Planning, Analysis and Designing of 2B+G+9 Residential Building using ETABS, AutoCAD and SAFE Software

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Abstract - *Designing a structure involves a blend of artistry and technical know-how, aiming to ensure safety, functionality, durability, and cost-effectiveness. It requires creativity, conceptual thinking, and a deep understanding of structural engineering principles, practical considerations, and building regulations. While architects focus on functional and aesthetic aspects, structural engineers prioritize safety, functionality, durability, and cost-effectiveness.*

In this specific project, a site has been selected for a nine-story residential building with four apartments per floor. The design process revolves around analyzing and designing the building, considering only dead and live loads. Dead loads are determined according to IS-875 (Part 1), and live loads are based on IS-875 (Part 2). AutoCAD is used for planning and creating the building's appearance.

For analysis, E-Tabs software is utilized, while structural elements such as slabs, beams, columns, and footings are manually designed. The project strictly adheres to building by-laws and complies with specified codes, including IS:456-2000 for Plain and Reinforced Concrete and SP-16 for Design Aids for Reinforced Concrete. Additionally, IS: 875 Part 1 and Part 2 are followed for design loads.

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

1.INTRODUCTION

In the complex process of planning, analyzing, and designing a residential building with two basements, a ground floor, and nine additional stories, a methodical approach is essential for a smooth progression from conception to completion. The initial planning stage entails thorough site selection, considering factors like accessibility, utility availability, and compliance with zoning regulations. Concurrently, client needs are diligently evaluated, laying the groundwork for subsequent design choices. The analysis phase, conducted with ETABS software, is crucial for ensuring the structural soundness and safety of the building. It involves assessing load-bearing requirements and conducting detailed load calculations, covering live loads, dead loads, and other pertinent factors. ETABS is also employed for seismic analysis, ensuring compliance with rigorous safety standards, particularly crucial for tall buildings. This phase is pivotal for determining the structure's strength and resilience against potential environmental challenges.

Following this, the design phase commences primarily using AutoCAD software. Here, comprehensive architectural designs are developed, including detailed floor plans and elevations. AutoCAD facilitates the integration of structural design elements, ensuring alignment with analysis findings from ETABS. The software aids in creating construction drawings with precise dimensions and specifications, laying the foundation for realizing the residential building physically. The process involves iterative refinements based on feedback and evaluations. Coordination between architectural and structural aspects is key, with AutoCAD serving as the preferred tool for revisions and updates, maintaining design coherence throughout the project's progression. Collaboration among architects, structural engineers, and other stakeholders is encouraged, fostering a comprehensive and well-coordinated design approach.

Each phase is accompanied by thorough documentation, meticulously recording design choices, calculations, and alterations made throughout the planning and design stages. This comprehensive collection of construction documents acts as a guide for the construction team, guaranteeing that the planned 2B+G+9 residential building is constructed exactly as intended. Essentially, the combination of ETABS and AutoCAD software in the planning, analysis, and design phases offers a sturdy framework for the effective and precise creation of a multi-story residential building.

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 spanning 22 floors (G+22) have been concluded successfully. This software is known for its user-friendly operation and visually intuitive interface, which improves efficiency and reduces time consumption. It simplifies the computation of necessary reinforcement in structures and offers a detailed 3D visualization of the building. ETABS enables the calculation of wind and seismic loads affecting the structure, underscoring its primary application in designing and analyzing reinforced concrete framed structures.

U C Ahammed Kutty et al. (2022) [2] The structural engineer encountered challenges but successfully addressed constraints to match the architectural drawings. ETABS was used to meticulously design RCC frame elements such as beams and columns, striving to meet standard specifications. The planning and design of a ten-story apartment building were carried out using ETABS V15.2 software for comprehensive analysis. This software, known for its outstanding performance, proved highly effective in managing various structural considerations. Based on the soil investigation report, an isolated footing design was adopted.

