

NUMERICAL STUDY ON ANALYSIS AND DESIGN OF OFFICE BUILDING USING ETABS (G+7)

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Abstract

This study focuses on the analysis and design of a G+7 office building in Chennai using the structural software ETABS. The building with a typical floor height of 3.9 m and 3.6 m at the stilt level. It has a length of 56 m and width of 25 m. As the structure is planned to be an office building for a tech park, majority of the floor is earmarked for computer systems, and cubicles, and thus will be a typical office floor, with pantry areas and restrooms located in certain marked areas, which will have sunken floors. In addition to the above-mentioned functions, there will be an electrical room with higher equipment loads, and staircase regions and lift lobby areas with higher live loads. In this project, ETABS software were used for modelling, analyse and design the office building for optimization of structural members, load distribution, efficiency of material selection and compliance with IS codes. Key findings from ETABS analysis includes storey drift, base shear, bending moment, shear force and deflection. The end use of this structure is for a IT park, so the required design life of the building is 50 years. To ensure that the building properly serves its function for the whole design life duration, necessary design considerations should be taken care of as per IS code.

Keywords: Diaphragm; Earthquake Loads; ETABS; Shear Wall; Wind Loads

Introduction

Designed to meet the evolving needs of businesses and professionals, G+7 office building offers a dynamic environment tailored for productivity, collaboration, and comfort. With seven floors of meticulously planned office spaces, each level promises a unique blend of style and functionality, catering to diverse industries and organizational requirements. At the heart of our building is a commitment to sustainability. From energy-

efficient design elements to eco-friendly materials, every aspect has been carefully curated to minimize environmental impact while maximizing efficiency. With features such as advanced HVAC systems, LED lighting, and green spaces, it strive to create a healthier workplace that fosters well-being and productivity. Hence, G+7 office building boasts state-of-the-art amenities and cutting-edge technology to support the needs of modern

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businesses. From high-speed internet connectivity to smart building management systems, it ensures seamless operations and enhanced user experience. This study aims to address, particularly in optimizing office building structures for IT parks using advanced numerical modeling tools.

Analysis Using Etabs

The structural frame was analyzed using ETABS software (Sekhar and Das, 2017). The building frame consists of numerous beams and columns, and the analysis required detailed information on member properties, loading conditions, and support specifications, including fixed supports with soil-structure interaction (Raikar *et al.*, 2020). The design parameters for concrete were specified according to IS 456:2000, while load calculations were performed in compliance with IS 875 (Parts I, II, and III, 2015). All selected beams and columns were modeled with rectangular cross-sections.

Plan of Building

The building is intended to serve as an office building for a tech park; hence, the majority of the floor area is designated for computer systems and

cubicles, as shown in Figure 1 (Tin, 2019). It will therefore be a standard office floor, with pantry spaces and restrooms situated in certain designated places that will have sunken floors. There will also be increased equipment loads in the electrical room, as well as higher live loads in the stairwell and lift lobby areas, in addition to the previously listed functions (Abhishek *et al.*, 2018). The overall elevation of the proposed office building is illustrated in Figure 2.

Site Location

The location of the project building is Chennai, which is located in the suburb regions of Chennai with road & metro connectivity of major hubs of the city (Karthikeyan *et al.*, 2023; as shown in Figure 3). A soil investigation was conducted by the geotechnical engineering team, and the report was generated based on the tests carried out. It was found that the sub-strata comprised medium dense soil, and a raft foundation was recommended based on the soil bearing capacity values (Ganesan *et al.*, 2025). It was also observed that there was no considerable amount of ground water in the specified location.



