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Seismic Behaviour Analysis of a Multi-Storey Reinforced Concrete Building using STAAD.Pro

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***Abstract*—**Modern reinforced concrete (RC) buildings in seismically active regions must be designed to resist earthquake loads. This study uses STAAD.Pro CONNECT Edition to analyze a typical G+4 RC moment-resisting frame located in Seismic Zone II of India. The model includes five stories (15 m tall) with 3 m story heights and 3 ×3 m bays. Material properties (M25 concrete, Fe500 steel) and member sections follow common practice and Indian codes. Loads considered include self-weight, wall loads, live loads (as per IS 875 [3]), and seismic loads (per IS 1893:2016 [1]). Seismic lateral forces were applied using the equivalent static procedure with parameters (Z=0.10, R=5, I=1.2) from IS 1893 [1]. The analysis extracts key responses: nodal displacements, base shear, and beam/column forces. Maximum roof displacement was only 3.2258 mm, and base shear was ~94 kN in both horizontal directions, indicating symmetrical stiffness. Beam end forces and column forces were plotted in Excel for interpretation. Results confirm that the frame remains well within serviceability and strength limits under the design earthquake. The approach validates fundamental seismic analysis concepts for civil engineering education and shows that a regular mid-rise RC frame behaves safely under IS 1893 loads.

***Keywords*—** *Seismic analysis, RC building, STAAD.Pro, base shear, displacement, IS 1893, structural modelling.*

I. INTRODUCTION

Seismic design and analysis of RC buildings is a vital aspect of structural engineering, even in regions with moderate earthquake risk. In India, codes like IS 1893:2016 provide guidelines for calculating earthquake forces based on seismic zone, building importance, and structural properties [1]. Computer-aided tools such as STAAD.Pro are widely used for such analysis [2]. For example, Kumar and Rahman performed a STAAD.Pro-based seismic study of RC multistory buildings, demonstrating the software's effectiveness. This study focuses on a five-story (G+4) residential-type RC frame in Jaipur (Zone II, Z=0.10 [2]). The frame has a regular layout with uniform bays and identical beam/column sizes. By modeling this structure and applying code-based loads, we examine its seismic response in terms of displacements, base shear, and internal forces. These results are interpreted via graphs (displacement profiles, base shear bar chart, force bar charts) for clear engineering insight. This work aims to reinforce understanding of seismic behavior in RC frames and exemplify STAAD.Pro analysis for training and educational purposes.

II. METHODOLOGY

A. Modelling Approach

A three-dimensional analytical model of the G+4 frame was created in STAAD.Pro. The frame has five levels (ground + 4) with uniform story height 3.0 m (total 15 m) and planar grids of 3 ×3 m bays. Beam sections are 230×450 mm; column sections are 300×450 mm. Concrete grade is M25 and steel grade Fe500, per IS 456:2000. The structure uses fixed-support columns down to a 1.0 m foundation. Floors are assumed rigid diaphragms. Fig. 1 shows the analytical model of the frame.

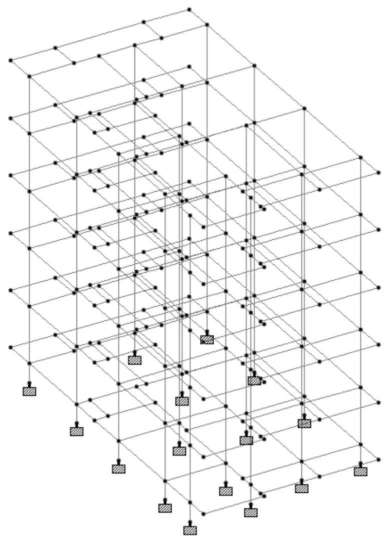

Fig. 1. Analytical Model of the G+4 RC Frame in STAAD.Pro

Material properties (density of concrete, elastic modulus of steel) were assigned according to Indian practice [2] (IS 456:2000). Beam and column elements were defined with corresponding sections. After assembling the geometry, STAAD's commands generated multiple load cases. The key steps in the workflow were:

1. Define geometry (nodes, beams, columns) in the analytical model.
2. Assign materials (M25 concrete, Fe500 steel) and section properties.

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3. Apply gravity loads (self-weight + wall loads) and live loads.
4. Define seismic parameters (Z, R, I, soil type) and generate equivalent static earthquake loads (IS 1893 method[1]).
5. Run the static analysis to obtain displacements and forces.
6. Extract results for key outputs and export to Excel for plotting.