Dr. Alok Singh et al. (2019) [3] extensive research, evaluation, and design efforts were undertaken for a multi-story residential building, spanning ground plus 25 stories. The building comprises ground-floor parking and upper-level apartments. AutoCAD was used to design and specify all structural elements, while both STAAD and conventional criteria were employed for analysis and design, making it suitable for addressing static and dynamic loads. Structural member sizes were determined, taking into account dead, live, and seismic loads. Thorough deflection and shear tests were carried out on beams, columns, and slabs to verify their safety. The project involved a combination of theoretical and hands-on work to ensure a well-rounded completion.

Manas Rathore et al. (2021) [4] The primary focus lies on achieving the most cost-effective column method, achieved through the reduction of section sizes. Given that the load distribution is heavier at the bottom compared to the top, it's unnecessary to employ larger column sizes towards the upper levels. Adhering to IS Codes enables the optimization of column design by providing the required specified amount. Typically, the steel area percentage ranges from 0.8% to a maximum of 6% of the Gross cross-sectional area as per IS code standards. As the structure height increases, the slenderness effect or long column effect becomes more significant. Utilizing ETABS software not only saves time but also ensures precise structural design.

Harendra Nath Pandey et al. (2020) [5] The design follows a model akin to E-Tabs, prioritizing serviceability, strength, and cost efficiency. ETABS software usage not only streamlines the process but also improves the accuracy of structural design. Structural elements were developed using a combination of manual techniques and software aids. In urban settings where land is scarce, constructing multi-story buildings is common to maximize vertical space usage. Opting for vertical towers instead of clearing forests and wetlands for housing, shopping complexes, and industrial facilities represents a sustainable approach to environmental conservation.

Dr.G.D.Awchat et al. (2021)[6] The use of ETABS software not only simplifies the analysis and design processes, leading to substantial time savings, but also guarantees precision. This software enables quick access to structural values, accommodating various zones and soil types. These values differ depending on soil conditions; for instance, soil type 1 yields lower values, whereas soil type 3 yields higher values. This observation suggests that soil type 1 has a lower base shear in comparison to soil types 2 and 3.

Dr. Yusuf et al. (2021) [7] - Analysis findings conform to geotechnical and structural engineering standards, aiding in predicting natural hazards, preventing issues, and understanding soil foundation behavior over time. Researchers have investigated soil profiles such as Aeolian and black cotton, which directly influence the Safe Bearing Capacity (SBC) and the stability of structures built on them. Improved bearing capacity during compaction is a notable feature in soft foundation conditions during the filling stage. Laboratory experiments in soil mechanics contribute to precise soil foundation design, enhancing failure prevention. Soil mixing techniques have been employed in geotechnical engineering to improve soil properties. Recognizing the significance of studying foundation design relative to soil conditions is essential for achieving stable and secure designs for tall and multi-story buildings. Assessment of earthquake-resistant structures, considering foundation depth, can be conducted manually or through software, utilizing both linear and non-linear methods for structural analysis. Evaluating bearing capacity, using manual techniques and tests like the Standard Penetration Test (SPT) and core testing, is vital before implementing building designs. Various software applications for analysis, including Praxis, FEM, ABACUS, and ETABS, incorporating 3D Finite Element Method (FEM) analysis, are explored. Some researchers focus on testing methodologies to analyze soil, foundation, and failure mechanisms.

Zia-abe Deen. S. Punekar et at. (2017) [8] The study concludes that in analyzing and designing Raft footings, particular emphasis is placed on critical envelope combinations, especially in dynamic scenarios. Regarding moment considerations, findings suggest that the steel area derived from the SAFE software's envelope combination aligns with that obtained from strip methods, confirming the validity of the design process for this combination. Furthermore, the study determines the mat/raft foundation to be resistant to punching shear or two-way shear, with a punching shear ratio below 1. Observations on deflection indicate a slight hogging deflection in the raft footing, deemed acceptable and not detrimental to the building. Compared to isolated footings, the detailing and casting process for raft footings are simplified, with excavation and concrete pouring done simultaneously, resulting in 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: Work alongside architects to develop the building layout, taking into account functional requirements, aesthetic preferences, and local zoning laws.

Utilize AutoCAD for thorough structural drafting, generating construction drawings with accurate measurements and specifications.

Ensure alignment 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 Modelling:

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.

