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Structural Response and Stability Analysis for Highrise Building in ETABS

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Abstract - This research presents ETABS-based structural analysis of a G+21 non-uniform high-rise RC building. The study includes modal analysis, response spectrum, P-Delta effects, wind gust calculations, eccentricity, torsional checks, storey drift, overturning checks and column verification in compliance with IS codes. The document includes generated figures and tables created from the numerical results available in the project file. All results satisfy codal criteria.

Key Words: ETABS, high-rise, seismic analysis, wind loads, modal participation, torsional irregularity

1.INTRODUCTION

Modern tall buildings often contain irregular shapes and non-uniform mass/stiffness distribution. This study evaluates a 69.81 m high G+21 structure subjected to wind and seismic forces per Indian standards. ETABS is used for modeling, load assignment, and dynamic analysis.

2. METHODOLOGY

This section describes the building geometry, loading conditions, analysis techniques, and codal provisions followed.

2.1 Building Geometry:
The structure has a height of 69.81 m with G+21 storeys. The slab is modeled as a membrane. Column and shear wall alignment follow architectural layout.

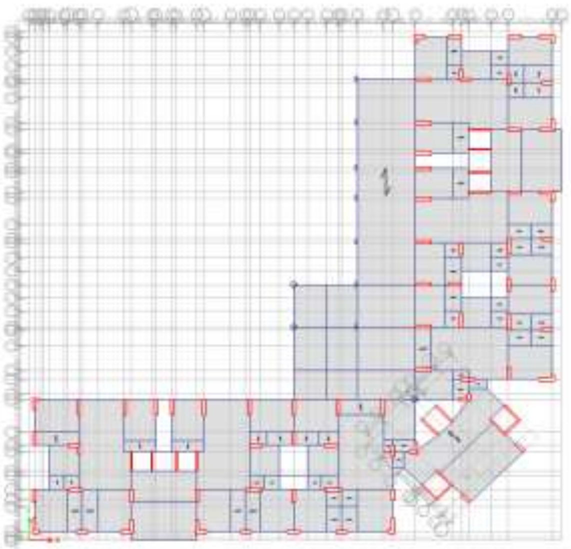

Fig -1: Figure of typical floor

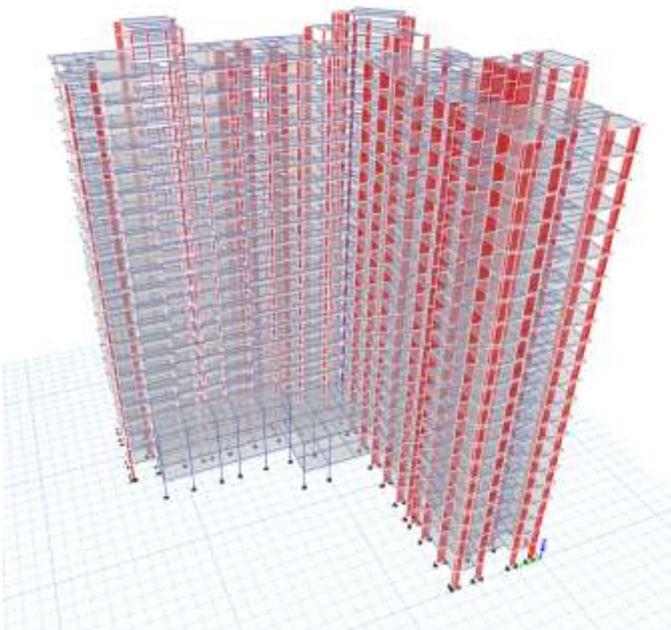

Fig -2: Figure of ETAB 3-D modal

2.2 Load Patterns:
Load patterns include DL, LL, floor finish, wall load, wind loads (WX, WY), and seismic loads (EQX, EQY).

Table -1: Table of loads

Load Pattern	Meaning	Typical Load
DEAD	Permanent loads (self-weight, structure)	Automatically from member weight
LIVE	Temporary loads (people, furniture)	Area load on slabs
FLOOR FINISH	Additional dead load on floor	1.0–1.5 kN/m²
WALL LOAD	Weight of walls on beams	Line load (e.g., 10 kN/m)
WINDX / WINDY	Wind force in +X or +Y direction	Auto wind load as per IS 875
EQX / EQY	Earthquake load in X and Y direction	Auto lateral load as per IS 1893

2.3 Load Combinations:
Load combinations were generated as per IS 456, IS 1893, and IS 875, ensuring worst-case load representation.

