Static analysis and design of G+10 RCC framed structure by using ETABS

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Abstract - *ETABS stands for Extended Three-Dimensional Analysis of Building Systems. Static analysis in ETABS primarily involves the examinations of a structure's behaviour under various static loads, aiming to determine its stability, strength, and deformation characteristics. It utilizes the finite element method to perform this analysis. This project presents a comprehensive study on the static analysis and design of a G+10 Reinforced Cement Concrete (RCC) framed structure employing ETABS software. The objective is to analyse the structural behaviour and ensure compliance with various design codes and standards. The study includes the modelling of the structure in ETABS, applying appropriate loads, and performing static analysis to evaluate its stability, strength, and performance under various conditions. Furthermore, the project explores the design aspects by considering factors like material properties, safety measures, and optimization techniques. The values of dead loads and live loads are taken as per* [6]. *Results obtained from the analysis are discussed, providing insights into the structural efficiency and integrity of the G+10 RCC framed structure designed through ETABS software.*

Key Words: *Static Analysis, ETABS, G+10, RCC, finite element method, static loads,*

1. INTRODUCTION

Understanding the structural behaviour of high-rise constructions like G+10 buildings is paramount for ensuring their resilience. This research employs advanced ETABS software to meticulously analyse the static characteristics, investigating the stability, and deformation tendencies of this ten-story structure. By delving into the intricate details of its structural performance, this study aims to offer comprehensive insights essential for optimizing design methodologies and fortifying the safety standards of similar high-rise edifices in the field of construction.

1.1 About ETABS: ETABS specializes in performing structural analysis, modelling, and design of buildings. Its capabilities encompass diverse functionalities, including but not limited to finite element analysis, seismic analysis, and design code compliance checks. ETABS utilized for simulating and evaluating the behaviour of structures under various loads, enabling precise assessment, design optimization, and ensuring compliance with international building codes and standards.

2. LITERATURE REVIEW:

k. Naga Sai Gopal and N. Lingeshwaran (2017), In the project they used the ETABS software due to company suggestion and to final stress analysis in slab, shear force for the beam and area reinforcement for the column and design the foundation depends upon the reaction and height of the foundation level depends upon site and safe bearing capacity of the soil stability purpose designed the retaining wall in this project.

Puneet Mittal; Nishant kad, all structures are analyzed & designed according to code requirements using manual calculations or by the use of many different analysis and design software like STAAD PRO, ETABS. But it has been found that it is difficult to perform manually, so to overcome this problem analyzing and designing is done by using software meant for this work.

3. OBJECTIVES

- To carryout analysis and design of main structural elements of super structure such as slabs, beams and columns.
- To perform analyse the forces, bending moments, stress, strain deformations or deflections for a complex structural system.
- Verify building safety under various loads to prevent structural failures.
- Ensure even stress distribution across structural elements for robustness.
- Enhance structural efficiency while maintaining safety standards.
- Assess building resilience in earthquakes and severe weather scenarios.
- Confirm alignment with building codes and industry standards for construction approval.

4. METHODOLOGY

4.1 BUILDING DESCRIPTION:

Building type: Residential building(G+10)

Buildup area: 836 m²

Floor height: 3m

Seismic zone: II zone

Importance factor: 1

Soil type: I-Rock

External wall thickness: 230mm

Internal wall thickness:115mm

Column size: 450*500

Beam size: 300*450

Cover: 60mm

Grade of concrete: 35MPa

Grade of steel: 500Mpa

Slab: 150mm, Shear wall: 200mm

4.2 LOAD DETAILS:

Floor finished load :1.5 KN/ m²

Live load: 2.5 KN/m² (IS 875 Part 2, 1987)

Dead load: 3.75KN/m² (IS 875 Part 1, 1987)