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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 CODE

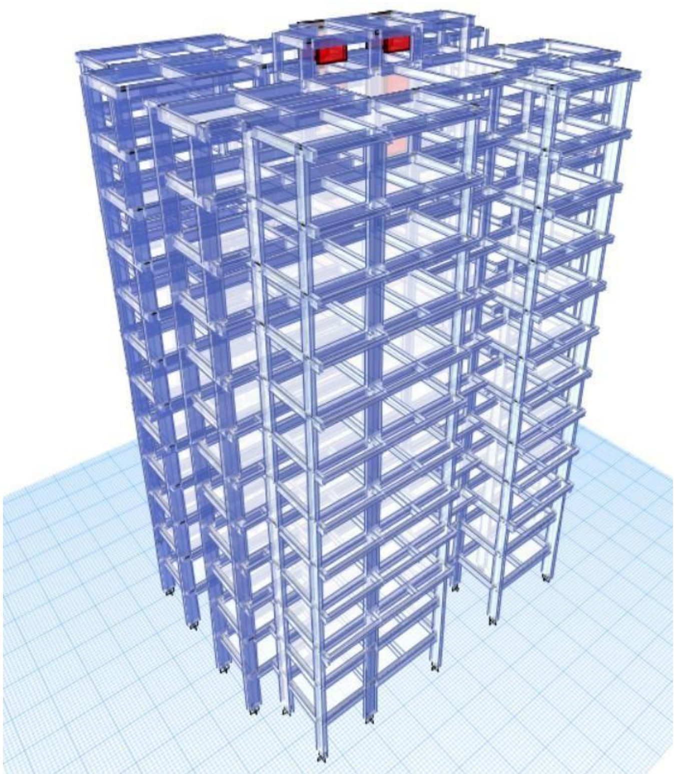

Figure 1 Framing Structure

4. STRUCTURE DATA

4.1. STOREY 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					

Figure 2 Story 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

Table 2 Section Properties

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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

Table 3 Notes 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

Table 4 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	

Table 5 Load Pattern

5. ANALYSIS IN ETABS

5.1. SEISMIC ANALYSIS

For the analysis purpose we consider two types of analysis Static analysis and Dynamic analysis both analyses 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

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

Table 6 General Design Parameter

CALCULATED BASE SHEAR

Function	Base shear
EX	2992.171
SPECX	2992.171
EY	2718.1135
SPECY	2718.1135

Table 7 Base Shear

5.2. WIND ANALYSIS

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

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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

Table 8 Wind Analysis Parameter

5.3. P-DELTA ANALYSIS

The P-Delta analysis is a type of Geometric nonlinearity, which accounts for secondary structural behavior when axial and transverse loads are simultaneously applied to beam or wall elements'-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

Figure 3 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 moment 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.

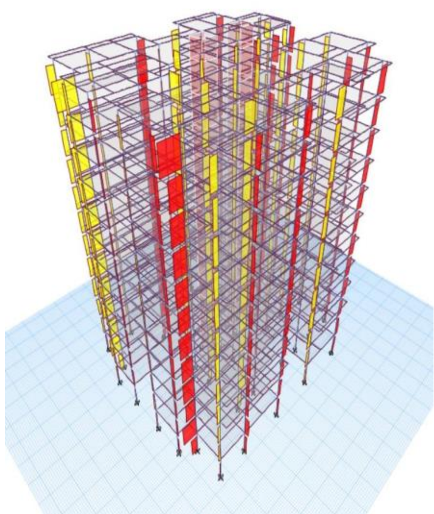

Figure 4 SHEAR FORCE DIAGRAM (IN 3-3 DIRECTION)

