Planning, Analysis And Designing Of 2B+G+9 Residential Building Using ETABS, Autocad And SAFE Software

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Abstract - *The process of planning and crafting a structure is an artistic endeavor with the goal of ensuring safety, functionality, durability, and cost-effectiveness. Successful structural planning requires not only creativity and conceptual thinking but also a solid grasp of structural engineering principles, practical considerations, design codes, and building regulations based on hands-on experience. While architects typically address functional and aesthetic aspects, structural engineers concentrate on guaranteeing the safety, functionality, durability, and cost-effectiveness of the structure.*

In this specific project, a site has been chosen for an 2B+G+9 story building with four apartments on each floor, providing essential residential facilities. The primary focus is on analyzing and designing the apartment building, considering only dead load and live load for analysis and design. Dead loads are determined following IS-875 (Part 1), and live loads are based on IS-875 (Part 2). AutoCAD is used for creating the plan and elevation, with a focus on the exterior appearance.

For analysis, E-Tabs software is employed, while the manual design of structural elements such as slabs, beams, columns, and footings is undertaken. The project strictly adheres to building by-laws, and the design complies with specified codes, including IS:456-2000 for Plain and Reinforced Concrete and SP-16 for Design Aids for Reinforced Concrete. Additionally, the Code of Practice of Design Loads (IS: 875 Part 1 and Part 2) is applied throughout the design process.

Key Words: ETABS, WIND ANALYSIS, P-DELTA ANALYSIS, BUCKLING ANALYSIS, MODAL ANALYSIS

1. INTRODUCTION

In the intricate process of planning, analyzing, and designing a 2B+G+9 residential building, a structured approach is imperative to ensure a seamless transition from conceptualization to execution. The initial planning phase involves meticulous site selection, taking into account factors such as accessibility, utility availability, and adherence to zoning regulations. Simultaneously, client requirements are carefully assessed, and project goals are defined, forming the foundation for subsequent design decisions.

The analysis phase, conducted using ETABS software, is a critical step in guaranteeing the structural integrity and safety of the building. Structural assessments are performed to understand the load-bearing requirements, followed by detailed load calculations encompassing live loads, dead loads, and other relevant factors. The utilization of ETABS for seismic analysis ensures that the structural design meets stringent safety standards, especially crucial for multi-story buildings. This phase is pivotal in determining the robustness and resilience of the structurein the face of potential environmental challenges.

Subsequently, the design phase unfolds, primarily orchestrated through AutoCAD software. This stage involves the creation of comprehensive architectural designs, including detailed floor plans and elevations. AutoCAD facilitates the integration of structural design elements, ensuring alignment with the analysis results obtained from ETABS. The software proves instrumental in developing construction drawings that provide precise dimensions and specifications, laying the groundwork for the physical realization of the residential building. The process is iterative, with constant refinements based on feedback and evaluations. Coordination between architectural and structural aspects is paramount, and AutoCAD becomes the tool of choice for revisions and updates, maintaining design consistency throughout the project's evolution. Collaboration among architects, structural engineers, and other stakeholders is fostered, ensuring a holistic and well-coordinated design approach.

A meticulous documentation process accompanies each phase, recording design decisions, calculations, and changes made during planning and design. This comprehensive set of construction documents serves as a blueprint for the construction team, ensuring that the envisioned 2B+G+9 residential building is executed precisely according to the design intent. In essence, the integration of ETABS and AutoCAD software in the planning, analysis, and design phases provides a robust framework for the efficient and accurate development of a multi-story residential structure

1.1 Objective of the Study

- Apply ETABS software for the design and analysis of a residential building encompassing two basements, a ground floor, and nine additional floors.
- Evaluate the structure's stability and workability against a range of natural events.
- Confirm the stability of beams and columns under the specified load conditions.
- Perform an analysis for shear and bending moments.
- Conduct the analysis in accordance with all applicable Indian Standard Codes for buildings.
- The primary objective of structural design is to guarantee the strength, stability, and workability of the structure. The design must fulfill three key requirements: stability to prevent overturning, sliding, or buckling; strength to resist induced stress in various structural elements; and serviceability to ensure satisfactory performance under service load conditions, maintaining ample strength, stiffness, reinforcement, and limiting deflection and vibration within acceptable limits
- Examining the dynamic performance of a raft footing under different loads and investigating structural behavior concerning factors such as moments, punching shear, and deflection using SAFE software.

2. LITERATURE REVIEW

Nidhish Vijay Pawar et al. (2023)[1] design and analysis of a residential building comprising 22 floors (G+22) has been successfully completed. This software is characterized by user-friendly handling and a visually intuitive interface, enhancing efficiency and saving time. It facilitates easy computation of required reinforcement in structures and provides a comprehensive 3D view of the structure.ETABS offers the capability to calculate wind loads and seismic loads acting on the structure, emphasizing its primary usage in the design and analysis of framed RCC structures.

U C Ahammed Kutty et al. (2022)[2] revealed challenges, and the structural engineer navigated constraints to align with architectural drawings Utilizing ETABS, the design of RCC frame components like beams and columns was meticulously undertaken, adhering to standard specifications as much as possible.The planning and design of a ten-story apartment building were executed, employing ETABS V15.2 software for thorough analysis. This software, renowned for its excellence, demonstrated remarkable efficacy in handling diverse structural aspects Following the findings of the soil investigation report, an isolated footing was implemented.

Dr. Alok Singh et al. (2019)[3]research, evaluation, and design process were undertaken for a multi-story residential building, consisting of ground plus 25 stories. The structure includes ground-floor parking and upper-level apartments. AutoCAD was employed to design and detail all structural components, while analysis and design utilized both STAAD and conventional criteria, making it an optimal choice for static and dynamic loads. Structural member sizes were calculated, incorporating dead, live, and seismic loads. Comprehensive deflection and shear tests were conducted on beams, columns, and slabs, confirming their safety. The project involved a blend of theoretical and practical work, ensuring a well-rounded completion.

Manas Rathore et al. (2021) [4] focuses on the most economical column method, aiming to achieve this by reducing section sizes. Given that the load is greater at the bottom than the top, it's unnecessary to provide a larger column size at the top. By adhering to IS Codes, we can optimize column design by providing the required amount specified. Typically, the minimum percentage of steel area is 0.8% of the Gross cross-sectional area, while the maximum is set at 6% according to IS code.With increasing structure height, the slenderness effect or long column effect becomes significant. Utilizing ETABS software not only saves working time but also facilitates accurate structure design.

Harendra Nath Pandey et al. (2020) [5] is modeled after E-Tabs, ensuring optimal serviceability, strength, and cost-effectiveness. Utilizing ETABS software not only saves time but also enhances the precision of structural design. Structural elements were devised through both manual methods and software assistance. Urban areas, constrained by limited land, prompt the construction of multi-story buildings to maximize vertical space utilization. Instead of clearing forests and swamps for housing, shopping centers, and factories, placing them in vertical towers is a sustainable approach to environmental preservation.