Wall loads on exterior Beams: 13.8 KN/m²

Partition wall loads: 6.9 KN/m²

Terrace load: 1.5 KN/m²

Parapet load: 3.45 KN/m²

Earthquake load: as per 1893 part 1 2016

Wind loads: IS 875 Part 3 2015

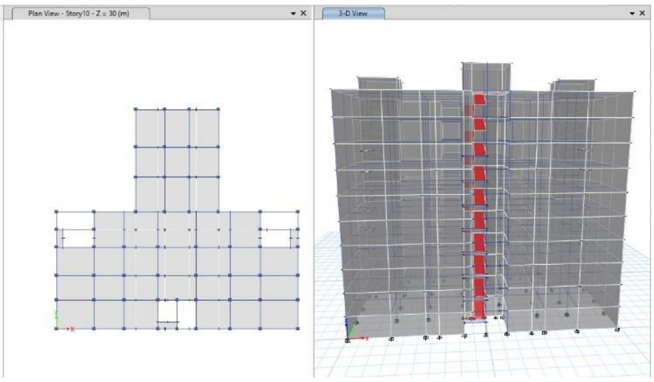


Fig: 1 Plan and 3D views

5. ANALYSIS RESULTS AND DISCUSSION

In the analysis results discussion, several crucial factors demand attention for comprehensive structural evaluation, Among these are overturning moments, pivotal in determining the rotational forces impacting a structure. Story shear, reflecting the maximum lateral force experienced at each building level,aids in reinforcing elements against lateral loads. Additionally, assessing maximum story displacement, highlighting the greatest vertical or horizontal movement between floors during seismic or wind events, is vital. These checks collectively guide engineers in fortifying structures, ensuring stability, and safeguarding against potential damage from various forces.

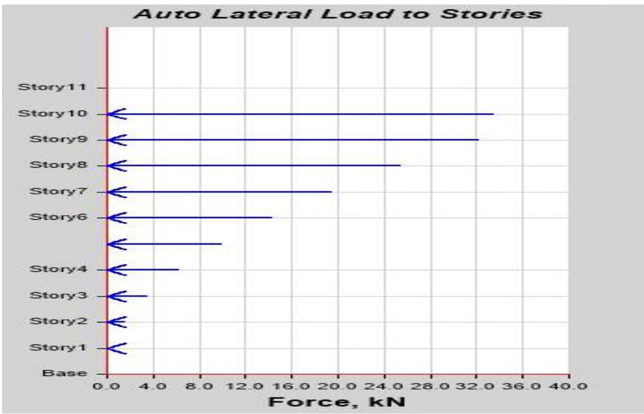


Fig :2 Load pattern EQ-X

5.1 Maximum story displacement: Maximum story displacement refers to the greatest vertical or horizontal movement experienced between floors during seismic or wind events. It's a critical parameter in structural assessment, guiding engineers to reinforce buildings against excessive movement, ensuring structural integrity and occupant safety.

Table: 1 Story response values

Story Response Values

Story	Elevation	Location	X-Dir	Y-Dir
	m		mm	mm
Story11	33	Top	0.982	2.005
Story10	30	Top	0.703	1.322
Story9	27	Top	0.576	1.085
Story8	24	Top	0.471	0.894
Story7	21	Top	0.377	0.719
Story6	18	Top	0.293	0.555
Story5	15	Top	0.221	0.409
Story4	12	Top	0.178	0.286
Story3	9	Top	0.151	0.187
Story2	6	Top	0.125	0.151
Story1	3	Top	0.107	0.185
Base	0	Top	0	0