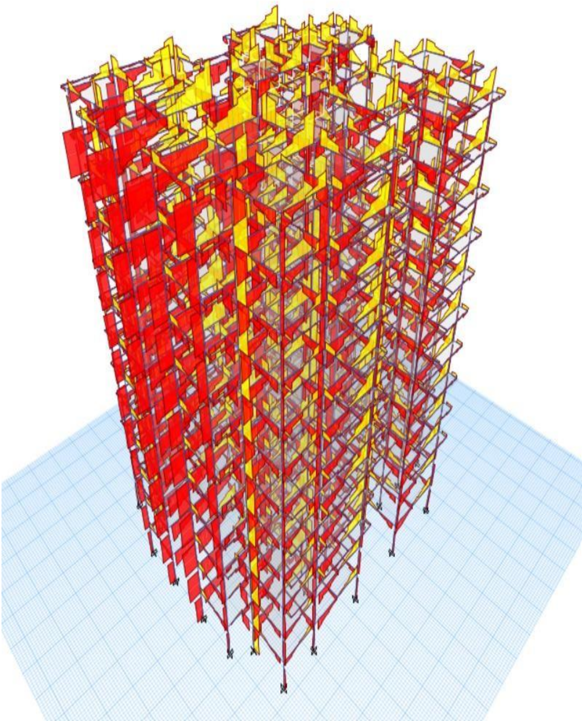

Figure 5 SHEAR FORCE DIAGRAM (IN 2-2 DIRECTION)

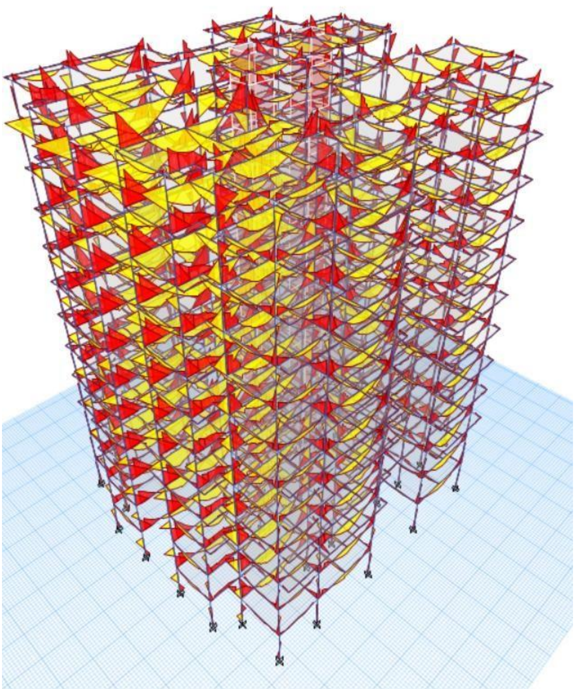

Figure 6 BENDING MOMENT DIAGRAM (IN 2-2 DIRECTION)