Dr.G.D.Awchat et al. (2021)[6] The utilization of ETABS software not only streamlines the analysis and design processes, significantly reducing time, but also ensures high accuracy. This software facilitates the easy retrieval of structure values, accommodating diverse zones and soil types. The values vary based on soil conditions; for instance, soil 1 yields lower values, while soil 3 presents higher values. This observation indicates that soil 1 has a lower base shear compared to soil 2 and soil 3.

Dr. Yusuf et al. (2021)[7] - analysis results align with geotechnical and structural engineering codes, aiding in predicting natural threats, preventing issues, and comprehending soil foundation behavior over time.Some researchers have explored soil profiles like Aeolian and black cotton, directly impacting the Safe Bearing Capacity (SBC) and the structures built on them.Enhanced bearing capacity during compaction is a key feature in the soft foundation during the subclass filling stage. Laboratory studies in soil mechanics contribute to precise soil foundation design, improving failure mitigation. Soil mixing designs have been utilized in geotechnical engineering to enhance soil properties. Emphasizing the importance of studying foundation design concerning soil conditions is crucial for achieving stable and secure designs for high-rise and multi-storey buildings. Evaluation of earthquake-resistant buildings, considering foundation depth, can be conducted manually or through software, utilizing both linear and non-linear approaches for structural analysis. Assessment of bearing capacity, employing manual methods and tests such as Standard Penetration Test (SPT) and Core test, is essential before constructing building designs. The study explores various software applications for analysis, including Plaxis, FEM, ABACUS, ETABS, incorporating 3D Finite Element Method (FEM) analysis. Some researchers base their studies on testing approaches to analyze soil, foundation, and failure mechanisms.

Zia-abe Deen. S. Punekar et at. (2017) [8] concludes that the analysis and design of the Raft footing focus on the critical envelope combination, particularly for dynamic scenarios. Regarding moment considerations, the study indicates that the steel area obtained from the SAFE software's envelope combination matches that obtained from strips, affirming the design process's validity for this combination. Additionally, the study finds the mat/raft foundation to be safe against punching shear or two-way shear, with a punching shear ratio below 1. Observations on deflection reveal a slight hogging deflection in the raft footing, deemed within acceptable limits and not detrimental to the building. The detailing and casting process for raft footings is simplified compared to isolated footings, with excavation and concrete pouring completed simultaneously, leading to cost and time savings.

3. METHODOLOGY

The methodology for planning, analyzing, and designing a residential building with two basements, a ground floor, and nine additional levels using ETABS and AutoCAD comprises several sequential steps:

Project Initiation:
Define the project's goals, limitations, and scope.
Collect information on the site, including geography, soil conditions, and local regulations.

Architectural Planning:
Collaborate with architects to devise the building layout, considering functional needs, aesthetics, and local zoning regulations.
Utilize AutoCAD for detailed structural drafting, creating construction drawings with precise measurements and requirements.
Ensure synchronization between structural and architectural drawings.

Structural Conceptualization:
Create an initial structural concept based on architectural plans.
Identify load-bearing elements, lateral force-resisting systems, and preliminary member sizes.

ETABS Modeling:
Generate a comprehensive 3D model of the structure in ETABS by inputting section and material information.
Assign names to the model's supports, loads, and constraints.

Structural Analysis:
Conduct structural analysis in ETABS to assess the building's response to various loads, such as gravity, wind, and seismic forces.
Evaluate stability, deflections, and member forces.

Design Optimization:
Refine the structural design based on the analysis results, ensuring compliance with safety and code standards.
Repeat the process as needed for optimization.

Detailing and Drafting:
Use AutoCAD for detailed structural drafting, producing construction drawings with precise dimensions and specifications.
Maintain coordination between architectural and structural drawings.

Foundation Design:
Consider structural requirements and soil conditions in designing the foundation system.
Utilize ETABS for foundation analysis and detailing.

Seismic Design:
Enhance the building's seismic performance through a thorough seismic study in ETABS, incorporating necessary design elements.

The architectural plan, section, and elevation of the building were drafted in AutoCAD 2021. Dead loads were derived from material unit weights specified in IS 875 (Part I): 1987. Live loads were determined based on IS 875 (Part II: 1987. Preliminary dimensions of beams and slabs conformed to IS 456-2000. Load calculations for one-way and two-way continuous slabs were performed using Excel Sheets. Universal Excel sheets were prepared for designing one-way continuous slabs and two-way continuous slabs. Earthquake load was calculated using IS 1893 (Part I): 2016. Building analysis was conducted using

ETABS 2021, and moments, shear forces, and axial forces were obtained. Structural element design, including beams, columns, and foundations, was carried out using the obtained results.

Design codes:

The structural design is carried out with the consideration of latest Indian codes and standards, the codes are which are referred for this project are shown below.

IS CODE	DESCRIPTION
IS 456:2000	PLAIN AND REINFORCEMENT CONCRETE
IS 875(PART 1) : 1987	DEAD LOAD
IS 875(PART 2) : 1987	LIVE LOAD
IS 875(PART 3) : 1987	WIND ANALYSIS
IS 1893:2016	SEISMIC ANALYSIS

Table 1; DESIGN CODES

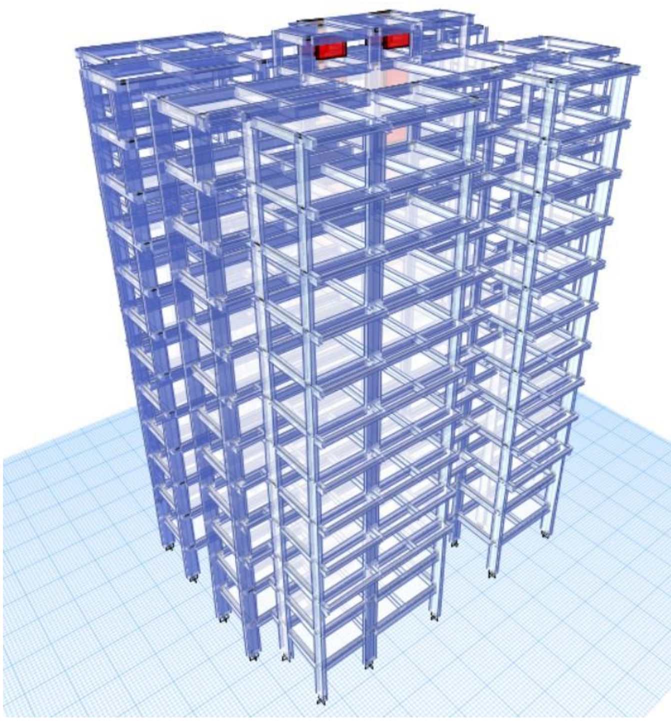

Fig 1: Framing Structure

4. STRUCTURE DATA

4.1. STORY DATA

Story	Height m	Elevation m	Master Story	Similar To	Splice Story	Splice Height m	Story Color
OHT LMR	1.8	36.7	Yes	None	No	0	
TERRACE	2.9	34.9	Yes	None	No	0	
9	2.9	32	Yes	None	No	0	
8	2.9	29.1	Yes	None	No	0	
7	2.9	26.2	Yes	None	No	0	
6	2.9	23.3	Yes	None	No	0	
5	2.9	20.4	Yes	None	No	0	
4	2.9	17.5	Yes	None	No	0	
3	2.9	14.6	Yes	None	No	0	
2	2.9	11.7	Yes	None	No	0	
1	2.9	8.8	Yes	None	No	0	
G	3	5.9	No	1	No	0	
PODIYUM	2.9	2.9	No	1	No	0	
BASEMENT		0					