Figure 1. Plan

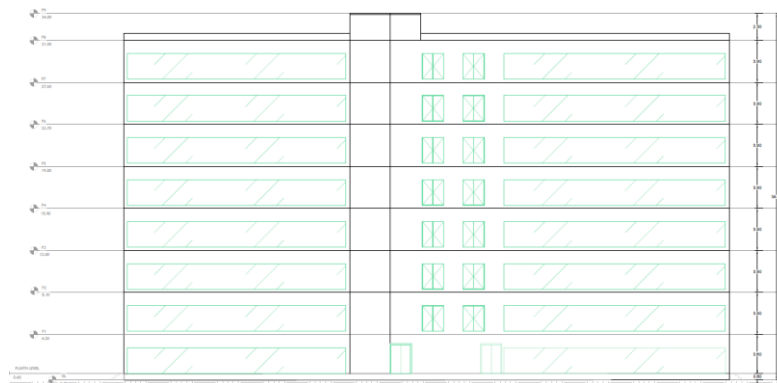


Figure 2. Elevation



Figure 3. Site Location

Design Life and Material Specifications

The end use of this structure is for an IT park, so the required design life of the building is 50 years (Khan and Hussain, 2021). To ensure that the building properly serves its function for the entire design life duration, necessary design considerations should be addressed as per IS code (Ramesh *et al.*, 2025). Table 1 specifies the grade of materials utilized in the structural study. M40 concrete was chosen for durability and strength, while Fe 500 steel ensures seismic ductility and structural efficiency (Antony Samy *et al.*, 2023).

Table 1. Material Specifications

Structural Element	Grade
Slabs and beams	M40
Columns	M40
Footing	M30

Main rebar is provided with Fe 500 grade steel and stirrups are provided with Fe 415 grade for better ductility and economy.

Table 2. Structural Elements' Cover Details

Structural Element	Nominal Cover
Slabs	25 mm
Beams	30 mm
Columns	40 mm
Shear Wall	40 mm
Footing	50 mm (bottom & sides) 30 mm (top)

Exposure and Cover

By referring to IS 456:2000, Table 3 (Tin, 2019), the project building is classified as having a moderate environmental condition. As noted by Karthikeyan *et al.* (2023), these values are determined based on the exposure of the structural elements; although the building is situated away from the shoreline, its proximity to the shore results in a classification of moderate exposure. In

accordance with Bureau of Indian Standards (1980), the nominal cover for the RCC elements is fixed, as summarized in Table 2.

Fire Requirements

In order to determine the fire safety requirements, the type of construction must first be identified. The floor area ratio (FAR) is calculated as the ratio of the total building area to the site area. For the present building, the total area is calculated as $56 \times 25 \text{ m} \times 8 \text{ floors} = 11,200 \text{ m}^2$. The site area, based on the provided site plan, is $88 \times 75 = 6,600 \text{ m}^2$. Therefore, the FAR is equal to 1.7.

According to Table 2 of the National Building Code (NBC), Vol. 1, Section 3, with the occupancy classified as Business and the type of construction identified as Type 3, the fire rating requirement can be established. From Table 1 of the NBC, Vol. 1, Section 3, the fire resistance for Type 3 construction-covering interior beams, columns, and similar structural members-is 120 minutes (2 hours).

Furthermore, as specified in IS 456:2000, Table 3, the minimum member sizes corresponding to this fire rating are to be adopted for design.

Table 3. Minimum size of members

Structural Member	Minimum Size
Beam Width	200 mm
Floor slab thickness	125 mm
Column	300 mm
Shear Wall	160 mm

Methodology

Step 1: New Model - The story height and measurements are entered into the grids at this step. The defined structural elements included slab sections, beams, and columns. The modelling of columns and beams is shown in Figures 1 and 2, respectively.

Step 2: Add Floor Openings - On multiple floors, the floor openings can be added at the same time. Figures 4, 5, 6, 7 and 8 displays the load arrangement, grid line diagram, material properties, slab thickness and loads assignment respectively

Step 3: Add Walls - Wall design is the task for this step (Interior and Exterior). Walls are included in the model as present configurations of wall stacks. The full modelling of the G+7 Office Building in ETABS is shown in Figure 9.

