

CAREER EPISODE 3

Seismic Analysis and Design of an Industrial Warehouse Using ETABS in Seismic Zone II

INTRODUCTION

CE 3.1

During my 7th semester at [REDACTED], I undertook a project on as part of my course “Construction Engineering and Management” and the project spanned from [REDACTED], lasting a total of four months. This period was a critical phase in my academic journey, where I applied theoretical knowledge to practical scenarios, focusing on the design and analysis of an industrial warehouse using the ETABS software so this project had provided me with significant insights into the complexities of structural engineering and reinforced my understanding of seismic design principles.

BACKGROUND

CE 3.2.1

The project was initiated to address the growing need for well-designed industrial warehouses due to rapid industrialization in India and so the primary goal was to design an industrial warehouse that meets the necessary structural and safety standards, particularly in seismic zones. Given [REDACTED] location in seismic zone II, it was essential to ensure that the warehouse could withstand potential earthquakes, thereby safeguarding both the structure and the stored goods and the project began with a comprehensive literature review to understand the different types of forces and load effects that need to be considered while designing an industrial warehouse and the warehouse was designed as a steel-framed structure, which is typical for industrial buildings due to its strength and flexibility. The design process involved using ETABS (Extended Three-Dimensional Analysis of Building Systems), a software known for its efficiency in analyzing and designing buildings under various loads and the focus was on performing a detailed seismic analysis to ensure the warehouse's stability and integrity.

CE 3.2.2

The specific objectives of the project included calculating displacements, shear, and overturning moments in seismic zone II and this involved detailed analysis using the Response Spectrum method to determine the maximum storey displacement, maximum overturning moment, storey drift, and storey shear and these calculations were critical in ensuring that the design could withstand the lateral loading effects of an earthquake and throughout the project, I was involved in various stages, including initial planning, design, and analysis. I collaborated with my batchmates and project supervisor to validate the design and ensure compliance with the relevant standards.

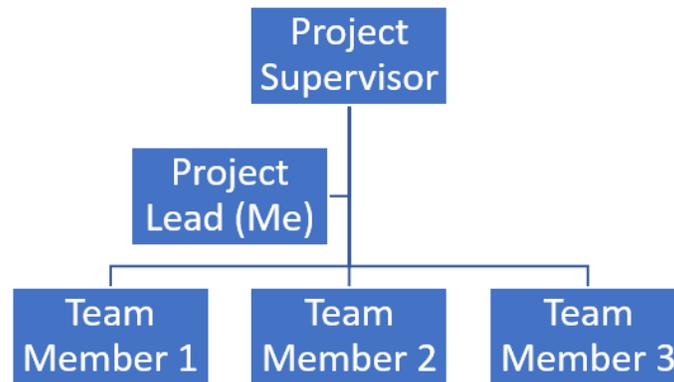


Figure 1: Hierarchy

Each member played their roles in various aspects of the project, from literature review and material procurement to experimental setup and data analysis and we had all worked collaboratively to design and execute the experiments, ensuring that all tasks were completed efficiently and effectively.

PERSONAL ENGINEERING ACTIVITY

CE 3.3.1

I began the project by identifying the need for a well-designed industrial warehouse to support the rapid industrialization in India and so to gain a comprehensive understanding of the requirements, I conducted a thorough literature review which had focused on the various forces and load effects that must be considered when designing an industrial warehouse and my primary references were the IS 800:2007 and IS 875:1987 which provide essential guidelines for structural design and load combinations necessary to ensure safety and functionality.

During my literature review, I came across numerous academic papers, industry reports, and case studies related to the design and construction of industrial warehouses and this extensive research helped me understand the typical challenges and best practices in the field and for instance, I learned about the significance of considering various load effects and then I reviewed several case studies that detailed the construction methodologies and materials used in successful warehouse projects and this background knowledge was crucial in shaping my approach to the project.

CE 3.3.2

After understanding the theoretical aspects, I selected ETABS (Extended Three-Dimensional Analysis of Building Systems) for the structural analysis and design and ETABS is renowned for its capability to model and analyze complex building structures under various load conditions, making it the ideal choice for this project and I had familiarized myself with the software's features and functionalities, ensuring I could effectively use it for the seismic analysis and design of the warehouse. I invested considerable time in learning the advanced features of ETABS through tutorials and manuals and this included understanding how to input various load types, define

material properties, and interpret the analysis results and so my goal was to ensure that I could maximize the software's potential to create a robust design and then I participated in online forums and discussions with other ETABS users, which provided valuable insights and tips for using the software effectively.

