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PERFORMANCE EVALUATION OF SOFT STOREY STRUCTURES UNDER EARTHQUAKE LOADING

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Abstract: Open Ground Storey (OGS) buildings are prevalent in Indian urban environments to accommodate parking at the ground floor. However, the abrupt reduction in lateral stiffness at this level makes them highly vulnerable to seismic forces. The Indian seismic code IS 1893:2016 prescribes a multiplication factor (MF) of 2.5 for the design of ground-storey members in OGS buildings without considering infill stiffness. This paper evaluates the applicability of this factor for low- to mid-rise OGS structures using Equivalent Static Analysis (ESA) and Response Spectrum Analysis (RSA) in ETABS for four building heights (G+4, G+8, G+10, G+15) in Seismic Zone V. Infill walls were modelled as equivalent diagonal struts. The results show that actual MF values range between 1.05 and 1.71, significantly lower than the code-specified 2.5, indicating that the provision may be conservative for certain cases.

Keywords Open Ground Storey, Multiplication Factor, Infill Stiffness, Seismic Performance, Equivalent Static Analysis, Response Spectrum Analysis.

I. INTRODUCTION

Urban India frequently uses Open Ground Storey (OGS) buildings to maximize parking and functional space. While practical, the absence of masonry infill at the ground floor leads to significant vertical irregularity, concentrating drift and damage in this storey during earthquakes. Past seismic events, notably the 2001 Bhuj earthquake, have shown catastrophic collapses linked to this soft-storey effect. IS 1893:2016 requires multiplying design forces for ground-storey elements by 2.5 when infill stiffness is ignored, yet the basis and applicability of this value for low- to mid-rise buildings is debatable. This study examines whether this factor is realistic by modelling and analysing representative OGS buildings with and without infill stiffness.

II. SCOPE OF THE STUDY

Structural engineers have noted that the **2.5 multiplication factor** recommended in IS 1893:2016 for the design of ground-storey beams and columns in open ground storey (OGS) buildings may not be fully suitable, especially for low- to mid-rise configurations. This concern highlights the importance of re-examining and, if necessary, revising the current code provision. A reliable evaluation of this factor requires comprehensive structural analysis of OGS buildings that accounts for the stiffness and strength provided by infill walls.

Infill walls located in the upper storeys of OGS structures have several important effects on seismic performance:

- They markedly enhance the lateral stiffness of the frame.
- They shorten the fundamental natural period of vibration.
- They increase the magnitude of base shear.
- They raise the shear forces and bending moments in ground-storey columns.

Considering these influences, a detailed reassessment of the design guidelines in IS 1893 is warranted to ensure they accurately reflect the actual structural behaviour of OGS buildings under earthquake loading.

III. OBJECTIVE OF STUDY

The objectives of this study are as follows:

- To carry out the analysis and design of low- to mid-rise reinforced concrete (RC) framed buildings incorporating a soft storey configuration.
- To evaluate the seismic performance of low- to mid-rise framed structures with soft storey characteristics under lateral loading conditions.
- To investigate the suitability and effectiveness of the multiplication factor prescribed in Clause 7.10.3(a) of IS

1893:2002 for designing soft storey columns in mid-rise buildings.

- To propose viable design strategies and structural modifications aimed at enhancing the seismic resilience of soft storey framed buildings.
- To examine the influence of infill wall strength and stiffness on the seismic response of open ground storey (OGS) buildings.
- To assess the relevance and adequacy of the multiplication factor of 2.5 recommended by IS 1893:2002 for the seismic design of low-rise OGS buildings.
- To analyze the impact of various support conditions on the seismic behavior of framed structures with open ground storey configurations.

IV. PROBLEM STATEMENT

A RC framed Open ground storey building is considered in Seismic Zone-V with Special Moment Resisting Frame (SMRF) is analyzed and Modeled in Etabs Software. Four Different models (G+15, G+10, G+8& G+4) having Fixed End support condition. Beams-Column joints are assumed to be rigid. Beams and columns in present study were modeled as frame elements with centre lines joined at the nodes using commercial Etabs Software.