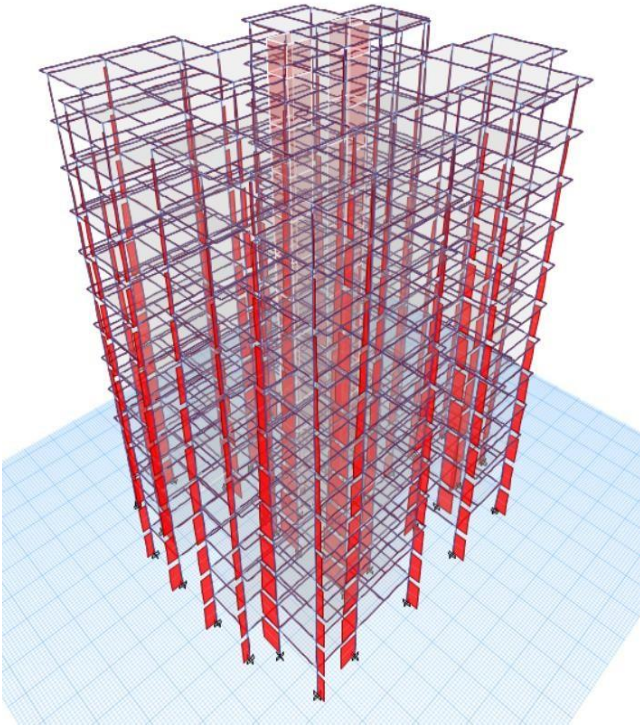

Figure 7 AXIAL FORCE DIAGRAM

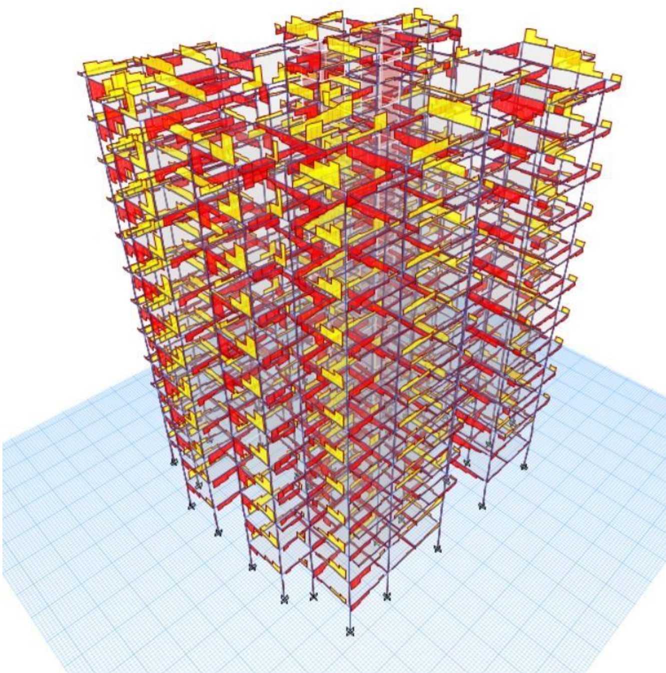

Figure 8 TORSION DIAGRAM (DEAD + LIVE)