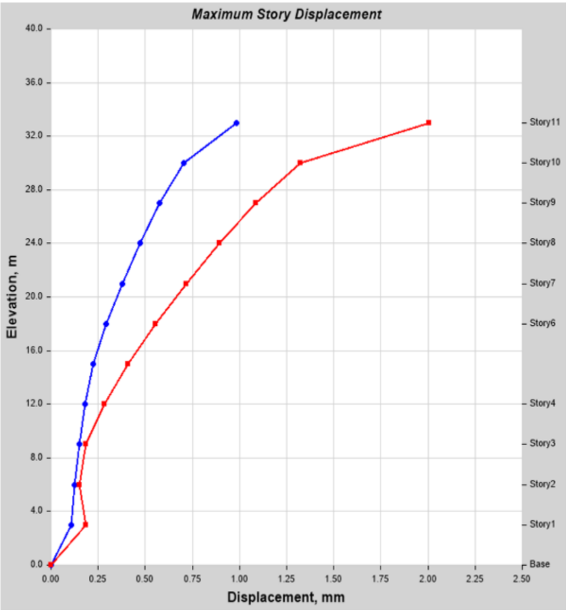


Fig: 3 Maximum story displacement

5.2 Maximum story drifts : Maximum story drift denotes the greatest lateral displacement between floors during seismic or wind events. Crucial in design, it informs engineers about structural movement, aiding in reinforcement strategies to maintain stability and minimize potential damage in buildings subjected to lateral forces.

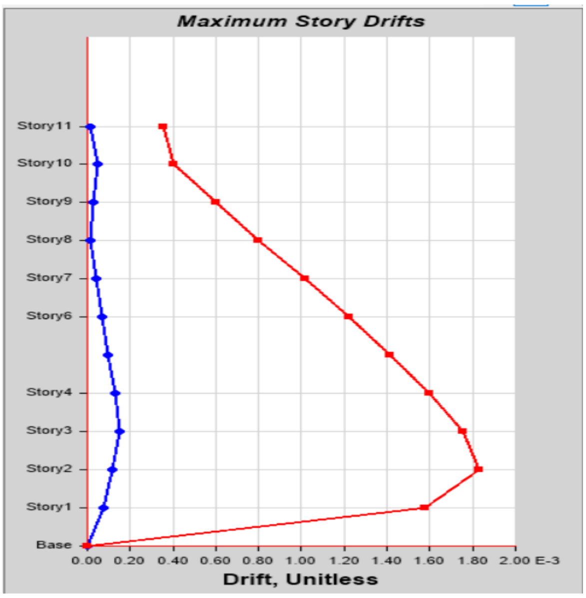


Fig: 4 Maximum story drifts (WIND-X)

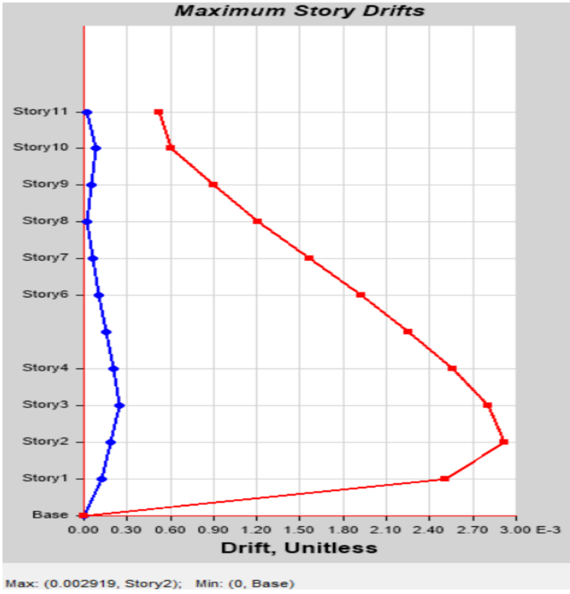


Fig: 5 WIND-Y

Table: 2 Maximum story drift value table (WIND-X)

Story	Elevation m	Location	X-Dir	Y-Dir
Story11	33	Top	1.5E-05	0.000352
Story10	30	Top	4.8E-05	0.000406
Story9	27	Top	2.8E-05	0.000604
Story8	24	Top	1.6E-05	0.000801
Story7	21	Top	4.1E-05	0.001018
Story6	18	Top	6.7E-05	0.001222
Story5	15	Top	9.6E-05	0.001416
Story4	12	Top	0.000127	0.001598
Story3	9	Top	0.000152	0.001755
Story2	6	Top	0.000116	0.00183
Story1	3	Top	7.8E-05	0.001575
Base	0	Top	0	0

Table: 3 Maximum story drift value table (WIND-Y)