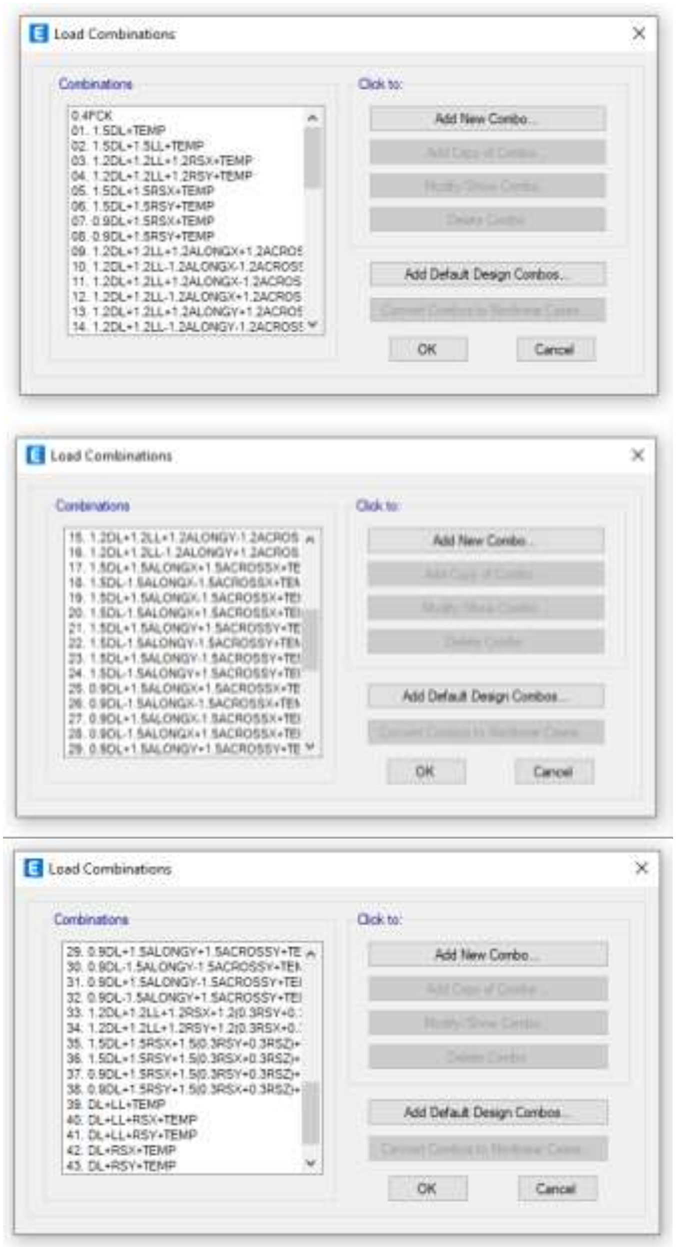

Fig -3: Figure of ETAB load combinations

2.4 P-Delta Analysis:
P-Delta effects were activated to account for second-order geometric nonlinearity.

Fig -4: Figure of ETAB P-delta

2.5 Response Spectrum Analysis:
RS curves were generated as per IS 1893 considering medium soil, 5% damping, and R and I factors.

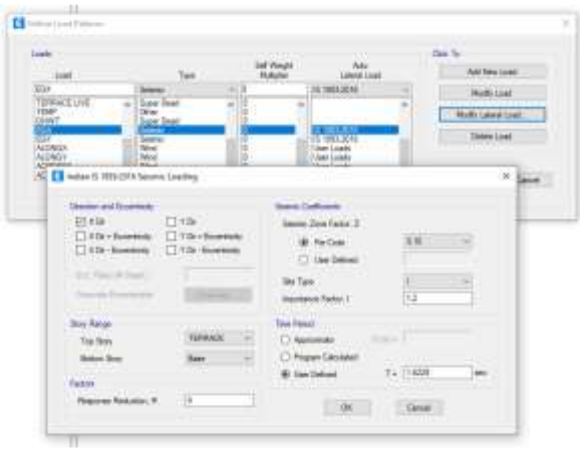

Fig -5: Figure of ETAB response spectrum

2.6 Wind Analysis:
Wind loads were calculated per IS 875 (Part 3) including gust factor G and along/across-wind components.