CE 3.3.3

With a clear understanding of the requirements, I defined the primary objectives of the project and so the main objective was to design an industrial warehouse that complies with IS 800:2007 standards and additionally, I aimed to perform detailed load analysis for dead, live, and wind loads as per IS 875:1987 and conduct a comprehensive seismic analysis for seismic zone II (Hyderabad) using ETABS and the ultimate goal was to ensure that the warehouse design could withstand various load conditions while maintaining structural integrity and safety. The scope of the project included designing a steel-framed warehouse structure, performing load calculations, and ensuring compliance with [REDACTED] Standard codes and furthermore, I aimed to develop a construction plan that detailed the step-by-step process of erecting the warehouse and this included defining the materials, construction methods, and safety measures to be implemented during the construction phase.

CE 3.3.4

I began by creating a preliminary design of the warehouse structure and this involved selecting appropriate materials and structural elements, including steel columns, beams, and trusses and I designed the warehouse as a single-storey steel structure with dimensions of 80m x 14m and a total height of 7.5m and so I chose steel for its strength, flexibility, and suitability for industrial buildings and the use of steel also facilitated quicker construction and provided better resistance to seismic forces.

Table 1: Details of warehouse

S.No	Particulars	Description
1	Type of building	Warehouse
2	Type of structure	Single Storey Industrial Structure
3	Location	Hyderabad
4	Area of site	1,820 sq.m
5	Type of building	Steel Building
6	Area of building	1,120 sq.m
7	Eave height	12m
8	Number of spans	2
9	Single span width	14 m
10	Number of bays	20
11	Single bay length	4 m
12	Total bay length	80m

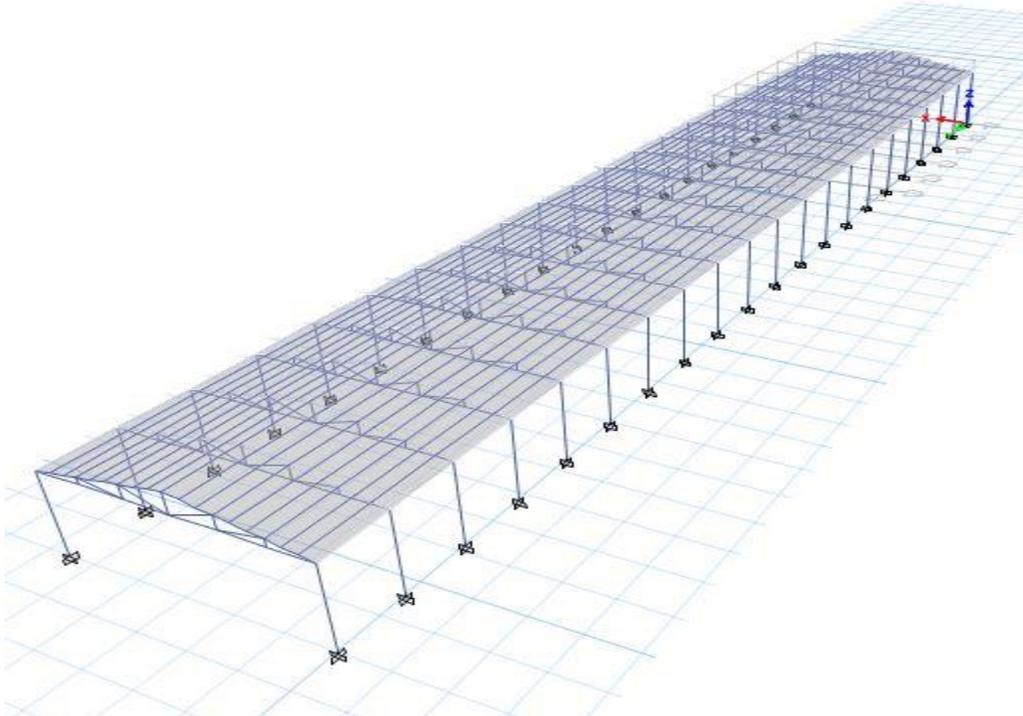


Figure 2: Roof assignment to the grid

Using ETABS, I created a 3D model of the warehouse and I defined the material properties, section properties, and load conditions based on the project requirements and the model included all the structural elements such as columns, beams, trusses, and bracings and I also specified the boundary conditions, assuming the frames were firmly fixed at the bottom and this modeling process allowed me to visualize the entire structure and identify any potential design issues early on. I meticulously inputted the dimensions and properties of each structural element into ETABS and this included specifying the type of steel to be used and then I also defined the connections between different elements to ensure that the structure would behave as a unified system under load.