Story	Elevation m	Location	X-Dir	Y-Dir
Story11	33	Top	2.3E-05	0.000527
Story10	30	Top	7.8E-05	0.000608
Story9	27	Top	4.8E-05	0.000901
Story8	24	Top	2.1E-05	0.001203
Story7	21	Top	6.3E-05	0.001571
Story6	18	Top	0.000107	0.001924
Story5	15	Top	0.000154	0.002256
Story4	12	Top	0.000204	0.002556
Story3	9	Top	0.000244	0.002804
Story2	6	Top	0.000186	0.002919
Story1	3	Top	0.000123	0.002508
Base	0	Top	0	0

5.3 Maximum story shear: Maximum story shear represents the highest lateral force experienced at a building level. It's critical in structural design, guiding engineers to reinforce elements against lateral loads like wind or earthquakes, ensuring structural stability and safety.

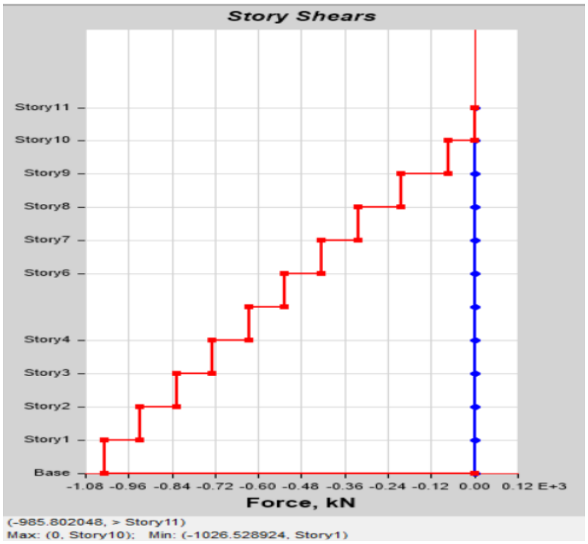


Fig: 6 story shears (WIND-X)

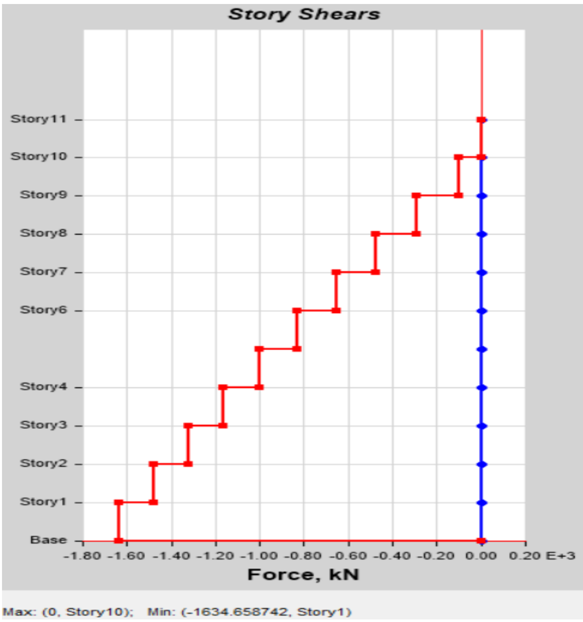


Fig: 7 story shears (WIND-Y)

5.4 Overturning moments: Overturning moments, pivotal in structural engineering, induce rotational forces aiming to topple a structure, Engineers counter these forces via foundation design, strategic structural elements, and stability considerations, crucial for preventing excessive rotation or collapse.