B. Building Properties and Structural Parameters

Table 1
General Building Details

Parameter	Value
Building Type	RC Moment-Resisting Frame
Number of Storeys	G + 4
Seismic Zone	II (Z = 0.10)
Soil Type	Medium
Storey Height	3.0 m
Foundation Depth	1.0 m
Concrete Grade	M25
Reinforcement Grade	Fe500
Beam Size	230 mm × 450 mm
Column Size	300 mm × 450 mm
Live Load	2.0 kN/m²
External Wall Load	9.7 kN/m
Internal Wall Load	6.7 kN/m

C. Loads Applied

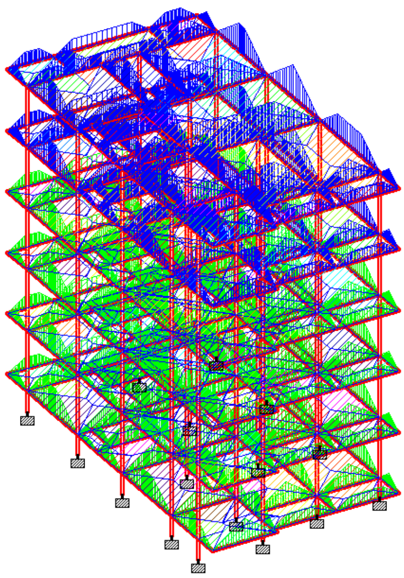

Fig. 2. Representation of Load Application

1) Dead Load

Included self-weight of slabs/beams/columns and wall loads. STAAD's SELFWEIGHT command automatically applied element weights, and additional line loads represented masonry walls.

- External wall load: **9.7 kN/m**
- Internal wall load: **6.7 kN/m**

2) Live Load

A uniform live load of 2.0 kN/m² on each floor slab (residential floors) was applied per IS 875 (Part 2) [3].

3) Seismic Load

Lateral loads were computed according to IS 1893:2016 [1] using the equivalent static method. Key seismic parameters were:

Table 2
Seismic Parameters

Parameter	Value
Zone Factor (Z)	0.10
Response Reduction Factor (R)	5
Importance Factor (I)	1.2
Soil Type	Medium
Damping	5%

These inputs were fed into STAAD's seismic load generation (equivalent static procedure) so that each floor's design base shear is distributed upward as per the code formula. Four lateral load cases (EQX+, EQX–, EQZ+, EQZ–) corresponding to positive/negative X and Z directions were defined.

4) Load Combinations

The software generated relevant factored combinations. In particular, the analysis used combinations like 1.2(DL+LL±EQX) and 1.2(DL+LL±EQZ) for seismic design as per IS 1893, and 1.5(DL+LL) for non-seismic checks.

III. ANALYSIS AND RESULTS

After defining the model and loads, a linear static seismic analysis was performed. The primary outputs examined are listed below. Selected plots (figures) illustrate these results.

- **Nodal displacements** (especially top-floor drift).
- **Support reactions / base shear** at the foundation level.
- **Beam internal forces** (max axial, shear, bending).
- **Column internal forces** (max axial, shear, bending)

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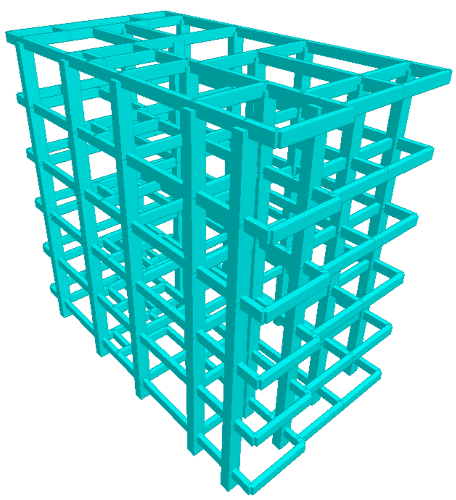

Fig. 3. 3D Rendered View of G+4 RC Frame Model in STAAD.Pro

A. Displacement Results

The peak horizontal displacement occurred at the roof under the EQX+ case. The maximum nodal displacement was **3.2258 mm** at node 236 (top corner) under EQX+ loading [4]. This corresponds to an inter-story drift of only 0.00108 (3.2258 mm/3000 mm) for each story. Code limits typically allow drift up to 0.004×story height [4][2], so the structure is very stiff and far from limit. No soft-story behavior was detected. The displacement pattern was approximately linear (increasing uniformly from base to top), as expected for an elastic frame. In practice, such low drift indicates a highly rigid building due to symmetrical geometry and stiff columns.

Table 3

Maximum Displacement from the analysis

Parameter	Value
Max Displacement	3.2258 mm
Node Number	236
Load Case	EQX+

B. Base Shear Results

The total base shear (sum of column support reactions) under the design EQX+ and EQZ+ cases was **94.03 kN** in each direction [5]. Table 4 shows these values. The equal shear in X and Z directions reflects the frame's symmetry. Balanced reactions imply that mass and stiffness distributions are uniform, so there is minimal torsion (twist) in the response [5].