FIG2: STOREY DATA

4.2. SECTION PROPERTIES

DESCRIPTION	SIZE	GRADE OF CONCRETE	GRADE OF STEEL (LONGITUDINAL)	GRADE OF STEEL (SHEAR)
Beam	B 230 X 230	M35	FE500	FE415
	B 230 X 450	M35	FE500	FE415
	B 230 X 600	M35	FE500	FE415
Column	C 230 X 450	M40	FE500	FE415
	C 230 X 600	M40	FE500	FE415
	C 230 X 750	M40	FE500	FE415
	C 230 X 900	M40	FE500	FE415
	C 230 X 1050	M40	FE500	FE415
	C 300 X 1050	M40	FE500	FE415
Shear wall	SW 230	M40	FE500	FE415
Slab	S 150	M35	FE500	FE415
	S 200	M35	FE500	FE415
	ST 200	M35	FE500	FE415

Table2: Section Properties

4.3. LOADS

S.NO	NAME	DEAD LOAD (IS 875 - PART-1) kN/m²	LIVE LOAD (IS 875 Part 2) kN/m²
1	General	1.5	2
2	Lobby	1.5	3
3	Bathroom	3	2
4	Staircase	3	3
5	Parking	0.5	4
5	Terrace	3	2
6	OHT	10	0.75
7	LMR	10	0.75

Table3 : LOADS ON SHELL ELEMENT

S.NO	NAME	WALL WIDTH (mm)	DEAD LOAD (IS 875 - PART-1) kN/m
1	EXTERNAL WALL	150	3.45
2	INTERNAL WALL	150	3.45
3	BALCONY WALLS	100	1.9
4	TERRACE WALLS	100	1.9

Table4 : LOADS ON FRAME ELEMENT

4.4. LOAD PATTERN

NAME	TYPE	SELF WEIGHT MULTIPLIER	AUTO LOAD
Dead	Dead	1	
Live	Live	0	
EQ X	Seismic	0	IS 1893:2016
EQ Y	Seismic	0	IS 1893:2016
W0	Wind	0	INDIAN 875:2015
W90	Wind	0	INDIAN 875:2015
Live>3	Live	0	

Table5 : Load Pattern

5. ANALYSIS IN ETABS

51. SEISMIC ANALYSIS

For the analysis purpose we consider two types of analysis Static analysis and Dynamic analysis both analysis have their own significance.

Mass source

Seismic weight of the structure – it is the sum of dead load and specified amount of imposed loads on the structure.
D=1 & L=0.25 if imposed load less than 3kN/m2.
D=1 & L=0.25 , L>3=0.5 if imposed load greater than 3kN/m2.
Refer IS 1893:2016 Part 1Table -10 Clause 7.3.1

Seismic Zone	III	Table 3 (clause 6.4.2)
Seismic Zone Factor (Z)	0.1	Table 3 (clause 6.4.2)
Site Type	Type II	Table 4 (clause 6.4.2.1)
Importance Factor (I)	1.2	Table 8 (Clause 7.2.3)
Response Reduction Factor (R)	3	Table 9 (clause 7.2.6)
Damping Ratio	0.05	(Clause 7.2.4)
Soil Profile	As per soil report	Type 2

Table6:General Design Parameter

CALCULATED BASE SHEAR

Function	Base shear
EX	2992.171
SPECX	2992.171
EY	2718.1135
SPECY	2718.1135

Table7:Base Shear

5.2. WIND ANALYSIS

Computation of Wind analysis parameter is done by referring **IS 875 Part 3 1987**

Class of the Structure	General	Clause 5.3.1 table 1
Probable Design Life (Years)	50	
Basic Wind Speed, (V_b)	47 m/s	Clause 5.2 Appendix A
Risk Co-efficient, K1	1.0	Clause 5.3.1
Terrain Category Factor, K2	2.0	Clause 5.3.2 Table 2
Topography Factor, K3	1.0	Clause 5.3.3

Table8: Wind Analysis Parameter

5.3. P-DELTA ANALYSIS

The P-Delta analysis is a type of Geometric nonlinearity, which accounts for secondary structural behaviour when axial and transverse loads are simultaneously applied to beam or wall elements.P-Delta effect usually becomes prevalent in a tall structure that is experiencing gravity loads and large lateral displacement due to wind or other forces. If the lateral displacement or the vertical axial loads are significant, P-Delta analysis should be performed.

This analysis is performed till the tolerance limit of 0.0001 D=1.5 or (D=1.2 +L=1.2) whichever is More (IS 456: Table 18).

In all types of analysis P-delta effect is considered.

5.4. MODAL ANALYSIS

First three modes should contribute more than 65% mass participation.

The fundamental natural time period of the building in the two principal plan directions are more than 10% difference and for principal plan directions to rotational mode 10% time period is mandatory

For N'th mode should contribute more than **90%** mass participation.

IS 1893: table-6(vii)