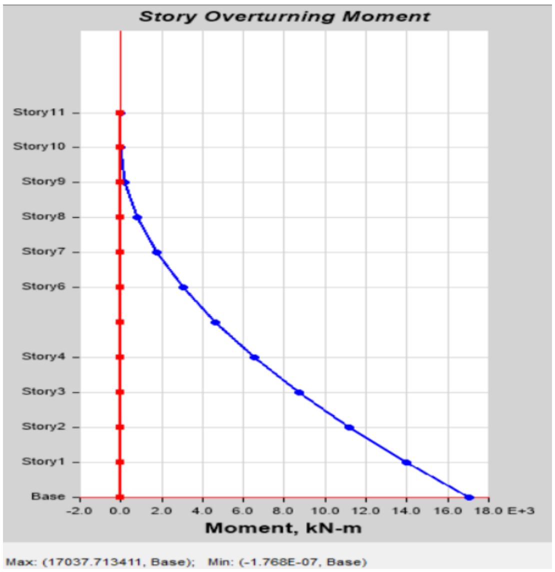


Fig:8 Story overturning moment(W-X)

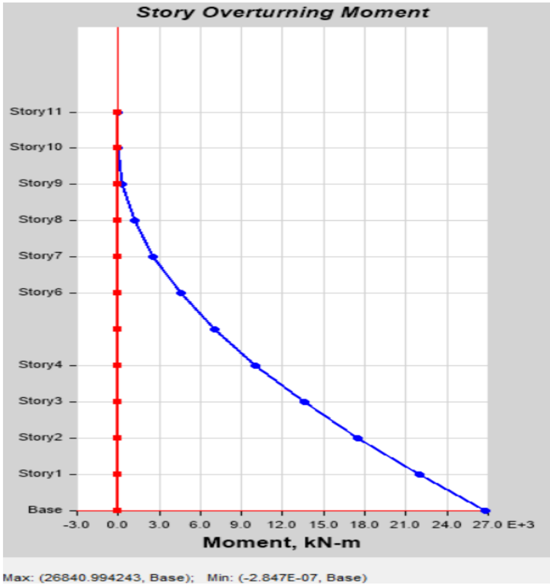


Fig:9 Story overturning moment

5.5 Shear force: Shear force in a building refers to the lateral force acting horizontally along the structure's floors and walls. Analysing and designing to mitigate these shear forces are critical to ensuring the structural strength and safety, often done using software like ETABS to simulate and optimize the structure's response to such forces.

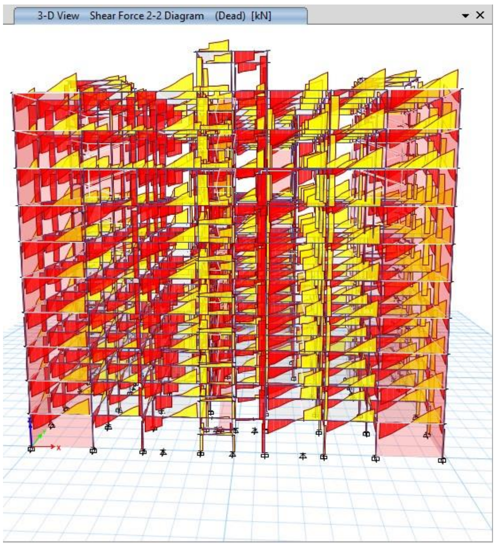


Fig: 10 shear force diagrams

5.6 Axial force: Axial forces in a building refer to the vertical loads transmitted through columns and walls, primarily from the building's own weight and imposed loads. These forces exert compressive or tensile stresses on structural elements, influencing their stability and load-bearing capacity, essential for ensuring the building's structural integrity.

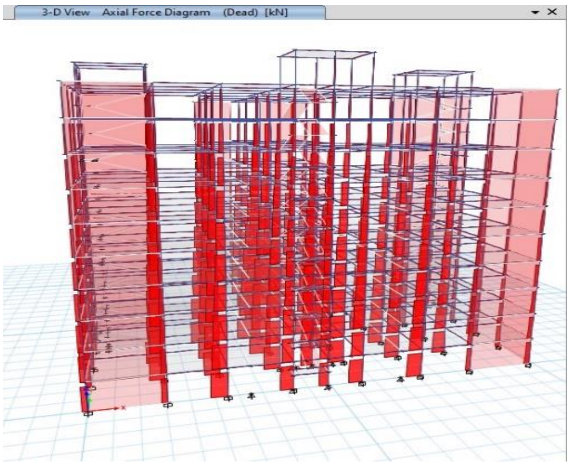


Fig: 11 Axial force diagrams

5.7 Bending moment: Bending moments in a building result from horizontal and vertical loads, causing flexural stresses in beams and slabs. These moments induce curvature and internal stresses, crucial for design considerations to ensure structural elements withstand imposed loads and maintain stability within the building' framework.