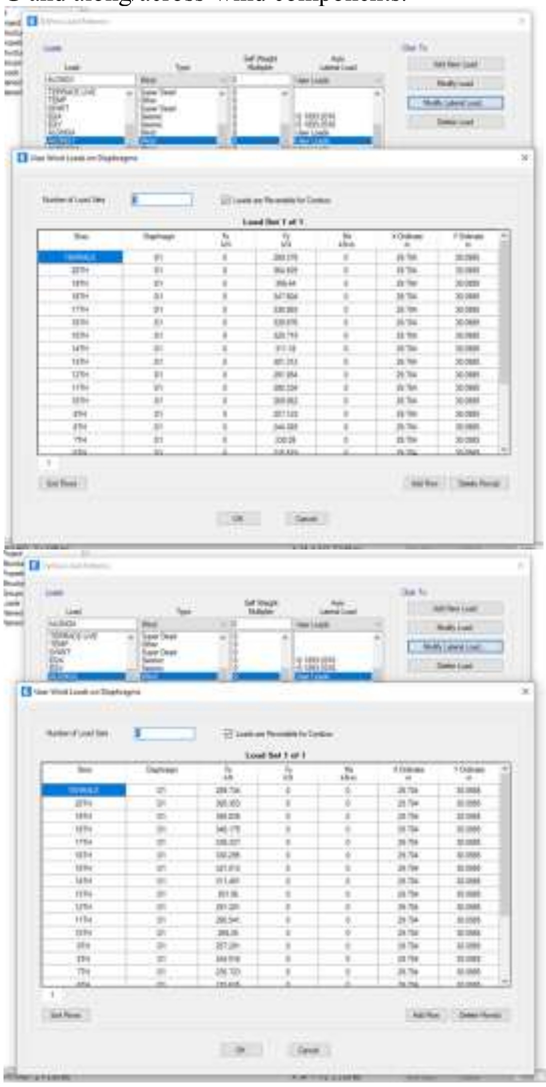

Fig -6: Figure of ETAB Along (x and y) data

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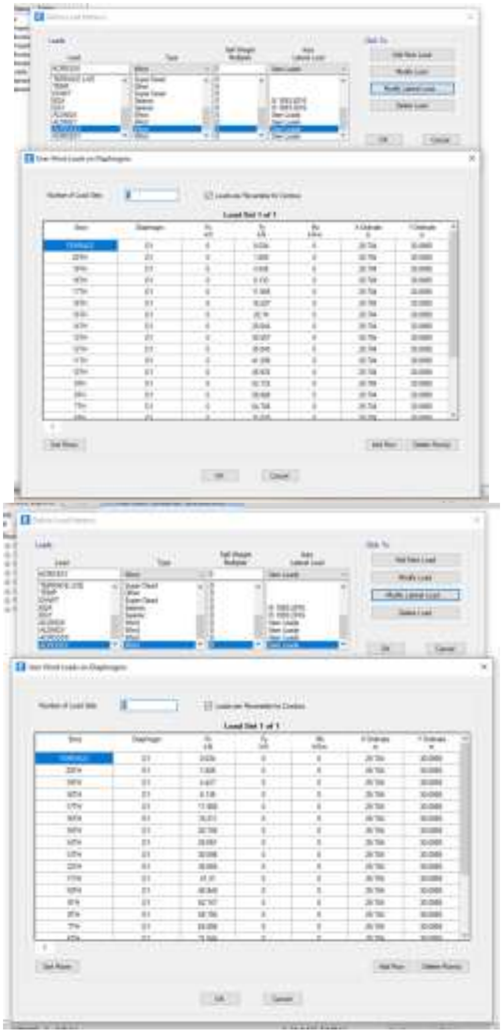
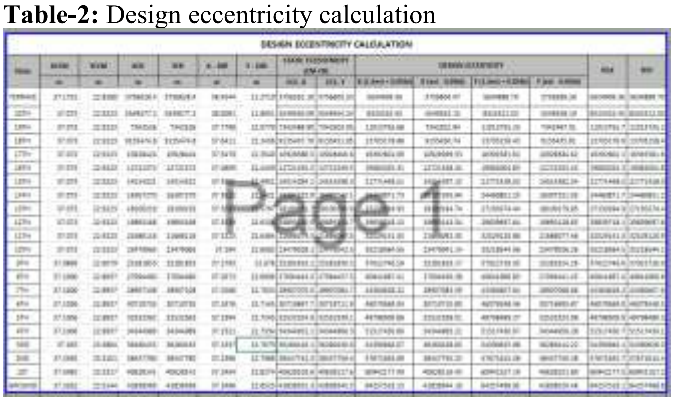


Fig -6: Figure of ETAB Across (x and y) data

2.7 Eccentricity Check:

- Accidental eccentricity equal to 5% of plan dimension was introduced as per IS 1893.
- Every building has:
  - a **centre of mass (CM)** → where the weight is concentrated
  - a **centre of rigidity (CR)** → where lateral stiffness resists earthquake forces
- If these two points do not lie on the same line, the building **twists** during an earthquake.
- IS 1893 requires adding **accidental eccentricity** to consider this twisting effect safely.