V. METHODOLOGY & MODELLING

The study followed a structured approach to evaluate the applicability of the multiplication factor prescribed by IS 1893:2016 for open ground storey (OGS) buildings.

1. **Model Selection** – Four reinforced concrete Special Moment Resisting Frame (SMRF) buildings of different heights were selected to represent low- to mid-rise structures: G+4, G+8, G+10, and G+15 storeys. All models had the ground storey open for parking and masonry infill walls in the upper storeys.
2. **Software and Codes** – Analytical modelling and analysis were carried out using ETABS 2018. The design conformed to IS 456:2000 for reinforced concrete structures and IS 1893:2016 for seismic loading.
3. **Modelling Approach** – For each building height, two models were developed:
   - o **Bare Frame Model**: Without considering infill stiffness.
   - o **Infilled Frame Model**: With masonry infill walls in upper storeys modelled as equivalent diagonal struts using stiffness parameters from Smith and Carter (1969).
4. **Material Properties** – M25 grade concrete and Fe 500 reinforcement were used. Infill panels were assumed to have a modulus of elasticity consistent with standard burnt clay brick masonry.
5. **Support and Load Conditions** –
   - o Base supports were assumed fixed.
   - o Dead load as per IS 875 Part 1, live load as per IS 875 Part 2 (2.0 kN/m² for floors, reduced for roof).
   - o Seismic parameters corresponded to Zone V with 5% damping, as per IS 1893:2016.
   - o Load combinations followed IS 456 and IS 1893 provisions.
6. **Analysis Methods** –
   - o **Equivalent Static Analysis (ESA)** for determining base shear, displacement, storey stiffness, and member forces.
   - o **Response Spectrum Analysis (RSA)** for capturing modal effects and dynamic response characteristics.
7. **Evaluation Parameters** – From the analysis, the following were extracted for both ESA and RSA:
   - o Base shear in both principal directions.
   - o Maximum displacement and drift.
   - o Storey stiffness.
   - o Bending moments in ground-storey beams and columns.
   - o Multiplication factor (ratio of forces/moments in infilled frame to bare frame).
8. **Comparison with Code** – The calculated multiplication factors were compared with the IS 1893:2016 recommended value of 2.5 to assess its applicability across varying building heights.

Table 5.1 Details of Building Models.

Type of Structure Multi- storey	Rigid Jointed Plane Frame (SMRF)
Seismic Zone	V
Number of Stories	G+15 (48m), G+10 (33m), G+8(27m), and G+4 (15m)
Floor Height	Ground Floor=3.0m, Intermediate Floors=3.0m
Infill Wall	100mmouter external wall, 100mmInternalwall, 100mm Parapet wall
Type of soil	Medium
Size of Column	G+15-(400x800)mm G+10-(400x600)mm G+8-(400x600) mm G+4-(300x600) mm
Size of Beam	300mmx500mm
Depth of Slab	150mm
Materials of Concrete	Column and Beam: M25 Slab:M25
Damping of Structure	5%
Modulus of Elasticity of Concrete	M30-27386 N/mm² M25-25000N/mm²
Modulus of Elasticity of Brick Z	550*fm 0.36

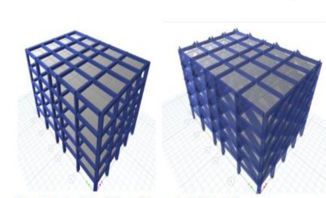

Fig. 5.1 G+4 Building (Bare & Infilled Frame)

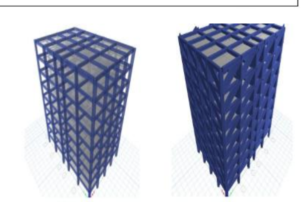

Fig. 5.2 G+8 Building (Bare & Infilled Frame)