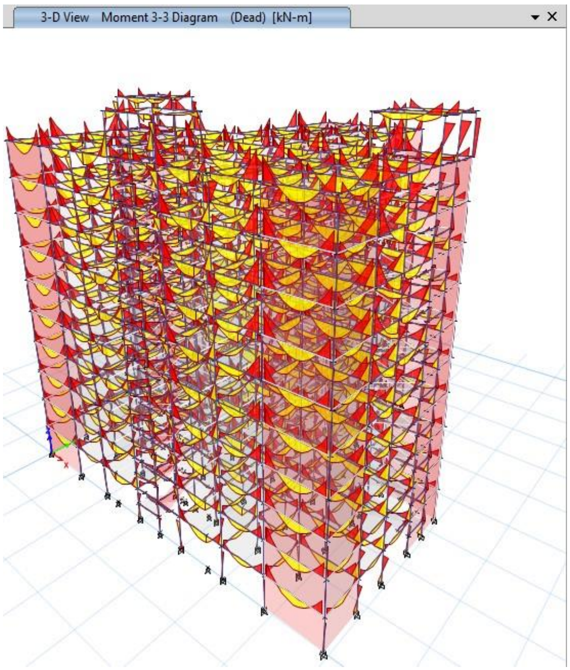
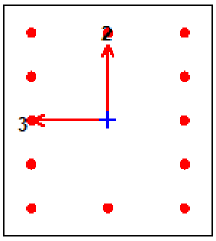


Fig:12 Bending moment diagrams

ETABS Concrete Frame Design
IS 456:2000 + IS 13920:2016 Column Section Design (Summary)



Column Element Details

Level	Element	Unique Name	Section ID	Combo ID	Station Loc	Length (mm)	LLRF	Type
Story10	C48	157	C450*500	DConS23	2550	3000	0.96	Ductile Frame

Section Properties

b (mm)	h (mm)	dc (mm)	Cover (Torsion) (mm)
450	500	60	30

Material Properties

E_c (MPa)	f_{ck} (MPa)	Lt. Wt Factor (Unitless)	f_y (MPa)	f_{ys} (MPa)
29580.4	35	1	413.69	413.69

Design Code Parameters

γ_C	γ_S
1.5	1.15

Axial Force and Biaxial Moment Design For P_u , M_{u2} , M_{u3}

Design P_u kN	Design M_{u2} kN-m	Design M_{u3} kN-m	Minimum M_2 kN-m	Minimum M_3 kN-m	Rebar Area mm^2	Rebar % %
153.9665	-28.3129	-106.6691	3.0947	3.3513	1800	0.8

Axial Force and Biaxial Moment Factors

	K Factor Unitless	Length mm	Initial Moment kN-m	Additional Moment kN-m	Minimum Moment kN-m
Major Bend(M3)	0.771761	2550	-5.7997	0	3.3513
Minor Bend(M2)	0.86706	2550	-11.3252	0	3.0947

Axial Compression Check for Seismic Design per IS 13920:2016 Section 7.1

Limit Compression Factor Unitless	Limit Compression Strength kN	Compression D/C Ratio Unitless	Status
0.4	3150	0.048878	OK

Shear Design for V_{u2} , V_{u3}

	Shear V_u kN	Shear V_c kN	Shear V_s kN	Shear V_p kN	Rebar A_{sv} /s mm^2/m
Major, V_{u2}	71.1127	99.8525	79.2003	71.1127	500.38
Minor, V_{u3}	71.9131	99.0902	78.0004	71.9131	555.98