Table-2: Design eccentricity calculation



DESIGN ECCENTRICITY CALCULATION

3. RESULTS AND DISCUSSION

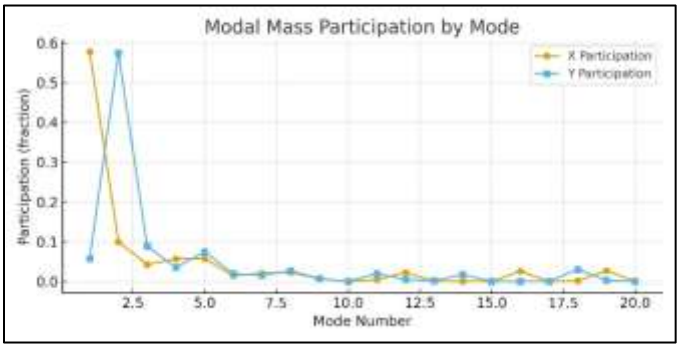
3.1 Modal Mass Participation:

Modal participation results (first 20 modes) used for dynamic analysis are shown below.

Table-2: Data for dynamic analysis

Mode	**Frequency In Hz**	**Time Period Sec.**	**X participation**	**Y participation**
1	0.217	4.6	0.5775	0.0576
2	0.220	4.553	0.0993	0.5741
3	0.248	4.025	0.0428	0.089
4	0.734	1.363	0.0568	0.0353
5	0.763	1.311	0.0574	0.0745
6	0.890	1.123	0.0146	0.0192
7	1.437	0.696	0.0209	0.0159
8	1.534	0.652	0.0227	0.0264
9	1.832	0.546	0.0067	0.0073
10	2.242	0.446	0.0002	3.32E-05
11	2.481	0.403	0.0045	0.0197
12	2.494	0.401	0.0228	0.0053
13	2.653	0.377	0.0012	0.0017
14	3.610	0.277	0.0004	0.0175
15	3.731	0.268	4.13E-05	5.04E-06
16	4.049	0.247	0.0256	3.92E-05
17	4.608	0.217	3.52E-06	0.0002
18	6.289	0.159	0.0017	0.0303
19	8.547	0.117	0.0273	0.003
20	10.204	0.098	0.0001	0.0002
Summation			0.9826	0.9774

Chart1



3.2 Torsional Irregularity Check:

Corner displacements and averages used for torsional irregularity check. Avg-X = 46.87 mm, Avg-Y = 42.37 mm. Percentage mass participation RSX and RSY reported in file: 89.86% and 89.23% respectively.

Check for Deflection in X Direction for Response Spectrum Case

Delta min = 42.12 mm (At node no 391 & Load case SpecX)
Delta max = 51.625 mm (At node no 437 & Load case SpecX)
Delta max < 1.5 x Delta min

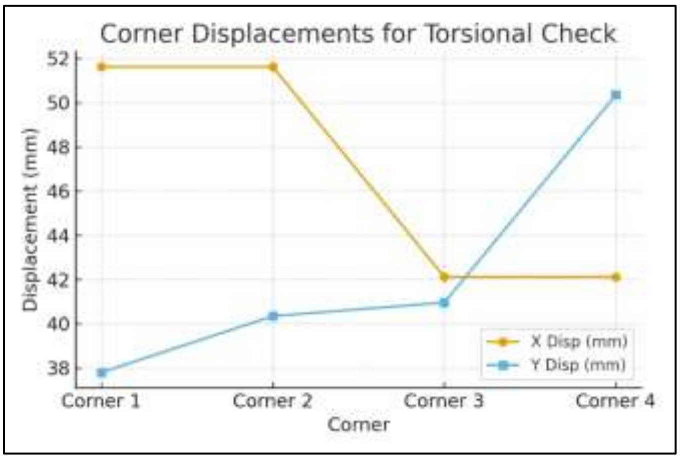
51.625 < 1.5 x 42.12 ….Hence OK.