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

Table 9 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

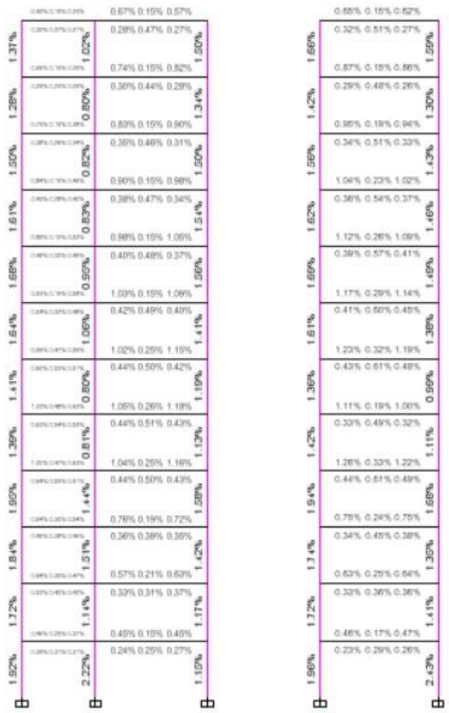

Figure 9 ELEVATION 2

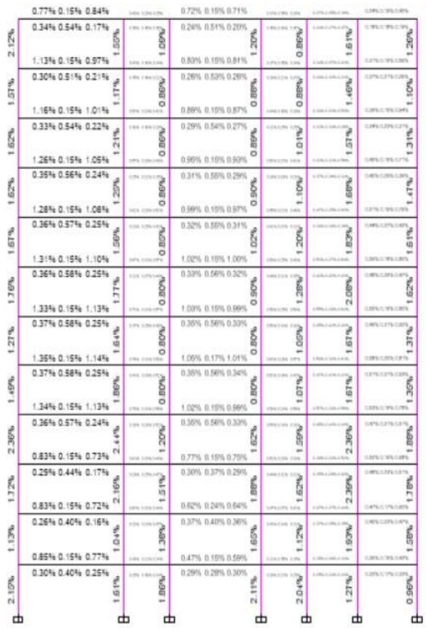

Figure 10 ELEVATION 3

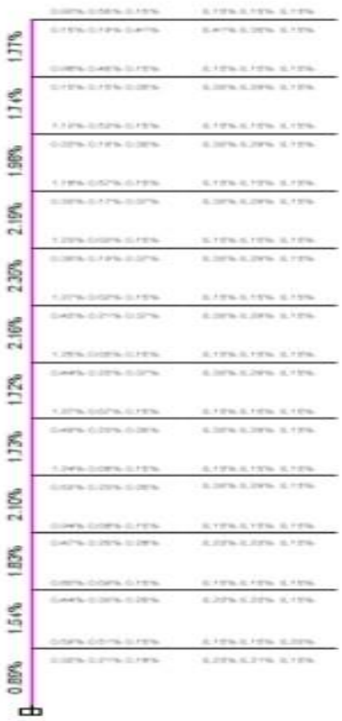

Figure 11 ELEVATION 4

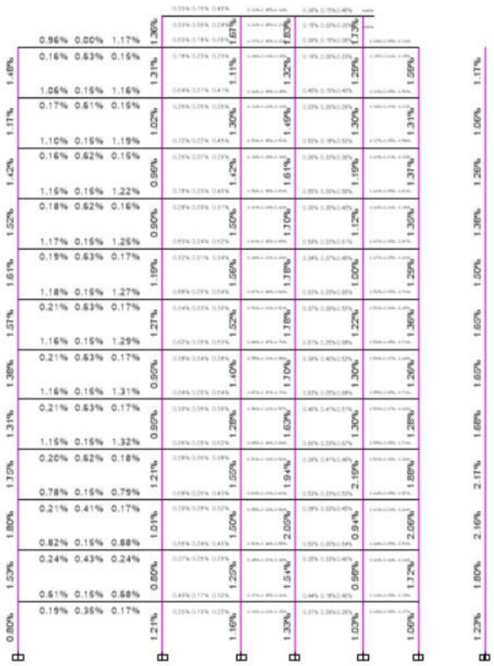

Figure 12 ELEVATION 5

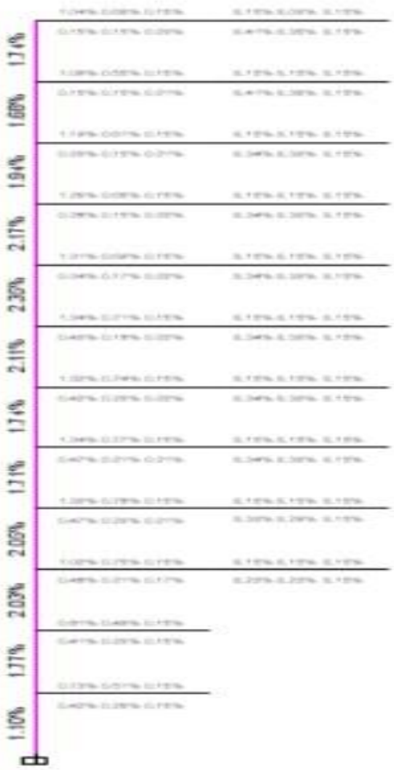

Figure 13 ELEVATION 7

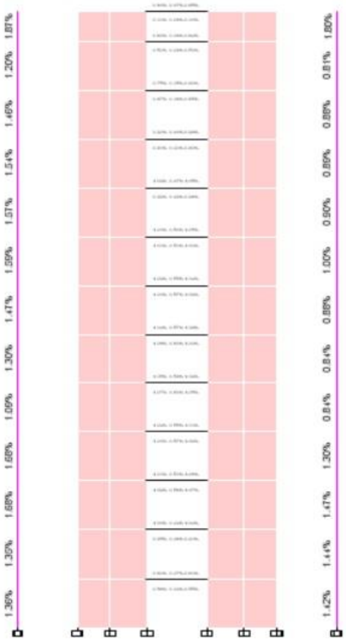

Figure 14 ELEVATION 6

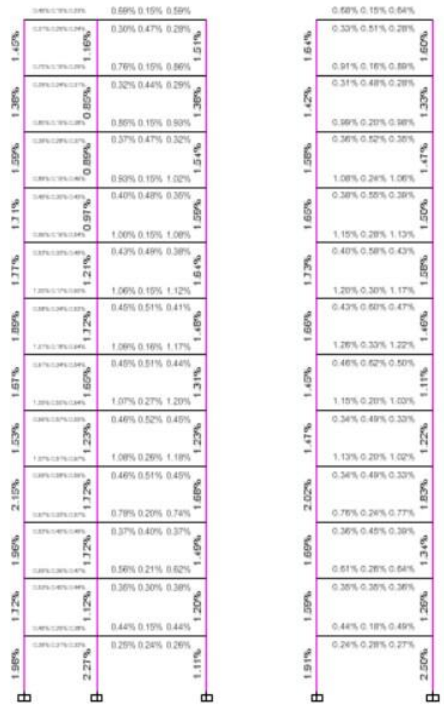

Figure 15 ELEVATION 8

