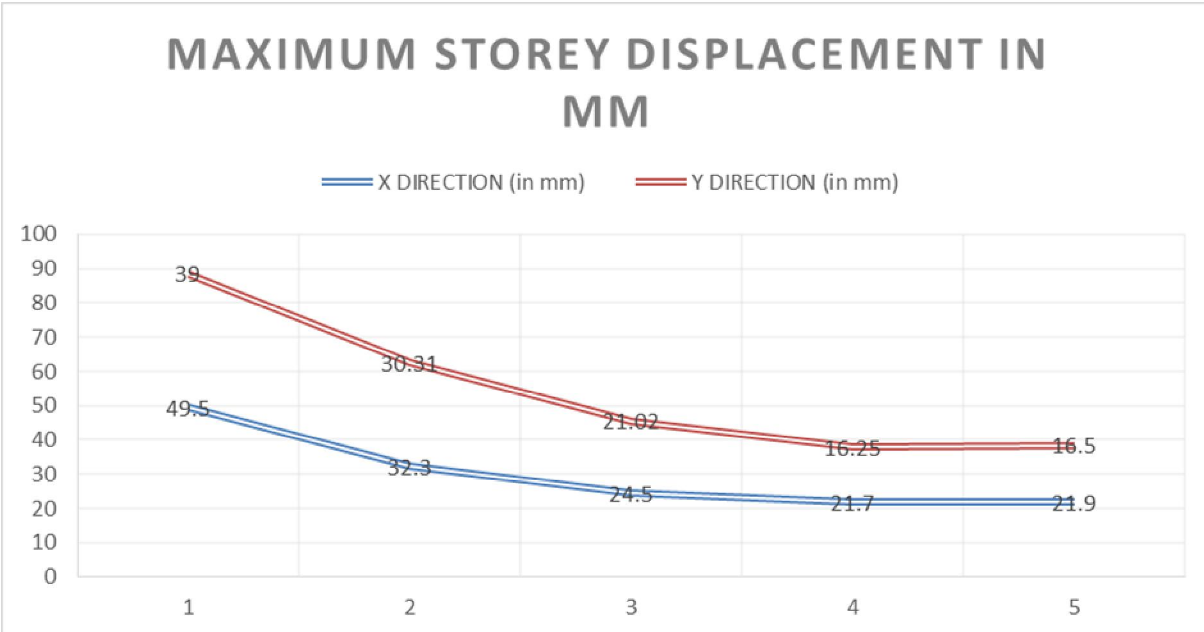

Figure 2: Comparison of max. Storey Displacements

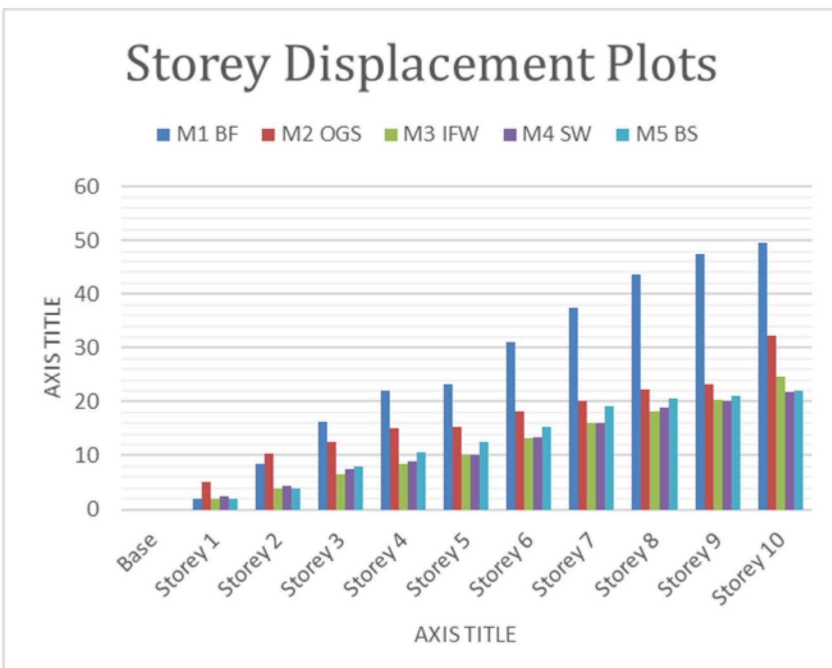

Figure 3: Representation of Storey Displacement

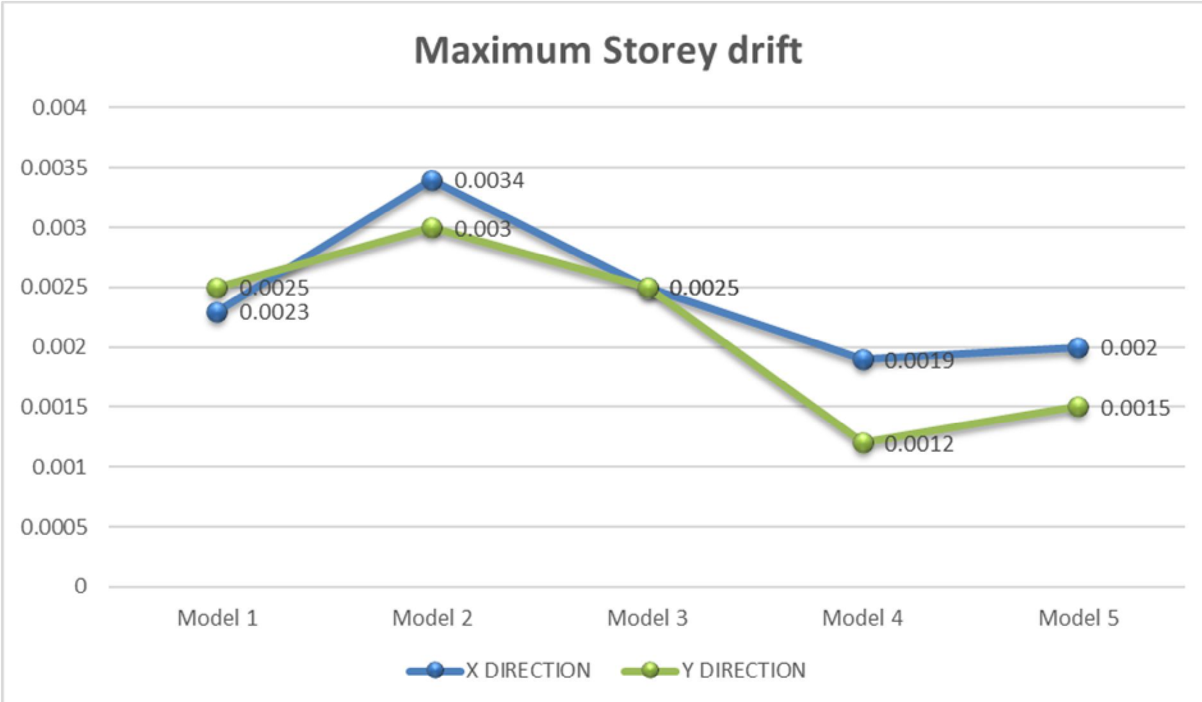

Figure 4: Comparison of max. Storey Drift from Response Spectrum Method

V. CONCLUSIONS

The shear wall reduced the Storey Displacement by more than half and storey drift by 99.86%. The Steel bracing reduced the Storey Displacement % and storeydrift . Finally, it has been found that the Shear wall reduces lateral displacement and storey drift, thus significantly contributing to greater structural stiffness. The analysis results recommended that the shear wall use reinforced concrete frames for the seismic hazard zones and the Steel bracing recommended for the high seismic zones. The storey shear for bare frame is lowest compared to infilled frame in X axis and in Y axis from the analysis. The storey shear was increased after providing shear wall at interior.