Step 4: The Load Patterns (Static) - This office building uses three types of loads: dead, live, and wind. The building's dead load is its own weight, whereas the live load is applied on the building's slab. It is possible to define the combination of load patterns.

Step 5: The rigid floor diaphragms' extent was built into the structure. The diaphragm was designed with seismic loads in mind to distribute the load in the slab appropriately. Floor systems were modelled by removing the in-plane degrees of freedom, resulting in rigid diaphragms with a considerable stiffness in-plane. Nevertheless, these diaphragms do carry stresses parallel to the plane in real site analysis. In order to transfer forces from the diaphragms into the lateral resisting frames and walls, chords and collectors were used in the diaphragm design and detailing process.

Step 6: The load cases (1.0(DL+LL), 1.5(DL+LL)) produced by the load patterns (Figure 9) will be examined.

Step 7: Both static and response spectrum analyses were performed to evaluate the structural response.

Step 8: Results can be viewed by using the toolbars at the top, such as SFD and BMD. The results of the analysis can be seen and examined after it is finished.

Step 9: The ETABS can be used to design concrete frames, which comprise slabs, columns, and beams. The structure can be analyzed once the entire structure has been modeled in ETABS and all property definitions-including material and section specifications, model geometry with tendon locations and profiles, jacking force assignments, member assignments, and loading combinations-have been specified (Suryawanshi *et al.*, 2020). The software calculates responses, member displacements, slab forces, and slab stresses for all specified load patterns and combinations while analyzing the structure (Mule *et al.*, 2020).

Utilizing the aforementioned design code, ETABS designs the structure, calculates the necessary quantity of rebar reinforcement, and completes the required punching shear checks (Anjaneyulu and Prakash, 2016; Sunil *et al.*, 2017). The program also automates several slab and mat

design procedures. The design of the rebar reinforcement is obtained, slab punching shear around the column supports is verified, and the slab design moments created in the design strips are determined (Shwetha *et al.*, 2019).

Load Specifications

Following are the loads to be included in the design of the building. Table 4 displays the different dead loads taken into account during the analysis.

Table 4. Dead Load Specifications

Materials	Unit weight (kN/m ³)
Reinforced Cement Concrete	25
Plain Cement Concrete/ Screed	24
Cement concrete block work	20
Steel	78.5
Soil	18
Aluminum	28
Glass	25

Dead Loads

Dead loads comprise of the self-weight of the elements. Unit weights of various materials used in the building are given below:

Superimposed Dead Loads

- I. Line load: Block walls & finishes
 - For 230 mm outer block wall (height = 3 m): $(0.20 \times 20 + 0.03 \times 24) \times 3 = 14.16$ kN/m
 - Approximated as 15 kN/m on all outer beams
- II. Floor finish (50 mm screed + 15 mm mortar + 10 mm tile thickness = 75 mm total)
 - SDL due to finish = $0.075 \times 24 = 1.8$ kN/m²
- III. Sunken slab (depth = 300 mm)
 - $SDL = 0.30 \times 24 = 7.2$ kN/m²
- IV. Weather proof course
 - Screed with waterproofing provided on roof with slope of 1:100 for drainage
 - Load on roof (thickness ~100 mm, considering two-way slope across 25 m width): $0.10 \times 24 = 2.4$ kN/m²
- V. Light weight partitions: Provide 1 kN/m²
- VI. False ceiling = 0.5 kN/m²
- VII. MEP Services = 0.5 kN/m²

Live Loads

Following live loads are considered for the different locations of the buildings based on IS 875 (Part 2):1987. The following live loads are applied in the structural model, as shown in Figure 4.

Based on the Indian Standard 875 - Part 2 2015, live load is computed. Table 5 discusses the live load requirements.