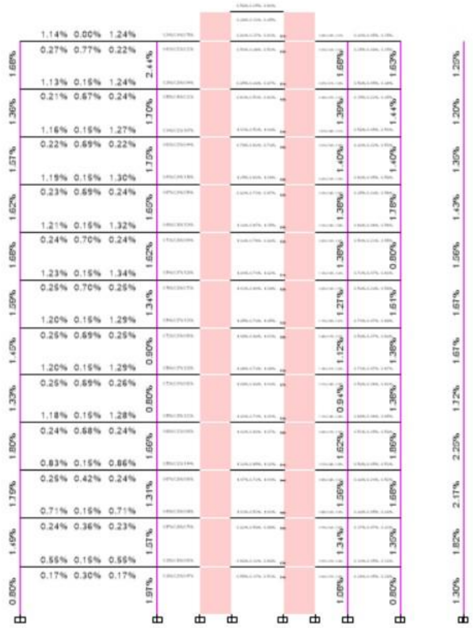

Figure 16 ELEVATION 9

9. FOUNDATION DESIGN

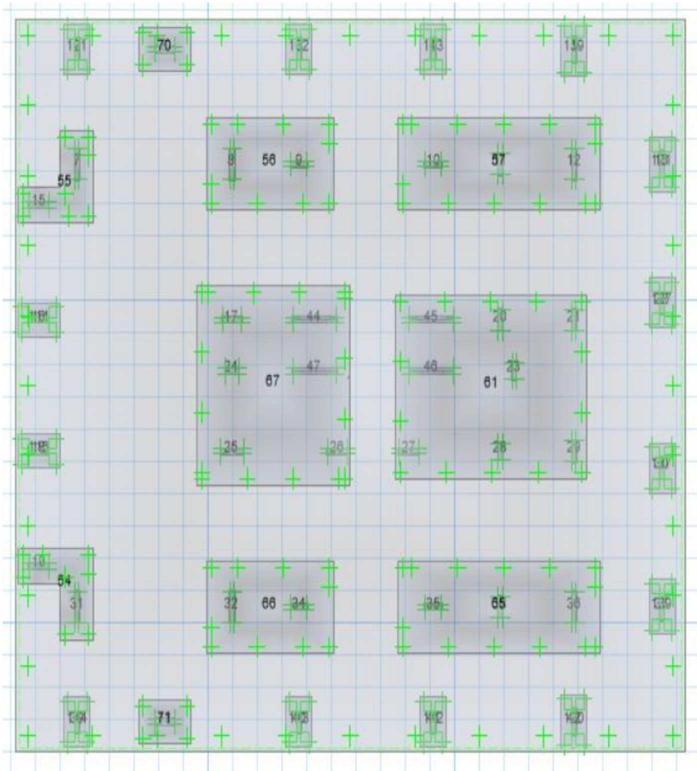

Figure 17 Mathematical Modal

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	

Table 10 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 mm
101	1130	1650	1000
70	2250	1430	1000
102	1130	1650	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

Table 11 Drop Size

9.3. Ground Bearing pressure check (GBP)

The ground bearing pressure should be less than SBC given in geotechnical report. The SBC is 300 KN/m2 > GBP 226 KN/m^2. Hence it is safe.