IS 1893 2016: clause 7.7.5.2

TABLE: Modal Participating Mass Ratios

Case	Mode	Period	UX	UY	UZ	SumUX	SumUY	SumUZ	RX	RY	RZ	SumRX	SumRY	SumRZ
		sec												
Modal	1	1.667	0.0017	0.6791	0	0.0017	0.6791	0	0.2228	0.0006	0.0746	0.2228	0.0006	0.0746
Modal	2	1.483	0.0405	0.0797	0	0.0422	0.7587	0	0.0224	0.0132	0.6509	0.2451	0.0138	0.7255
Modal	3	1.332	0.711	0.0007	0	0.7532	0.7594	0	0.0002	0.2379	0.0418	0.2453	0.2517	0.7673
Modal	4	0.531	0.0002	0.1155	0	0.7534	0.875	0	0.4113	0.0004	0.0113	0.6566	0.2522	0.7785
Modal	5	0.48	0.0033	0.0091	0	0.7567	0.8841	0	0.0403	0.0105	0.1067	0.6969	0.2626	0.8852
Modal	6	0.421	0.1225	0.00001675	0	0.8792	0.8841	0	0.0001	0.4277	0.0032	0.697	0.6903	0.8884
Modal	7	0.298	2.195E-05	0.0431	0	0.8792	0.9271	0	0.0749	4.226E-05	0.0032	0.7719	0.6903	0.8916
Modal	8	0.273	0.0006	0.0019	0	0.8797	0.9291	0	0.0035	0.001	0.0402	0.7753	0.6913	0.9318
Modal	9	0.233	0.0466	7.094E-07	0	0.9263	0.9291	0	1.694E-06	0.0806	0.0006	0.7753	0.7719	0.9324
Modal	10	0.197	0	0.0216	0	0.9263	0.9507	0	0.0743	7.934E-07	0.0001	0.8497	0.7719	0.9326
Modal	11	0.182	0.0002	0.00001838	0	0.9265	0.9507	0	0.0001	0.0005	0.0204	0.8498	0.7724	0.9529
Modal	12	0.156	0.0172	0	0	0.9437	0.9507	0	0	0.058	0.0003	0.8498	0.8304	0.9532
Modal	13	0.151	0.0032	2.533E-06	0	0.9469	0.9507	0	5.833E-06	0.0097	0.0000144	0.8498	0.8401	0.9532
Modal	14	0.143	0.0001	0.0001	0	0.9471	0.9508	0	0.0003	0.0005	0.0000113	0.8501	0.8406	0.9532
Modal	15	0.141	1.204E-05	0.012	0	0.9471	0.9628	0	0.031	3.615E-05	0.0003	0.8811	0.8406	0.9535
Modal	16	0.13	0.0004	0.0003	0	0.9475	0.9632	0	0.001	0.001	0.011	0.882	0.8416	0.9645
Modal	17	0.127	0.0022	0.00003147	0	0.9497	0.9632	0	0.0001	0.0048	0.0006	0.8821	0.8464	0.9651
Modal	18	0.114	0.0078	0.00003318	0	0.9575	0.9632	0	0.0001	0.0206	0.0002	0.8822	0.867	0.9653
Modal	19	0.109	0.0001	0.0086	0	0.9575	0.9719	0	0.0296	0.0001	0.0005	0.9118	0.8672	0.9658
Modal	20	0.105	0.0042	0	0	0.9618	0.9719	0	5.104E-07	0.0132	0.0001	0.9118	0.8803	0.9659
Modal	21	0.099	1.252E-05	0.0005	0	0.9618	0.9723	0	0.0017	3.784E-05	0.0089	0.9135	0.8804	0.9748
Modal	22	0.091	0.0009	0.0047	0	0.9627	0.977	0	0.0135	0.0031	0.0001	0.9269	0.8835	0.9748
Modal	23	0.09	0.0047	0.0009	0	0.9674	0.9779	0	0.0027	0.0158	0.0001	0.9296	0.8993	0.9749
Modal	24	0.085	1.998E-05	0.0003	0	0.9675	0.9783	0	0.0009	0.0001	0.0002	0.9305	0.8993	0.9751
Modal	25	0.085	1.745E-05	0.0007	0	0.9675	0.979	0	0.0023	0.000038	0.0009	0.9328	0.8993	0.976

Fig3: Modal Analysis

5.5. BUCKLING ANALYSIS:

Whenever the elevation aspect ratio is greater than 4 then the building is govern by buckling analysis

It is global analysis

Height ratio (H/W) = 1.66

In this project buckling analysis is not govern

6.ANALYSIS RESULTS

The structure underwent ordinary momemt resisting frame analysis utilizing the joint coordinate command to define joint coordinates and initiate structural specifications. The member incidence command was employed to establish connectivity between joints, modeling columns and beams with beam elements. Specific member properties were designated for each member. The analysis provided maximum design loads, moments, and shear for each member, guiding the subsequent structural design process.

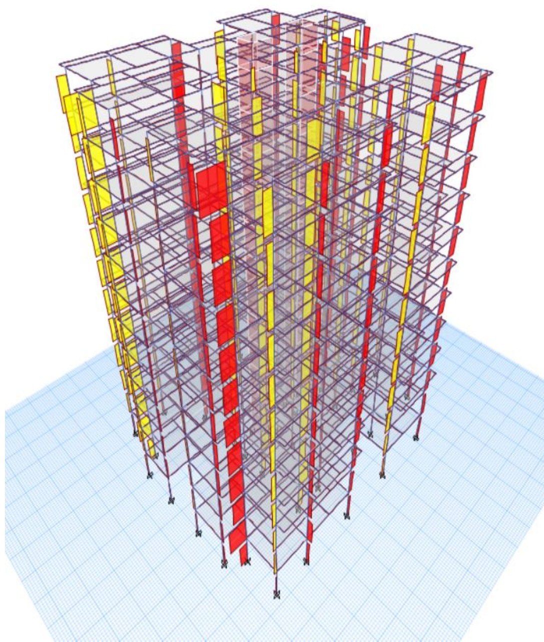

FIG4: SHEAR FORCE DIAGRAM (IN 3-3 DIRECTION)

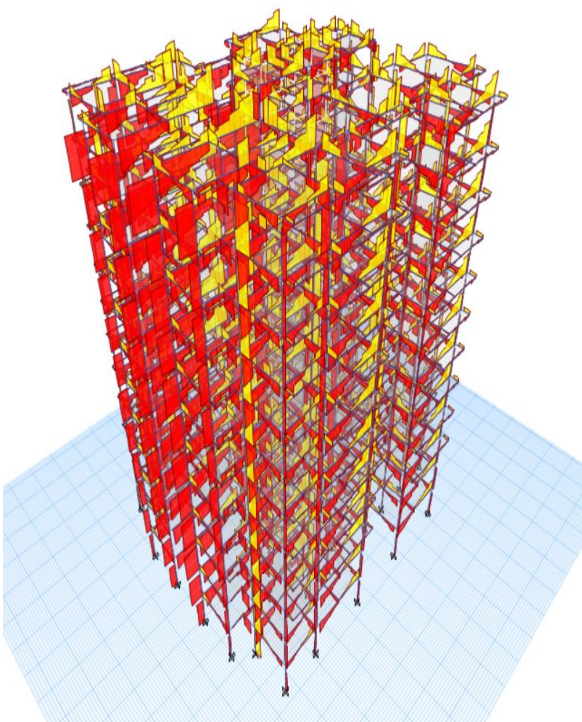

FIG5: SHEAR FORCE DIAGRAM (IN 2-2 DIRECTION)

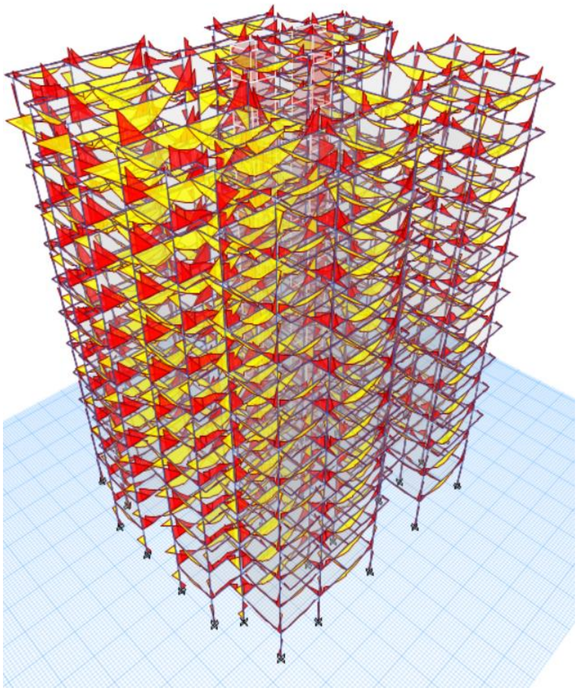

FIG6: BENDING MOMENT DIAGRAM (IN 3-3 DIRECTION)