Figure 4. Loads

Table 5. Live Load Specifications

Description	Classification	Load Intensity (kN/m ²)
Office area	- Rooms without storage - Corridors, passages & lobbies	4.0
Lobby area	Whole area	4.0
Roof	With access	1.5
Service rooms	- AHU & Electrical rooms - Pantry - Toilets	5.0 3.0 2.0

Wind Loads

The wind pressure is calculated based on the data as per IS 875 (Part-3):2015.

- Basic wind speed (V_b) = 44 m/s
- Risk co-efficient, (k₁) = 1.00
- Terrain category (k₂) = 2
- Topography factor (k₃) = 1.00
- Importance factor for cyclonic regions, (k₄) = 1.00
- Wind directionality factor, (k_d) = 1.0

In accordance with IS 875:2015 (Part 3), the software was given the necessary parameters to analyse the structure for wind load as well. The structure is situated in Chennai. (Shinde and Phuke, 2013) Therefore, the above wind load characteristics that were determined based on site considerations. Wind and seismic loads are not considered simultaneously as per IS 1893:2016.

Seismic loads

The loading due to earthquake is assessed based on the provisions of IS 1893:2016. Chennai is considered as seismic zone III as per IS 1893:2016 (Bahoria and Parbat, 2013), and this classification is used to determine the earthquake loads on the

building. Ductile detailing of reinforced concrete elements is considered as per IS 13920:2016.

Base shear calculation

The total load on the building was calculated as:

$$W = (DL + SDL) + (0.5LL_{>3} + 0.25LL_{<3}) \times Area$$

This yields an approximate total load of 10,696 kN per floor, resulting in a cumulative load of 74,872 kN for the entire structure.

The design horizontal seismic coefficient (A_h) was computed in accordance with IS 1893, as shown below:

- X-direction:

$$A_{hX} = \frac{Z}{2} \times \frac{I}{R} \times \frac{S_a}{g} = \frac{0.24}{2} \times \frac{1}{5} \times 2.5 = 0.06$$

- Y-direction:

$$A_{hY} = \frac{Z}{2} \times \frac{I}{R} \times \frac{S_a}{g} = \frac{0.24}{2} \times \frac{1}{5} \times 2.0 = 0.048$$

Accordingly, the base shear values were obtained as:

- X-direction:

$$V_{bX} = W \times A_{hX} = 74,872 \times 0.06 \approx 4,492 \text{ kN}$$

- Y-direction:

$$V_{bY} = W \times A_{hY} = 74,872 \times 0.048 \approx 3,593 \text{ kN}$$

The above base shear values, bending moment, and deflection values have been validated in Table 6 (Atif *et al.*, 2015; Priyanka *et al.*, 2018).

Table 6. Comparison of Results

Base Shear	ETABS Analysis	Manual Calculation
Base Shear in X direction	4492 kN	4562 kN
Base Shear in Y direction	3593 kN	3612 kN
Bending Moment for beam B74	269.66 kNm	266.15 kNm
Deflection for beam B74	3.112 mm	3.32mm

Load combinations

With all the loads calculated, load combinations for the building must be considered based on IS 456:2000. The following load patterns were included in the analysis:

- Dead Load (DL)
- Live Load (LL)
- Wind Load (WIND X+)
- Wind Load (WIND Y-)
- Seismic Load (EQ X+)
- Seismic Load (EQ Y+)

The load combinations considered in the analysis, based on Indian Standard codes, are presented below (Guleria, 2014).