Joint Shear Check/Design

	Joint Shear Force kN	Shear V_{Top} kN	Shear $V_{u,Tot}$ kN	Shear V_c kN	Joint Area cm^2	Shear Ratio Unitless
Major Shear, V_{u2}	0	0	199.9122	1331.118	2250	0.15
Minor Shear, V_{u3}	0	0	205.5916	1331.118	2250	0.154

(1.4) Beam/Column Capacity Ratio

Major Ratio	Minor Ratio
0.338	0.354

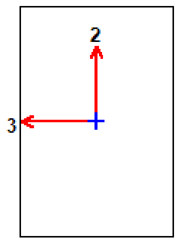
Additional Moment Reduction Factor k (IS 39.7.1.1)

A_g cm^2	A_{sc} cm^2	P_{uz} kN	P_b kN	P_u kN	k Unitless
2250	18	4102.2254	1586.9978	153.9665	1

Additional Moment (IS 39.7.1)

	Consider M_a	Length Factor	Section Depth (mm)	KL/Depth Ratio	KL/Depth Limit	KL/Depth Exceeded	M_a Moment (kN-m)
Major Bending (M_3)	Yes	0.85	500	3.936	12	No	0
Minor Bending (M_2)	Yes	0.85	450	4.913	12	No	0

IS 456:2000 + IS 13920:2016 Beam Section Design (Summary)



Beam Element Details

Level	Element	Unique Name	Section ID	Combo ID	Station Loc	Length (mm)	LLRF	Type
Story10	B212	179	B 300*450	DConS26	3200	3200	1	Ductile Frame

Section Properties

b (mm)	h (mm)	b_f (mm)	d_s (mm)	d_{ct} (mm)	d_{cb} (mm)
300	450	300	0	60	60

Material Properties

E_c (MPa)	f_{ck} (MPa)	Lt.Wt Factor (Unitless)	f_y (MPa)	f_{ys} (MPa)
29580.4	35	1	413.69	413.69

Design Code Parameters

γ_C	γ_S
1.5	1.15

Factored Forces and Moments

Factored M_{u3} kN-m	Factored T_u kN-m	Factored V_{u2} kN	Factored P_u kN
-19.5948	1.6375	34.9407	3.5806

Design Moments, M_{u3} & M_t

Factored Moment kN-m	Factored M_t kN-m	Positive Moment kN-m	Negative Moment kN-m
-19.5948	2.4081	0	-22.0029

Design Moment and Flexural Reinforcement for Moment, M_{u3} & T_u

	Design -Moment kN-m	Design +Moment kN-m	-Moment Rebar mm^2	+Moment Rebar mm^2	Minimum Rebar mm^2	Required Rebar mm^2
Top (+2 Axis)	-22.0029		402	0	159	402
Bottom (-2 Axis)		0	100	0	0	100

Shear Force and Reinforcement for Shear, V_{u2} & T_u

Shear V_e kN	Shear V_c kN	Shear V_s kN	Shear V_p kN	Rebar A_{sv} /s mm^2/m
76.8607	0	85.5941	41.9172	610.11

Torsion Force and Torsion Reinforcement for Torsion, T_u & V_{U2}

T_u kN-m	V_u kN	Core b_1 mm	Core d_1 mm	Rebar A_{svt} /s mm^2/m
1.6375	34.9407	200	350	0

6. CONCLUSION:

The project on the static analysis and design of the G+10 RCC framed structure using ETABS software signifies a comprehensive endeavour in understanding the structural behaviour of high-rise constructions. Through meticulous analysis and simulations, this project aimed to unravel crucial insights into the stability, strength, and overall performance of the structure. The findings and design considerations obtained from ETABS have provided valuable knowledge essential for optimizing the design, ensuring structural integrity, and adhering to stringent safety standards. Displacement increases as move to top story. Failed beams can be resized by selecting particular beams and columns. Beams and columns dimensions should increase to resist wind loads and seismic loads. This study serves as a foundation for further advancements in high-rise construction methodologies, emphasizing the importance of robust analysis tools like ETABS in shaping safer and more efficient structural designs for future developments."

7. REFERRENCES

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