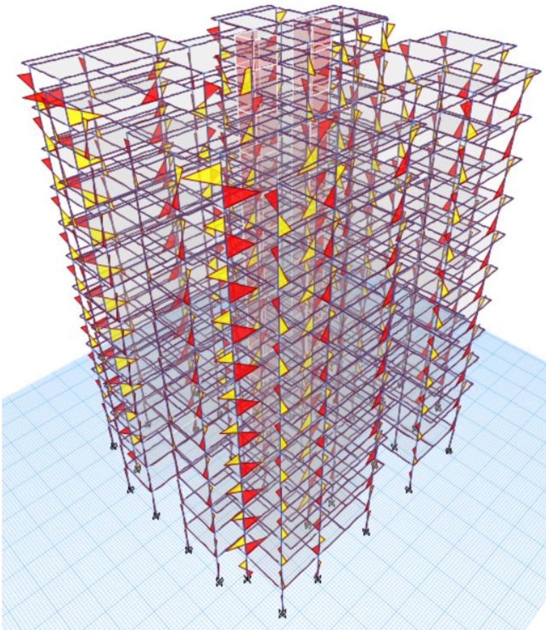

FIG7: BENDING MOMENT DIAGRAM (IN 2-2 DIRECTION)

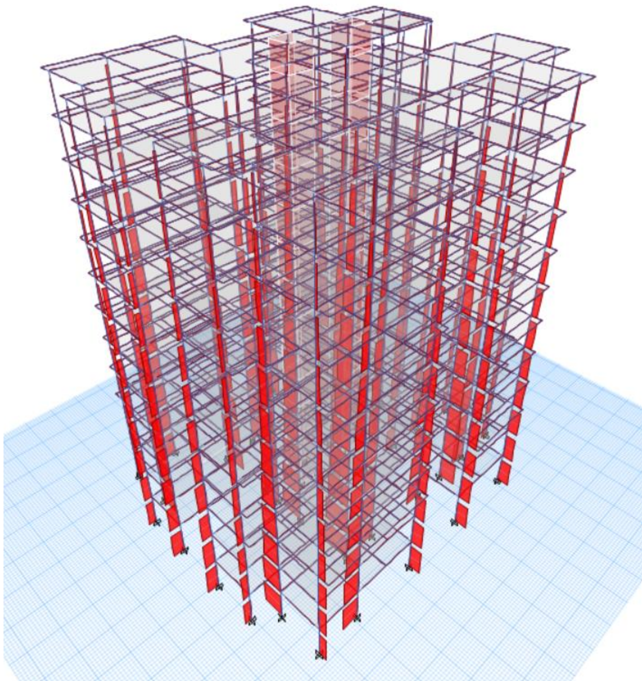

FIG8: AXIAL FORCE DIAGRAM

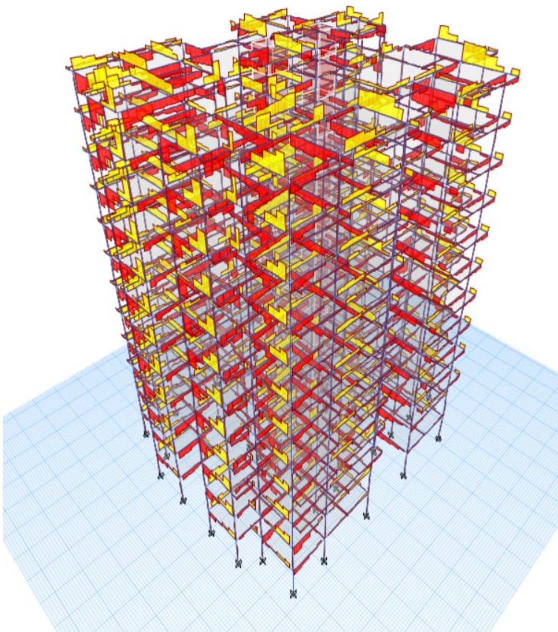

FIG9: TORSION DIAGRAM(DEAD + LIVE)

7.CONCRETE FRAME DESIGN:

7.1.DESIGN LOAD COMBINATIONS:

Designing structures would become prohibitively expensive if all types of forces were applied at all times for maintaining serviceability and safety. To address this, the concept of characteristic loads has been embraced, ensuring that in at least 95 percent of cases, these loads are calculated based on the average or mean load from logical combinations of all mentioned loads. Standards such as IS 456:2000, IS 875:1987 (Part-V), and IS 1893 (Part-I):2002 specify the load combinations to be considered in structural design.

SNO.	DESIGN LOAD COBINATION
1	1.5 D
2	1.5 D + 1.5 L
3	1.5 D + 1.5 W0
4	1.5 D - 1.5 W0
5	1.5 D + 1.5 W90
6	1.5 D – 1.5 W90
7	1.2 D + 1.2 L + 1.2 W0
8	1.2 D + 1.2 L - 1.2 W0
9	1.2 D + 1.2 L + 1.2 W90
10	1.2 D + 1.2 L – 1.2 W90
11	0.9 D + 1.2 W0
12	0.9 D – 1.2 W0
13	0.9 + 1.2 W90
14	0.9 D – 1.2 W90
15	1.5 D + 1.5 SPEC X
16	1.5 D + 1.5 SPEC Y
17	1.2 D + 1.2 L + 1.2 SPEC X
18	1.2 D + 1.2 L + 1.2 SPEC Y
19	0.9 D + 1.5 SPEC X
20	0.9 D + 1.5 SPEC Y

Table9: Load Combinations

8. Design of RC Building

The primary goal of structural design is to ensure that the designed structure can effectively fulfill its intended function and safely endure the various influences it will encounter throughout its useful life. These influences mainly include loads and other forces exerted upon the structure. Additionally, considerations should be given to factors like temperature fluctuations and foundation settlements. The design methods employed for reinforced concrete structures encompass the working stress method, ultimate load method, and limit state method. In this context, the limit state method has been chosen for the design of slabs, beams, columns, and stairs.In the limit state method, the structure is engineered to safely withstand all foreseeable loads during its lifespan while meeting serviceability requirements such as limiting deflection and preventing cracking. The acceptable safety and serviceability limits before failure are termed limit states. To ensure an adequate level of safety and serviceability, all relevant limit states must be taken into account during the design process. The structure should be designed based on the most critical state and subsequently verified against other limit states.