Load combinations for serviceability

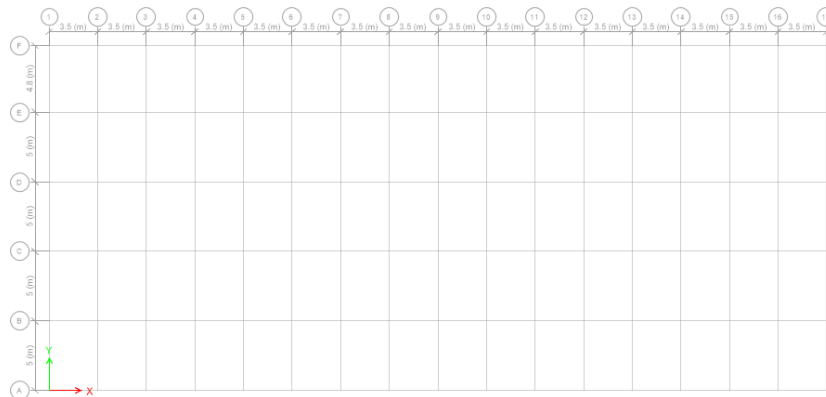
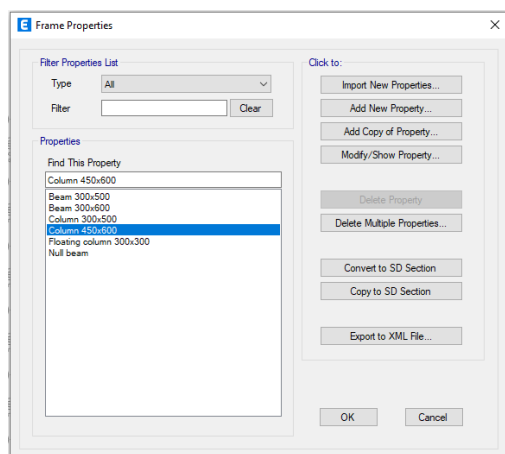
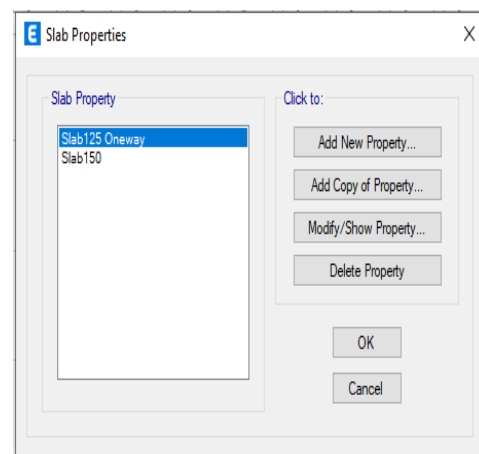
- 1.0 DL + 1.0 LL
- 1.0 DL + 0.8 LL + 0.8 EQ/WL

Load combinations for strength

- 1.5 DL + 1.5 LL
- 1.2 DL + 1.2 LL + 1.2 EQ/WL
- 1.5 DL + 1.5 EQ/WL
- 0.9 DL + 1.5 EQ/WL

It should be noted that both earthquake loads (EQ) and wind loads (WL) are represented in the above expressions. However, wind and seismic loads are not considered to act simultaneously on the structure (Sardiwal *et al.*, 2019).

The structural response under these loading conditions, including storey drift, base shear, bending moment, shear force, and deflection, is illustrated in Figures 5-11.