Check for Deflection in Y/ Z Direction for Response Spectrum Case

Delta min = 37.80 mm (At node no 437 & Load case SpecY)
Delta max = 50.36 mm (At node no 398 & Load case SpecY)
Delta max < 1.5 x Delta min

50.36**< 1.5 x 37.80 ….Hence OK.**

Chart 2



3.3 Story drift:

Story drift is the lateral displacement of one floor of a building relative to the one directly above or below it, typically caused by lateral forces like earthquakes or wind. It is calculated by finding the difference in displacement between two adjacent stories and is often expressed as a ratio of the story drift to the story height.

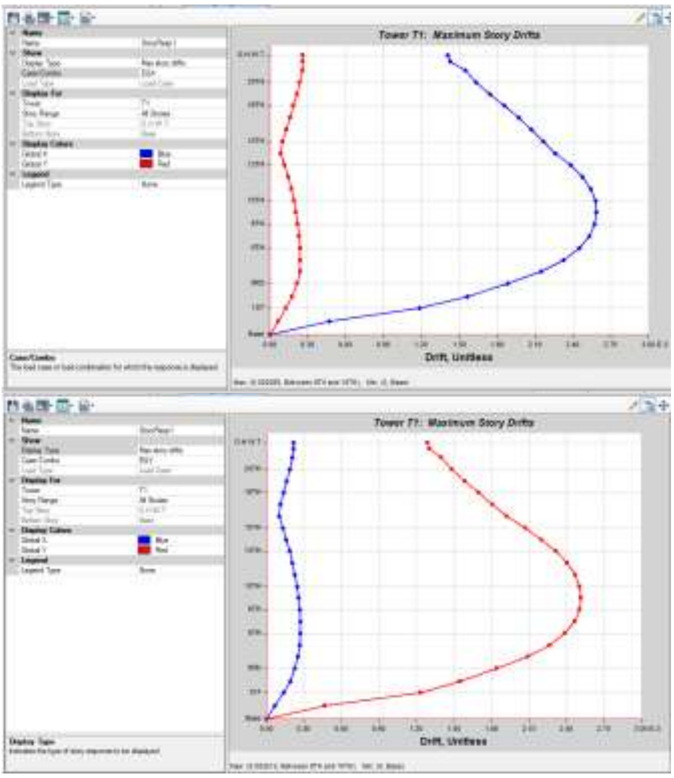


Fig -7: Figure of story drift for seismic analysis

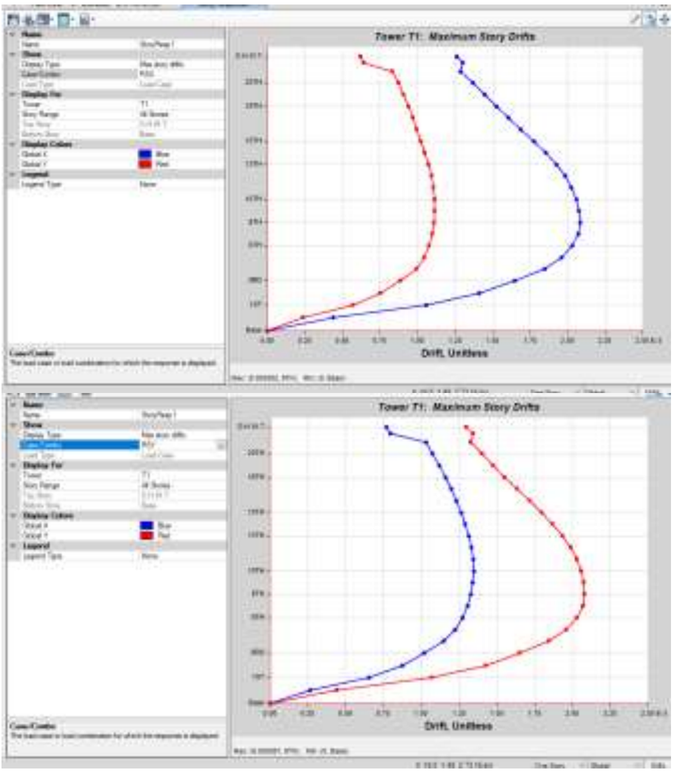


Fig -8: Figure of story drift for response analysis

Max Storey Drift in X Direction for Response Spectrum Case

Storey drift max = 0.00256 m (Load case SpecX)
Storey drift max < 0.004 x height

0.00256**< 0.004 x 69.81 ….Hence OK.**

Max Storey Drift in Y Direction for Response Spectrum Case

Storey drift max = 0.002515 m (Load case SpecX) Storey drift max < 0.004 x height