Column Rebar Percentage

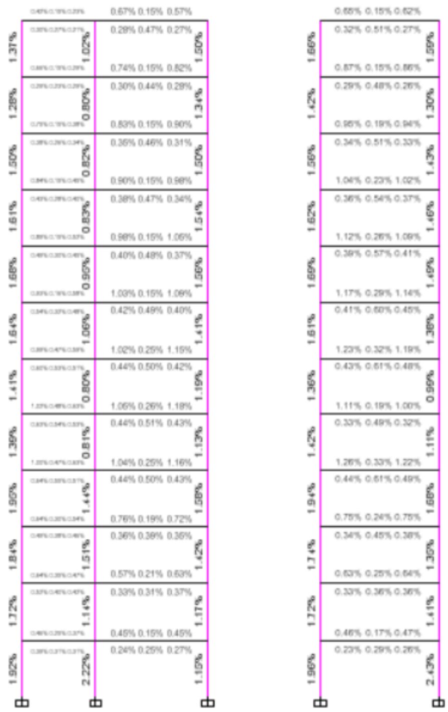

FIG10: ELEVATION 2

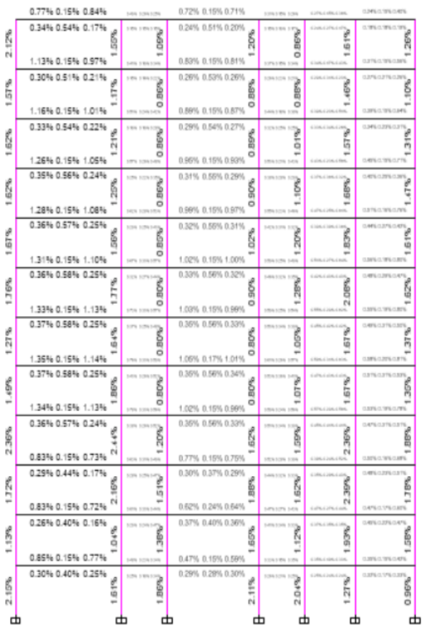

FIG11: ELEVATION 3

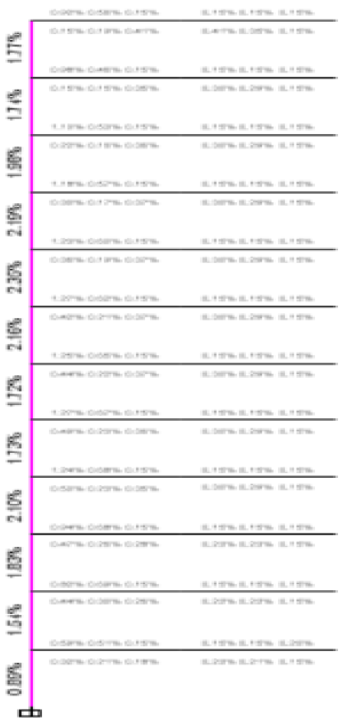

FIG12: ELEVATION 4

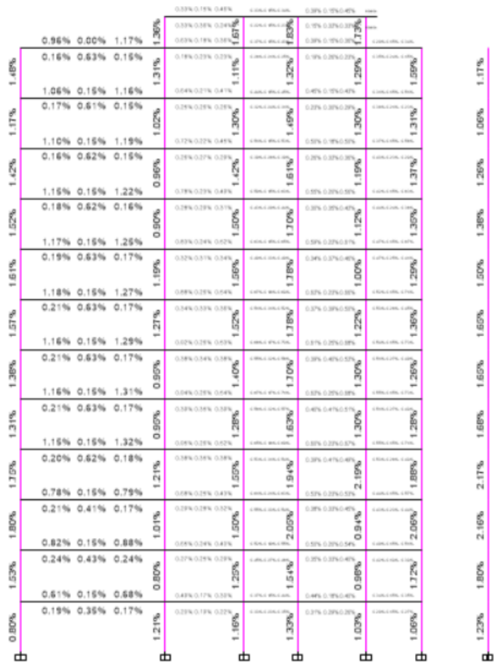

FIG13: ELEVATION 5

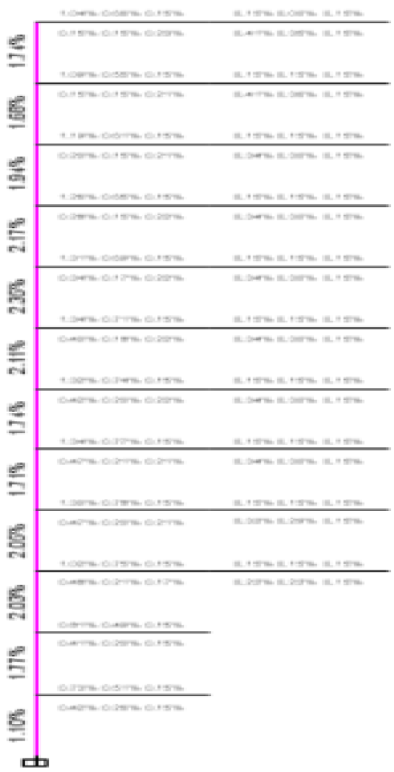

FIG14: ELEVATION 7

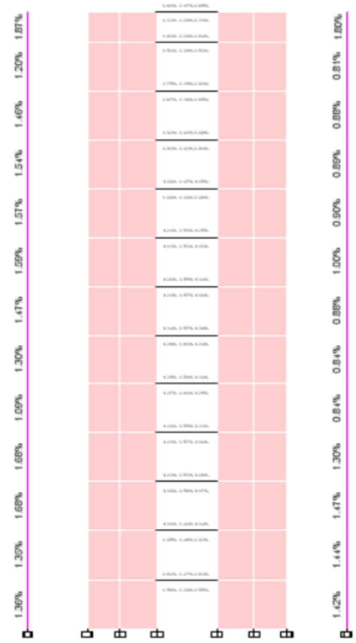

FIG15: ELEVATION 6

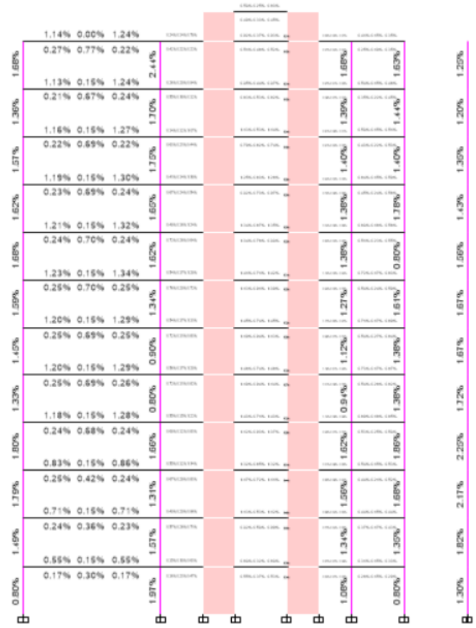

FIG17: ELEVATION 9

FIG16: ELEVATION 8

9. FOUNDATION DESIGN

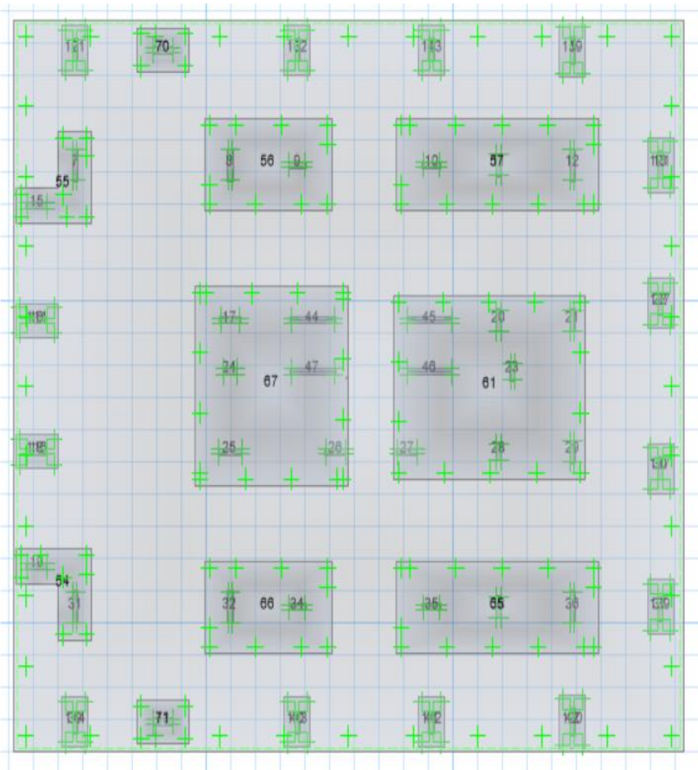

FIG18:Mathematical Modal

Foundation **is a** part of a structural system that supports and anchors the superstructure of a building and transfers its loads directly to the earth.

In this project we have considered isolated footing based on geotechnical report.
The SBC of the soil is 250 kN/m² based on geotechnical report.
The allowable settlement for isolated footing is 50 mm.
We have used M40 concrete grade, Fe500 & Fe 415 steel grade

9.1. Load combinations used for analysis and design of foundation

STRENGTH LOAD COMBINATION	SERVICE LOAD COMBINATION
1.5 D + 1.5 L	1 D + 1 L
1.5 D + 1.5 SPEC X	1 D + 1 SPEC X
1.5 D + 1.5 SPEC Y	1 D + 1 SPEC Y
1.5 D + 1.5 W0	1 D + 1 W0
1.5 D – 1.5 W0	1 D – 1 W0
1.5 D +1.5 W90	1 D + 1 W90
1.5 D – 1.5 W90	1 D – 1 W90
1.2 D + 1.2 L + 1.2 W0	1 D + 0.8 L + 0.8 SPEC X
1.2 D + 1.2 L – 1.2 W0	1 D + 0.8 L + 0.8 SPEC Y