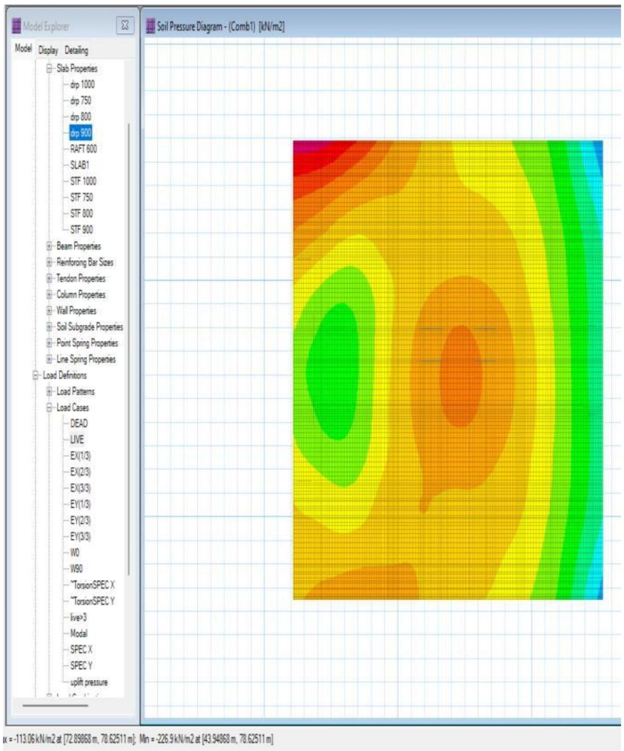

Figure 18 GROUND BEARING PRESSURE

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.

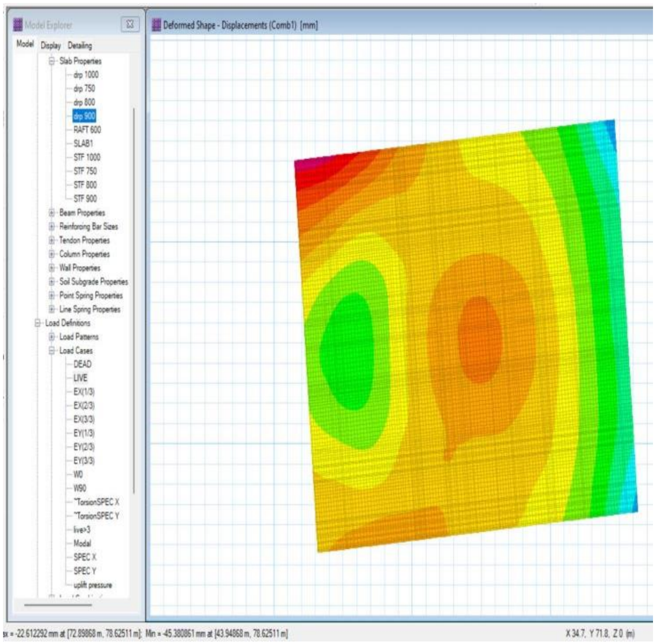

Figure 19 SETTLEMENT

9.5. Punching shear check

Punching is a service criterion 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.

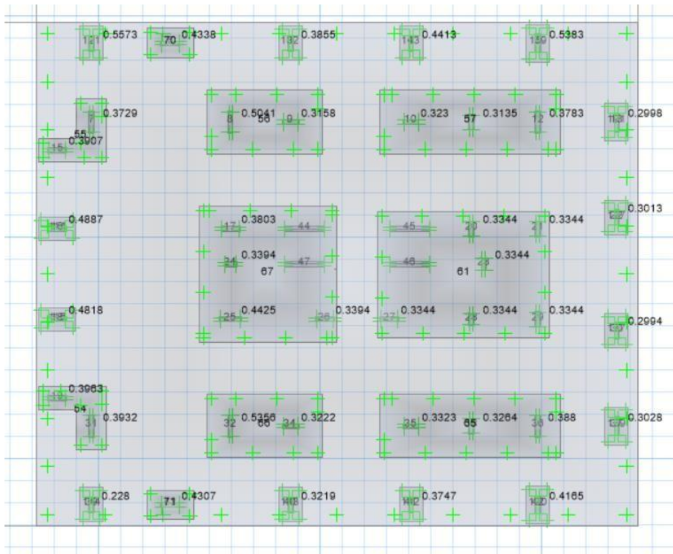

Figure 20 Punching Shear

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

Figure 21 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 footing 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-1	750	7500	Layer-1 20@100	**PASS**
					Layer-1 25@100	

Table 12 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 (a_{st}) 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-story 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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