Table 4

Computed base shear in each principal direction.

Direction	Base Shear (kN)
X (EQX)	94.03
Z (EQZ)	94.03

Such balanced base shear indicates that the equivalent lateral loads in X and Z were the same (due to identical spans and mass distribution) and that the frame resisted them symmetrically. Fig. 4 plots the base shear values for the two directions, showing identical bars for X and Z (94.03 kN each). This confirms that the lateral load demand is evenly shared. Uniform base shear means the building will not experience significant torsional irregularity [5].

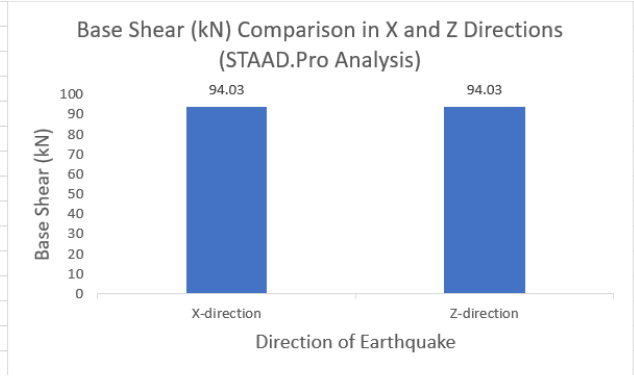

Fig. 4. Base Shear Distrinution (X & Z direction)

The Bar chart of base shear in X and Z directions (both ~94.0 kN) Shows the symmetry indicates nearly identical lateral stiffness.

C. Beam Force Results

Beams primarily carry gravitational loads (axial) and transmit seismic loads (shear and moment). All beam end forces were extracted and the maxima noted. Table 5 lists the maximum beam axial, shear, and bending values.

Table 5

Maximum beam forces from the analysis.

Force Type	Maximum Value
Axial Force	59.512 kN
Shear Force	14.347 kN
Bending Moment	149.909 kN-m

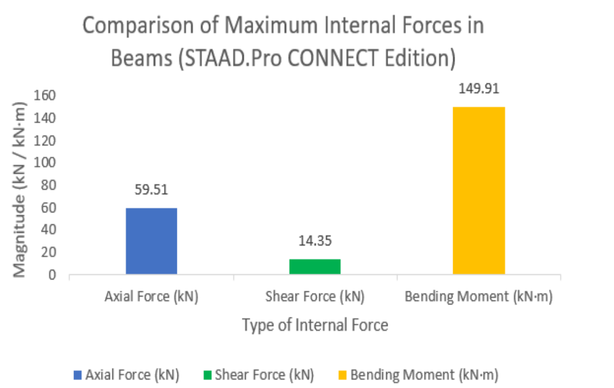

Fig. 5. Maximum forces in beams: bending moments (kN·m) dominate over axial and shear forces (kN). Beam design is governed by flexure.

Fig. 5. shows these peak values in a bar chart. Bending moments (149.9 kN·m) dominate the beam design, whereas axial (59.5 kN) and shear (14.3 kN) are much smaller. This is typical for mid-rise RC frames: beams are mainly flexural members and seldom reach high axial or shear demands unless

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supporting extreme loads [7]. The results indicate that beams are governed by bending (moment capacity is critical), in line with standard RC beam design practice [7]. No beam force exceeded usual design capacities, confirming the members' adequacy.

D. Column Force Results

Columns carry most of the gravity load and contribute to resisting lateral loads. Table 6 summarizes the peak column forces from the seismic load cases.

Table 6

Maximum column forces from the analysis.

Force Type	Maximum Value
Max. Axial Force	1807.511 kN
Max. Shear Force	58.927 kN
Max. Bending Moment	165.657 kN-m

Fig. 6 plots these column values. As expected, axial forces are by far the largest (1807.5 kN), reflecting the weight of upper stories transferred to the foundation through columns. The maximum bending moment in columns (165.7 kN·m) occurs at the column base or near ends due to lateral sway. Column shear is moderate (59 kN). The high axial-to-shear ratio indicates that columns are carrying mostly compressive loads (gravity-dominated) with moderate seismic shear demands [9].

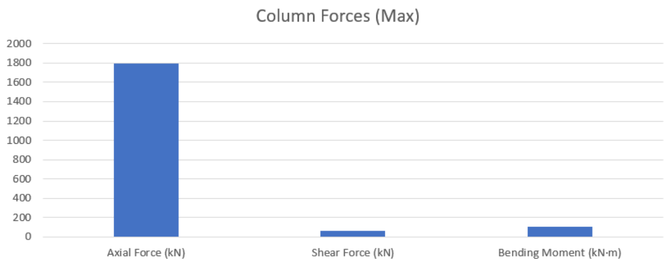

Fig. 6. Maximum internal forces in columns: axial force (kN), shear (kN), and bending moment (kN·m). Axial forces dominate.