1.2 D + 1.2 L + 1.2 W90	1 D + 0.8 L + 0.8 W0
1.2 D + 1.2 L – 1.2 W90	1 D + 0.8 L – 0.8 W0
1.2 D + 1.2 L + 1.2 SPEC X	1 D + 0.8 L + 0.8 W90
1.2 D +1.2 L + 1.2 SPEC Y	1 D + 0.8 L – 0.8 W90
0.9 D + 1.5 W0	
0.9 D – 1.5 W0	
0.9 D +1.5 W90	
0.9 D – 1.5 W90	
0.9 D + 1.5 SPEC X	
0.9 D + 1.5 SPEC Y	

Table10: Load Combination

9.2.Material properties

Raft size – 28.95 m X 24.25 m X 0.6 m.
Drop size

GROUPING LABEL NO	LENGTH (L) mm	BREATH (B) mm	DEPTH (D) mm
101	1130	1650	1000
70	2250	1430	1000
102	1130	1650	1000
103	1130	1650	1000
119	1130	1800	1000
55	1430	3040	1000
56	5540	3050	1000
57	8740	3050	1000
121	1130	1800	1000
114	1800	1130	1000
67	6640	6580	1000
61	8280	6075	1000
127	1130	1650	1000
116	1800	1130	1000
137	1130	1650	1000
54	3265	3040	1000
66	5540	3050	1000
65	8740	3050	1000
139	1130	1800	1000
144	1130	1650	1000
71	2250	1430	1000
143	1130	1650	1000
142	1130	1650	1000
120	1130	1800	1000

Table11: Drop Size

9.3.Ground Bearing pressure check (GBP)

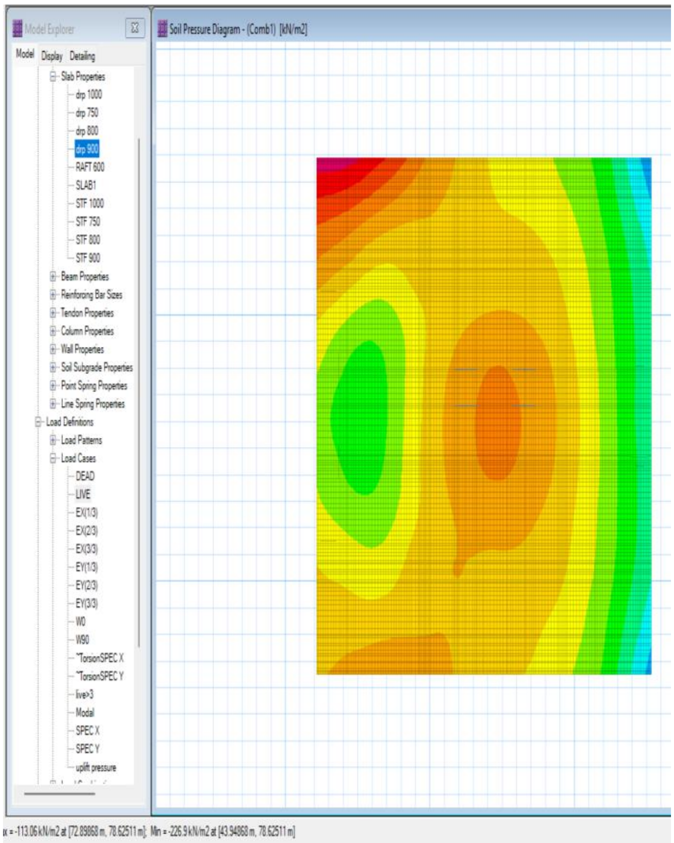

Fig19: GROUND BEARING PRESSURE

The ground bearing pressure should be less than SBC given in geotechnical report.
The SBC is 300 kN/m² > GBP 226 kN/m². Hence it is safe.

9.4. Settlement check

The maximum allowable settlement for Raft foundation is 50mm for (D+L) combination.
The allowable settlement **(50mm)** > the settlement occurring **(45mm)**, Hence safe.