**Figure 5. Grid lines****Figure 6. Material Properties****Figure 7. Slab thickness**

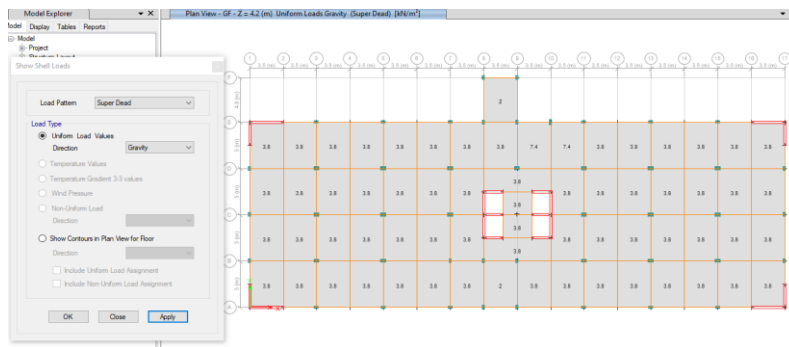


Figure 8. Loads

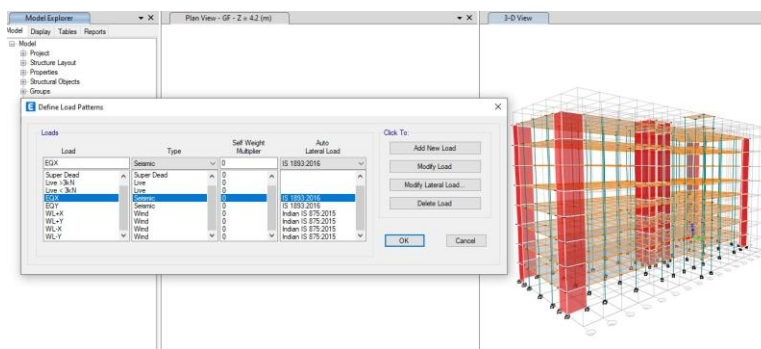


Figure 9. Load Patterns

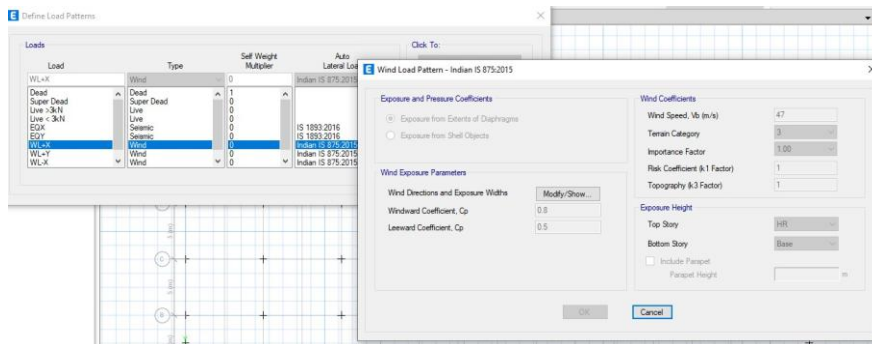


Figure 10. Wind Load Parameters

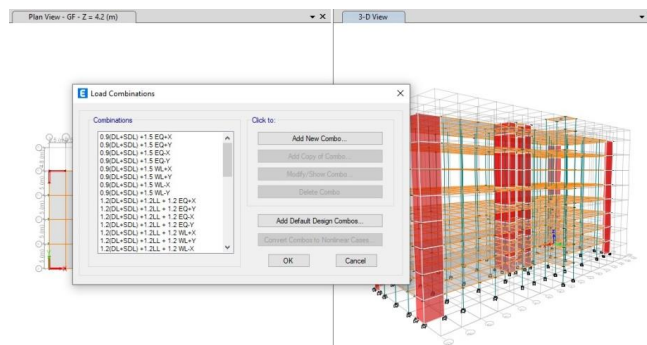


Figure 11. Load Combinations

Results and Discussion

The total base shear value is cross checked with values obtained with manual calculation as per section 2.7 and validated with ETABS results. The maximum storey displacement, measured at storey 6, was determined to be 13.46 mm which is within the permissible limit. The permissible storey drift limit has been calculated as per IS 1893:2016 cl.7.11.1 using $0.004 \times \text{storey height}$ ($0.004 \times 3.9 = 0.0156 \text{ m}$ ie. 15.6 mm. Figures 12, 13, 14, 15 and 16 displayed the storey-wise displacement variation, Base shear, Concrete reinforcement, Deflection of Beam, Axial Force Diagram and Bending Moment Diagram respectively. The ETABS is consulted for

the maximum Shear Force and Bending Moment values for important sections, and manual structural element design calculations are performed.

ETABS allows the visualization of the deformed structural shape under various applied load combinations. As illustrated in Figures 8 and 9, the deformation patterns vary according to the respective load cases and conditions (Prajapati and Bedi, 2019).