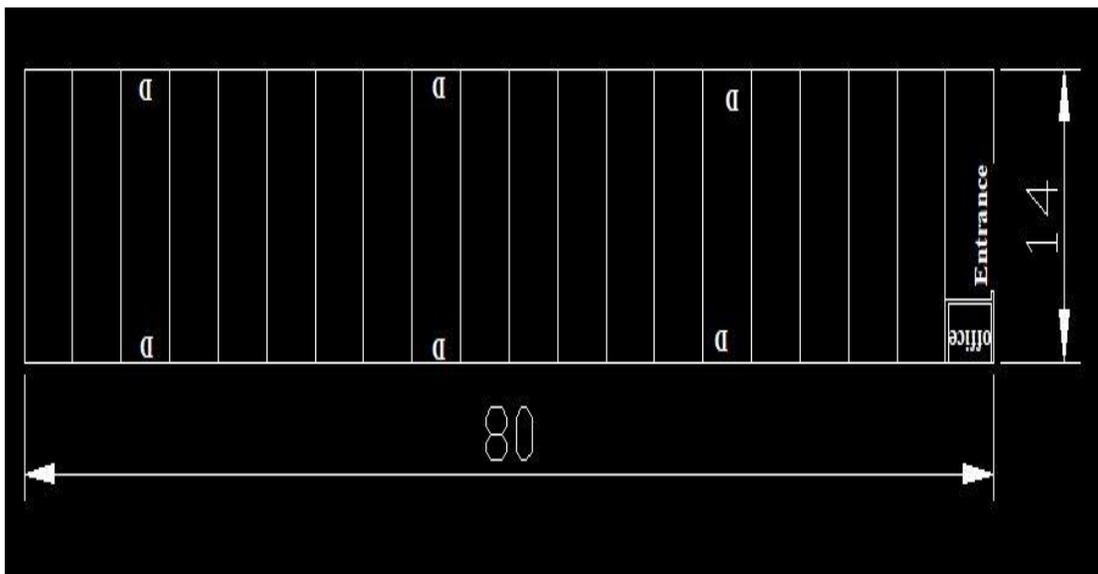


Figure 3: The plan of structure 80mx14m

Load Calculation and Application

Next, I performed detailed calculations for various loads acting on the structure and the loads considered included dead loads, live loads, and wind loads. I referred to IS 875:1987 for these calculations.

1) Angle of roof truss

Consider the smaller portion i.e half roof truss

$\tan \alpha = \text{opp side/adj side}$

$$1.5/7 = 0.2$$

$$\tan \alpha = 0.2$$

$$\alpha = \tan^{-1}(0.2)$$

$$\alpha = 11.30$$

2) Length of principal rafter

$$PR^2 = (\text{Rise})^2 + (\text{Half length})^2$$

$$PR^2 = (1.2)^2 + (7)^2$$

$$PR = \sqrt{(1.5)^2 + (7)^2}$$

$$PR = 7.15\text{m}$$

For the dead load calculation, I considered the weight of the roof material, purlins, self-weight of the truss, and wind bracing and the weight of the galvanized iron (GI) sheet used for roof covering was 150 N/m². I also accounted for the weight of purlins, which I assumed to be 120 N/m² on the plan area and additionally, I considered the self-weight of the roof truss and wind bracing and this cumulative load was then evenly distributed across the panel points. For the live load calculation, I determined the live load based on the intended usage of the warehouse and for the roof, the live load was calculated as 0.75 KN/m², adjusted for the slope of the roof and this adjustment was crucial to accurately reflect the load that the roof would experience in real-world conditions. For the wind load calculation, I used the static wind method and I considered factors such as the basic wind speed in Hyderabad (44 m/s) and the terrain category. The calculation involved determining the velocity pressure and applying it to the roof structure, ensuring that the design could withstand potential wind forces. These loads were then applied to the ETABS model, ensuring all relevant load combinations were considered and this comprehensive load application was crucial for accurate structural analysis and design.

CE 3.3.5

Given Hyderabad's location in seismic zone II, it was crucial to perform a detailed seismic analysis and I used the Response Spectrum method for this purpose, which is suitable for seismic analysis of structures and the analysis involved defining seismic parameters as per IS 1893 (Part 1): 2002

and this included factors such as the zone factor, importance factor, and response reduction factor and these parameters were essential for accurately modeling the seismic forces that the structure would need to withstand. I generated the response spectrum for seismic zone II and applied it to the ETABS model and the response spectrum represents the peak response of the structure to seismic excitation, allowing for a comprehensive analysis of potential seismic impacts and I ran the seismic analysis in ETABS, which involved calculating the displacements, shear forces, and overturning moments for different load combinations and the analysis provided critical values which were essential for the design validation process. The results of this analysis were thoroughly reviewed to ensure the design met all safety and performance criteria and I meticulously checked the values against the permissible limits specified in the Indian Standard codes and any discrepancies were addressed by adjusting the design and re-running the analysis until the results were satisfactory.