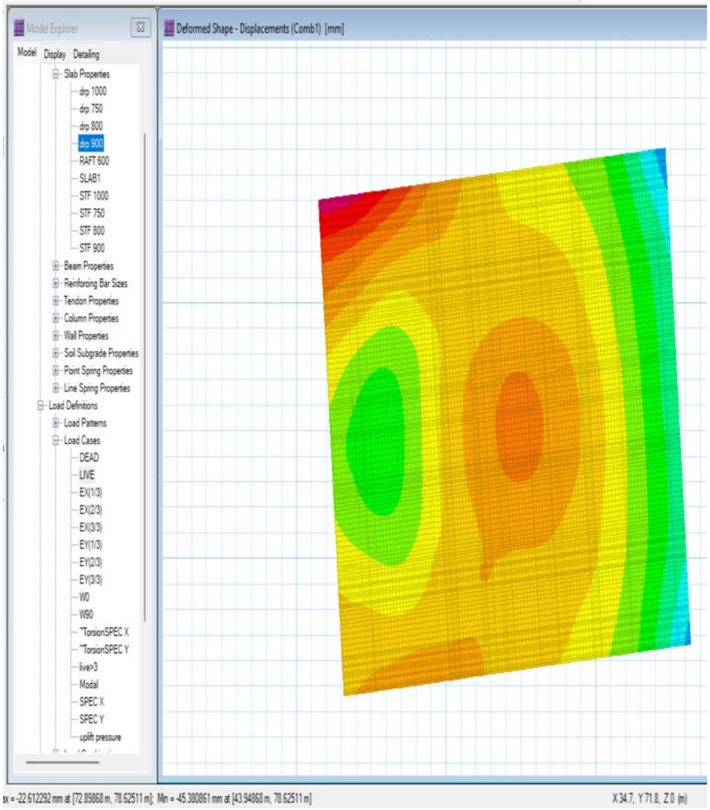

Fig20: SETTLEMENT

9.5. Punching shear check

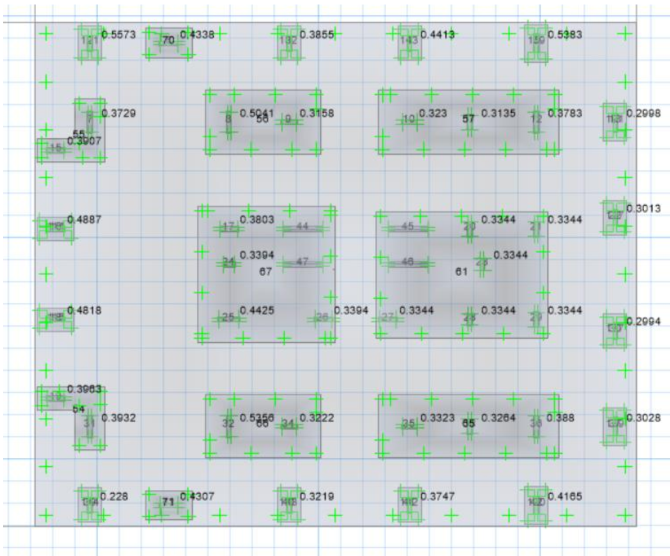

Fig2:Punching Shear

Punching is a service criteria so the punching is checked in service load combination.
The punching ratio should be less than 1.
The punching ratio is not displayed for shear wall it should be manually checked.
The punching ratio is less than 1, Hence safe.

9.6. Punching check for shear wall

SHEAR WALL	Fck	L	B	ßs	Ks		PUNCHING SHEAR FROM SAFE τ_v	ALLOWABLE LIMIT FOR SERVICE τ_c	$\tau_v<\tau_c$ SERVICE	ALLOWABLE LIMIT FOR STRENGTH τ_c	$\tau_v<\tau_c$ STRENGTH
SW 230 M30 (1)	40	1950	230	0.117949	0.617949	S13 MIN.	0.05	0.625320136	YES	0.846161131	YES
						S13 MAX.	0.52		YES		YES
						S23 MIN.	0.12		YES		YES
						S23 MAX.	0.59		YES		YES
SW 230 M30 (2)	40	1950	230	0.117949	0.617949	S13 MIN.	0.32	0.625320136	YES	0.977062713	YES
						S13 MAX.	0.42		YES		YES
						S23 MIN.	0.169		YES		YES
						S23 MAX.	0.25		YES		YES
SW 230 M30 (3)	40	1950	230	0.117949	0.617949	S13 MIN.	0.02	0.625320136	YES	0.977062713	YES
						S13 MAX.	0.42		YES		YES
						S23 MIN.	0.05		YES		YES
						S23 MAX.	0.6		YES		YES
SW 230 M30 (4)	40	1950	230	0.117949	0.617949	S13 MIN.	0.32	0.625320136	YES	0.977062713	YES
						S13 MAX.	0.48		YES		YES
						S23 MIN.	0.169		YES		YES
						S23 MAX.	0.36		YES		YES

Fig22: Punching Cheak For Shear Wall

Punching stresses at the distance **d/2** from the edge of the column should be less than

$0.25\sqrt{fck}$ (β+0.5) for strength envelope.

The stress SW1 & SW2 and SW Combined foting are < Tc, hence safe.

Slab reinforcement design & Crack width check

GROUP	DEPTH	DIRECTION	MOMENT (Kn-m)	Area of steel required (AST REQ) (mm^2/m)	Provided AST (mm^2/m)	Crack width< 20 mm
Raft	600	Dir-1	1250	8200	Layer-1 20@100	**pass**
					Layer-1 25@100	
		Dir-2	750	7500	Layer-1 20@100	**pass**
					Layer-1 25@100	

Table12:Slab Reinforcement Detail

Crack width is performed in non-linear type of analysis in strength load combination.

The moment (m11) in direction 1 and the moment (m22) in direction 2 is calculated using service envelope.

The area of steel required (ast) is calculated using strength combination in both direction 1& 2.For isolated footing only bottom reinforcement is given & for combined footing both top and bottom is given. Maximum crack width allowed is 0.2 mm.

10. Conclusion

- The design based on E-Tabs ensures the adequacy of the structure concerning serviceability, strength, and cost-effectiveness.
- The use of ETABS software not only saves time but also improves the precision of structural design.
- Structural elements underwent design using a combination of manual methods and software assistance. Urban areas, dealing with limited available land, choose multi-storey constructions to maximize the utilization of vertical space.
- Instead of clearing forests and swamps for construction, vertical towers can accommodate residences, shopping centers, and factories, contributing to the preservation of the environment.

11. Future Scope

- The design and analysis tasks performed using ETABS can also be replicated in Staad Pro for result comparison.
- In addition to designing, attention must be given to the provision of foundations and tanks within the project scope.
- Dynamic analysis is a crucial aspect that needs to be conducted to assess the structural response effectively.
- Diverse options for slabs, columns, various footing types, and foundation designs can be explored and applied as part of the project's flexibility and adaptability.
- Utilizing both software and manual analysis methods, providing comprehensive details on various depth cases, assessing the number of floors needed based on the soil's safe bearing capacity, presenting a case study demonstrating plate load test execution, illustrating the subsurface strata profile in a specific research location, and conducting foundation analysis using software mechanisms for different types.

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