After that, ETABS was used to design the concrete, and all of the concrete members' reinforcement details were acquired. Figures 11 and 12 depict the concrete frames for design verification and the final concrete design.

Story	Label	Unique Name	Output Case	Case Type	Step Type	Step Number	Ux mm	Uy mm	Uz mm
7F	40	987	1.5(DL+SDL) ...	Combination	Mis		-2.275	-36.295	-0.77
7F	40	987	0.9(DL+SDL) ...	Combination	Mis		-2.275	-36.295	-0.77
7F	40	987	Envelope of S...	Combination	Mis		-29.783	-36.295	-2.607
7F	40	987	DConS34	Combination	Mis		-2.275	-36.295	-0.77
7F	40	987	DSBs34	Combination	Mis		-2.275	-36.295	-0.77
7F	40	987	DWts34	Combination	Mis		-2.275	-36.295	-0.77
7F	104	988	1.5(DL+SDL) ...	Combination	Mis		-1.706	-36.278	-4.173
7F	104	988	0.9(DL+SDL) ...	Combination	Mis		-1.706	-36.278	-4.173
7F	104	988	Envelope of S...	Combination	Mis		-29.501	-36.278	-4.173
7F	104	988	DConS34	Combination	Mis		-1.706	-36.278	-4.173
7F	104	988	DSBs34	Combination	Mis		-1.706	-36.278	-4.173
7F	104	988	DWts34	Combination	Mis		-1.706	-36.278	-4.173
7F	39	928	1.5(DL+SDL) ...	Combination	Mis		-1.129	-36.258	-7.592
7F	39	928	0.9(DL+SDL) ...	Combination	Mis		-1.129	-36.258	-7.592
7F	39	928	Envelope of S...	Combination	Mis		-29.261	-36.258	-8.17
7F	39	928	DConS34	Combination	Mis		-1.129	-36.258	-7.592
7F	39	928	DSBs34	Combination	Mis		-1.129	-36.258	-7.592
7F	39	928	DWts34	Combination	Mis		-1.129	-36.258	-7.592
7F	36	991	1.5(DL+SDL) ...	Combination	Mis		-2.49	-36.226	-2.303