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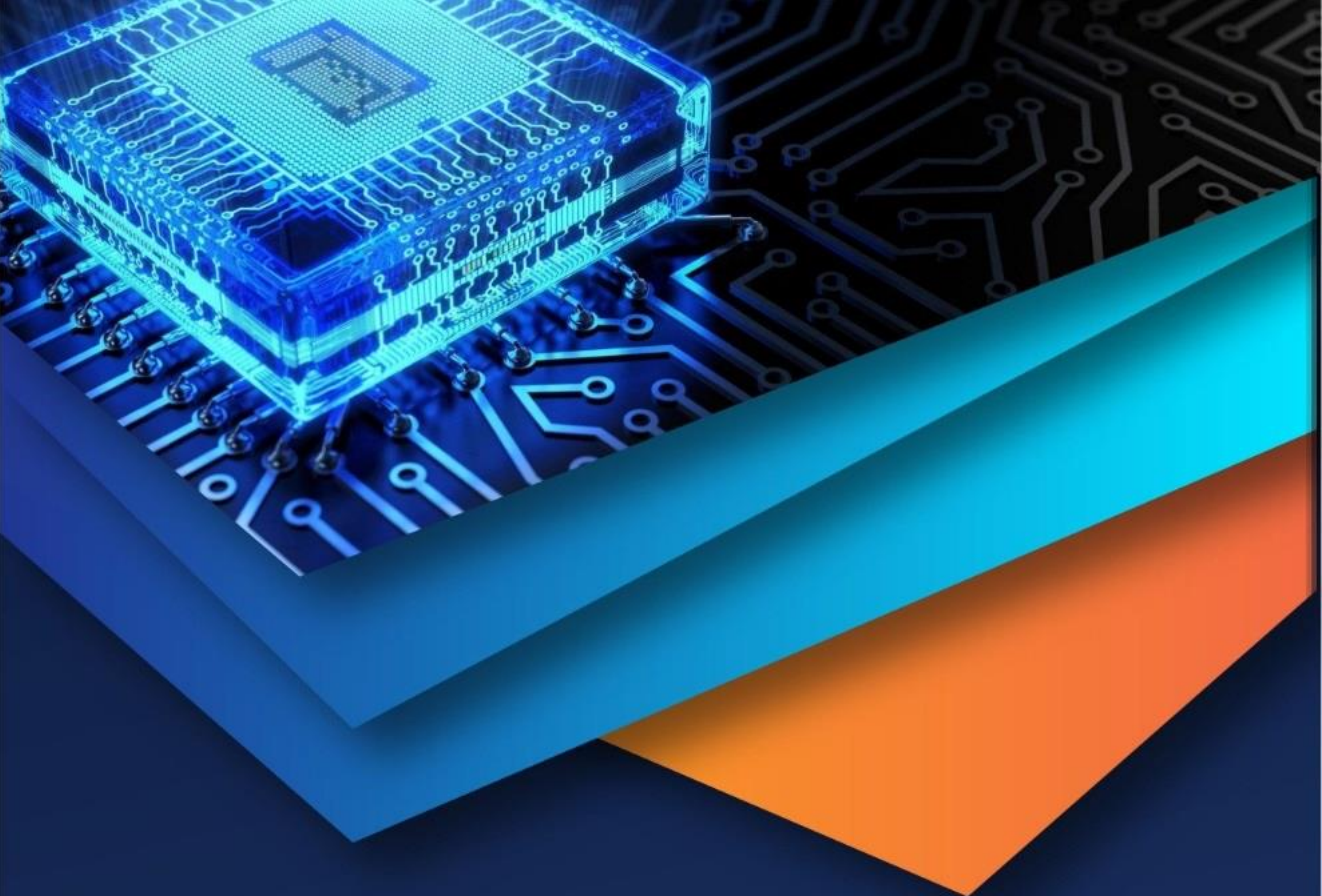

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