0.002515< **0.004 x 69.81 ….Hence OK.**

Max Storey Drift in X Direction for Seismic case

Storey drift max = 0.002082 m (Load case EX) Storey drift max < 0.004 x height

0.002082 **< 0.004 x 69.81 ….Hence OK.**

Max Storey Drift in Y Direction for Seismic case

Storey drift max = 0.002081 m (Load case EY) Storey drift max < 0.004 x height

0.002081**< 0.004 x 69.81 ….Hence OK**

3.4 Overturning moment:

Overturning moment is the rotational force that causes a structure to tip over around a pivot point, typically the base. It is the "torque" or "rotational force" generated by external loads like wind, earthquakes, or seismic activity, and is calculated by multiplying the horizontal force by its perpendicular distance from the pivot point. If the overturning moment exceeds the resisting moment (created by the structure's own weight), the structure will overturn.

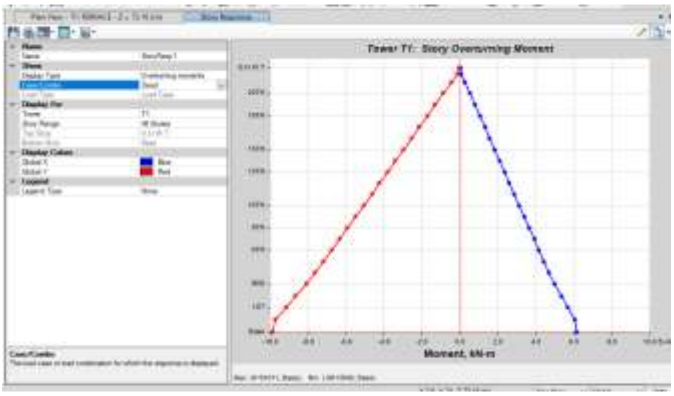


Fig -9: Figure of overturning for dead load

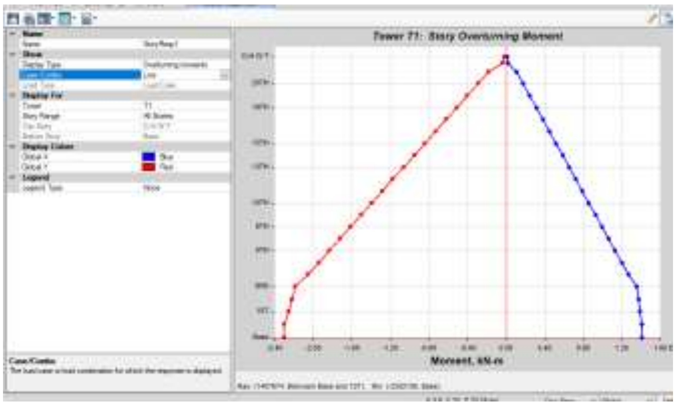


Fig -10: Figure of overturning for live load

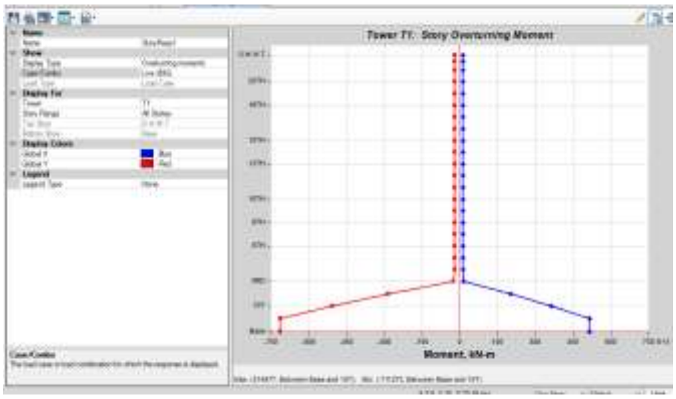


Fig -11: Figure of overturning for live(big) load

Overturning(restoring)>1.2(D.L)+1.4(L.L)

=0.9*d(pivot)*W>100.76

866.01>**100.76….Hence OK.**

4. CONCLUSIONS

The analysis demonstrates that the high-rise irregular RC building satisfies all structural safety requirements under seismic and wind loads. The ETABS model effectively captured dynamic characteristics including mode shapes, drift profiles, and stability performance. The study confirms the importance of including P-Delta effects and wind–gust calculations in tall building analysis.

ACKNOWLEDGEMENT

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