Figure 12. Deflection

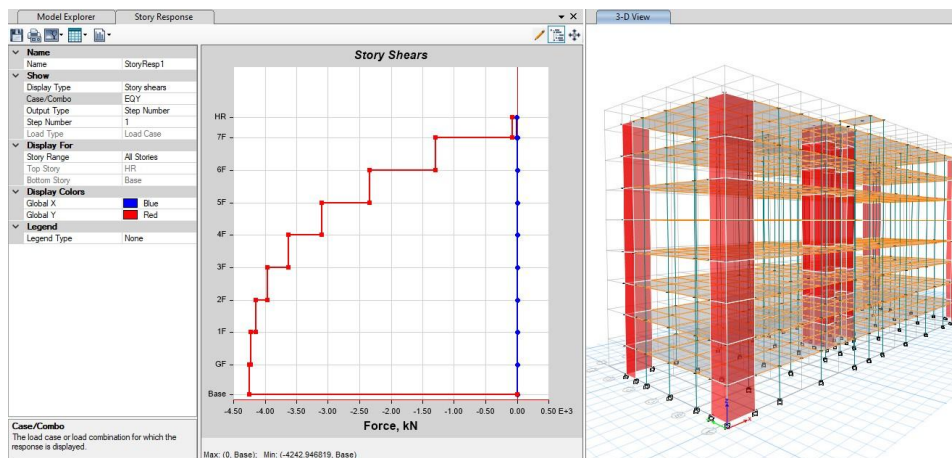


Figure 13. Load Patterns

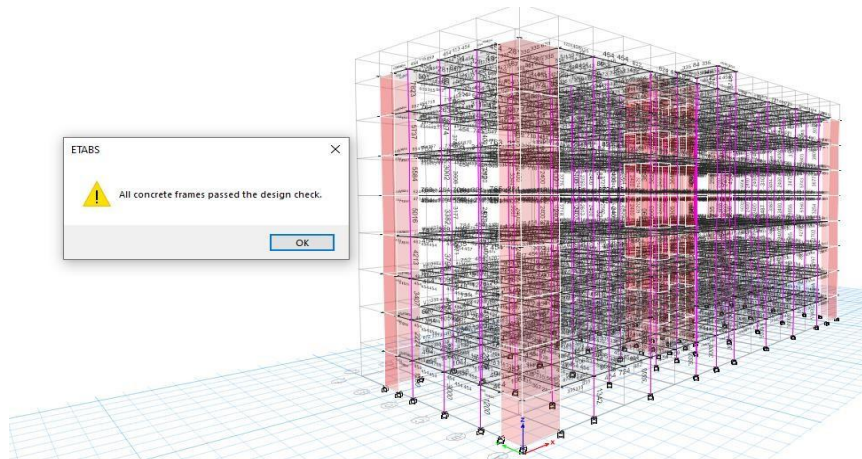


Figure 14. Concrete Reinforcement

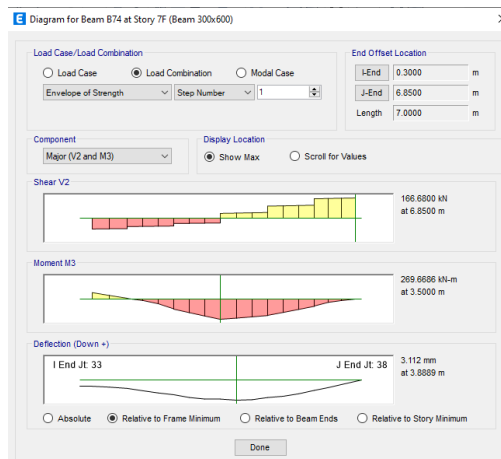


Figure 15. Deflection of Beam

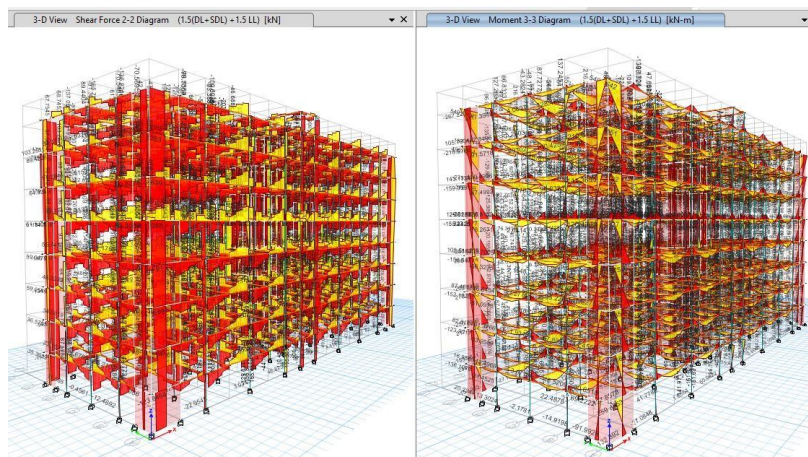


Figure 16. Axial force and Bending Moment

Conclusion

- Based on the knowledge gained from theoretical studies and guidelines from IS 456:2000, IS 875, and IS1893, the Planning Analysis and Design of the G+7 Office Building was thoroughly completed using ETABS for structural performance.

- Slabs, beams, column, footing, and staircases were all designed using ETABS software. It is discovered that while manual computation produces small inaccuracies in static analysis, the ETABS yields accurate results. It focus on static and response spectrum analysis without a full dynamic time history analysis.

- The analysis results' bending moment and shear force were taken into account when designing the beams, columns and shear wall. By using ETABS software, analysis and design time are reduced. Future research includes time history analysis to assess seismic response in greater detail.

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