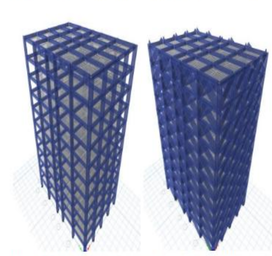

Fig. 5.3 G+10 Building (Bare & Infilled Frame)

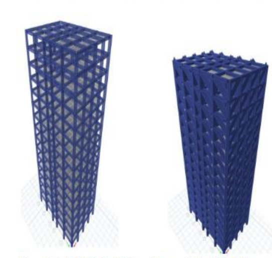

Fig. 5.4 G+15 Building (Bare & Infilled Frame)

VI. RESULTS AND DISCUSSION

6.1 Base Shear

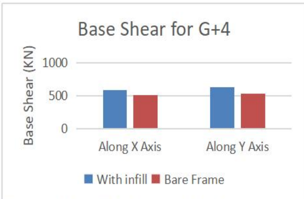

Figure 6.1 Base Shear for (G+4) Building

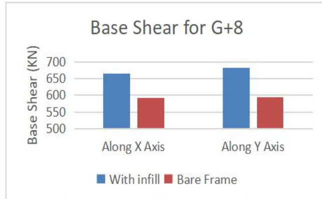

Figure 6.2 Base Shear for (G+8) Building

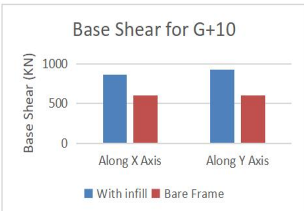

Figure 6.3 Base Shear for (G+10) Building

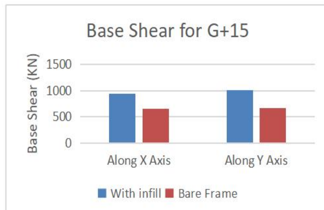

Figure 6.4 Base Shear for (G+15) Building

6.2 ESA Results

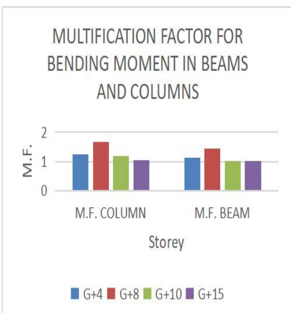

Figure 6.5 M.F. for Bending Moment in Beams & Columns

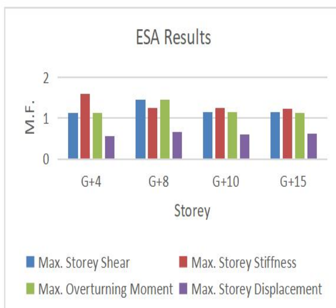

Figure 6.6 ESA Results

6.3 RSA Results

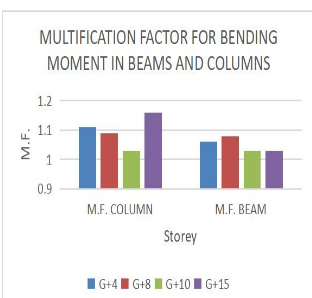

Figure 6.7 M.F. for Bending Moment in Beams & Columns

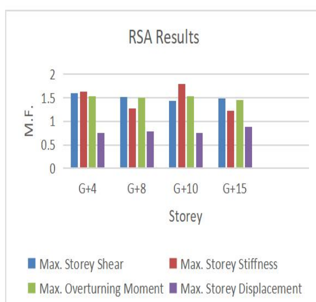

Figure 6.8 RSA Results

VII. CONCLUSION

Within the scope of present work, following conclusions are drawn form results:

1. Masonry infill walls significantly increase lateral stiffness and base shear, while reducing top-storey displacement.
2. Actual MF values are consistently below 2.0, with maximum observed 1.71 for base shear and 1.68 for bending moments, far lower than the IS 1893:2016 recommendation of 2.5.
3. The code's MF provision appears conservative for low- to mid-rise OGS buildings, particularly with fixed supports.
4. A refined MF based on building height and infill properties may optimize safety and economy.

VIII. REFRENCES

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