Columns on the windward side (in X or Z) see much higher compression, while those on the opposite face see tension. In fact, one can compare maximum compression vs maximum tension in columns. Fig. 7 contrasts the peak compressive axial force (1807.5 kN) with the largest tensile force (from columns on the opposite side of loading). The tension value is much smaller, showing that overturning effects are limited. This asymmetry is typical: one side of a building sees uplift under lateral load, but that uplift capacity tends to be governed by minor forces. Overall, column forces remain within safe limits for G+4 design.

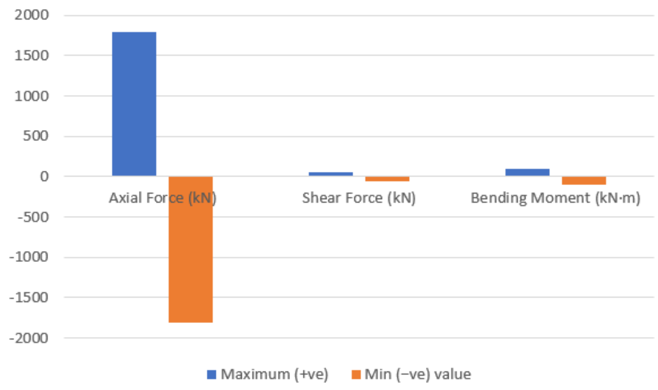

Fig. 7. Maximum column axial force in compression vs. the maximum tensile force. The large compressive force (≈1807.5 kN) far exceeds any tension, indicating stable behavior under the design lateral load.

IV. DISCUSSION

The seismic performance of the building can be interpreted in several ways:

1. Displacement Behaviour

The roof drift of 3.2258 mm (drift ratio ≈0.0011) is very low. Typical code limits for inter-story drift (for severe earthquakes) are on the order of 0.004 of story height [10]. Our structure's drift is well below that, implying a stiff system. No soft-story or irregular drift behavior was observed. This stiffness arises from the uniform frame geometry and substantial column sizes.

2. Base Shear

With nearly equal base shear in X and Z (~94 kN each), the building shows no torsional irregularity. Symmetric plan and mass distribution lead to balanced reactions [5]. In practice, this means the equivalent lateral forces predicted by code [1] were resisted uniformly. The total base shear magnitude (188.06 kN combined) is consistent with expectations for a 15 m, 400–500 kN story weight structure in Zone II (Z=0.10, R=5) [2].

3. Beam Forces

The beams exhibited small axial and shear forces, with bending moment as the critical design parameter. This matches the conceptual understanding that gravity frames (without shear walls) have beams mainly bending under lateral loads[7].

The maximum beam moment (149.9 kN·m) would govern reinforcement design, while the shear (14.3 kN) is minor. Since all values are low for M25/Fe500 sections, no overstress is indicated.

3. Column Forces

Columns carried the expected heavy axial loads (≈1.8 MN max) due to vertical weight. The additional bending (165.7 kN·m) and shear (58.9 kN) from seismic action are moderate by comparison. The large compression vs small tension in columns is typical for lateral sway of a symmetric frame. These internal forces would be checked per IS 456 design criteria, but they are within norms for the chosen section (300×450 mm) under combined loading.

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4. Structural Safety

All values lie within acceptable safety margins. No warnings, instabilities, or overstress indications appeared in STAAD.Pro.

Overall, the analysis confirms the frame's safety under code-level earthquake loading. There were no instabilities or code violations indicated. The results are consistent with similar studies showing that regular mid-rise RC frames can behave elastically under minor zones like Zone II [5]. Future work could extend this approach to dynamic spectrum analysis or higher seismic zones for performance-based design.

V. CONCLUSION

This study used STAAD.Pro to model and perform a linear static seismic analysis of a G+4 RC moment-resisting frame. Key conclusions are:

- Under IS 1893:2016 seismic loads, the structure remains highly stiff with very low drift (~3.23 mm at roof).
- Base shear values in X and Z are nearly equal (~94 kN), indicating symmetric behavior and no torsional irregularity.
- Beam end forces are low; bending moments govern beam design. Column axial forces are large (gravity effect) with moderate bending and shear.
- All computed forces and displacements are well within acceptable limits per Indian codes [1]–[3]. No overstress or serviceability issues were found.

These findings demonstrate that the modeled RC frame is seismically adequate for Zone II conditions. The methodology (STAAD.Pro + code-based loading + Excel plotting) provides clear insight into frame behavior, useful for students and practitioners. For enhanced analysis, one may employ dynamic spectrum methods or evaluate higher seismic zones. The analytical results here lay a sound foundation for such further study.

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