CE 3.3.6

After obtaining the analysis results, I reviewed the design to ensure it met all safety and performance criteria and so I validated the design against the relevant Indian Standard codes, checking for compliance with IS 800:2007 and IS 456:2000 and the maximum storey displacement was found to be 95.575mm, which was within acceptable limits, indicating that the structure would remain stable and functional under seismic forces. The maximum overturning moment was 7.298 KN-m, while the minimum was -2.714E and these values were within the permissible limits, ensuring the structure's resistance to overturning during seismic events and the maximum storey drift was 0.0155mm, ensuring the structure's stability under seismic loads and this minimal drift was crucial for maintaining the integrity of the building during an earthquake and the maximum storey shear was 6.234E-09, and the minimum was -1.157593 and these values were within the acceptable range, indicating that the design could effectively resist shear forces during seismic activity. Based on these results, I made necessary adjustments to the design to optimize the structural performance and this involved fine-tuning the dimensions and sections of structural elements to achieve the desired safety and efficiency and for instance, I increased the cross-sectional dimensions of certain beams and columns to enhance their load-bearing capacity and then I also adjusted the spacing of the trusses and bracings to improve the overall stability of the structure.

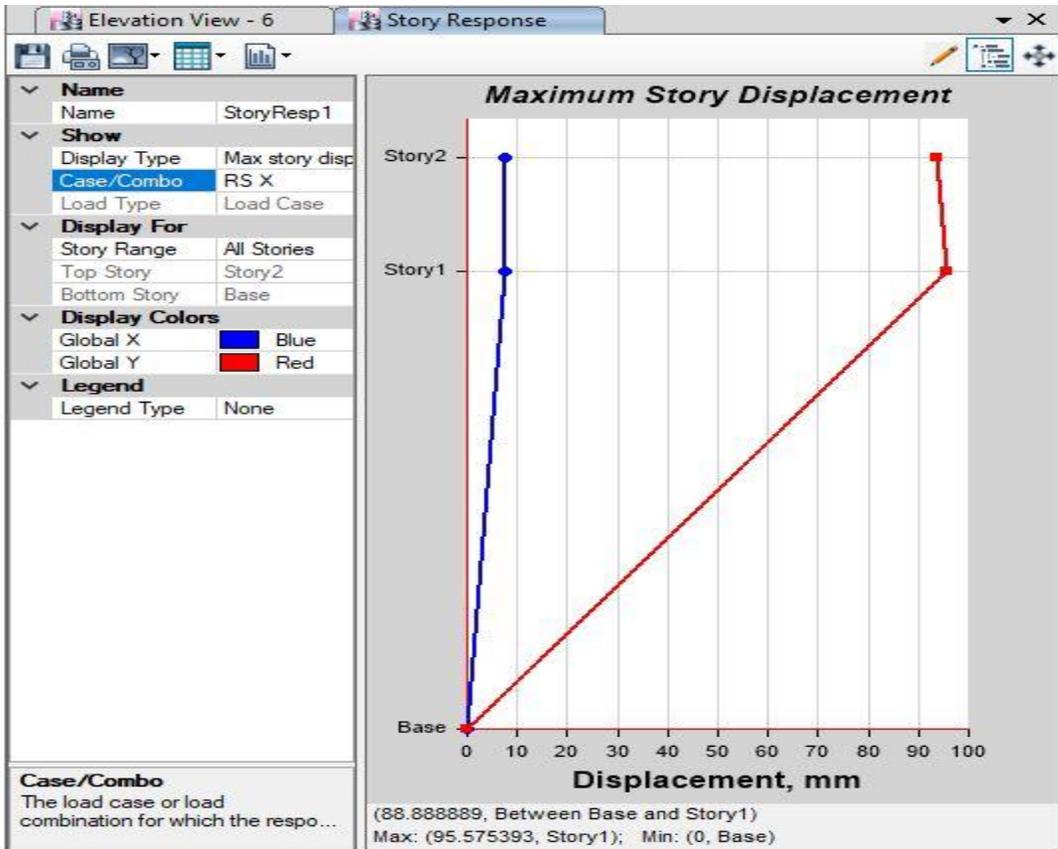


Figure 4: Maximum storey displacement is 95.575mm

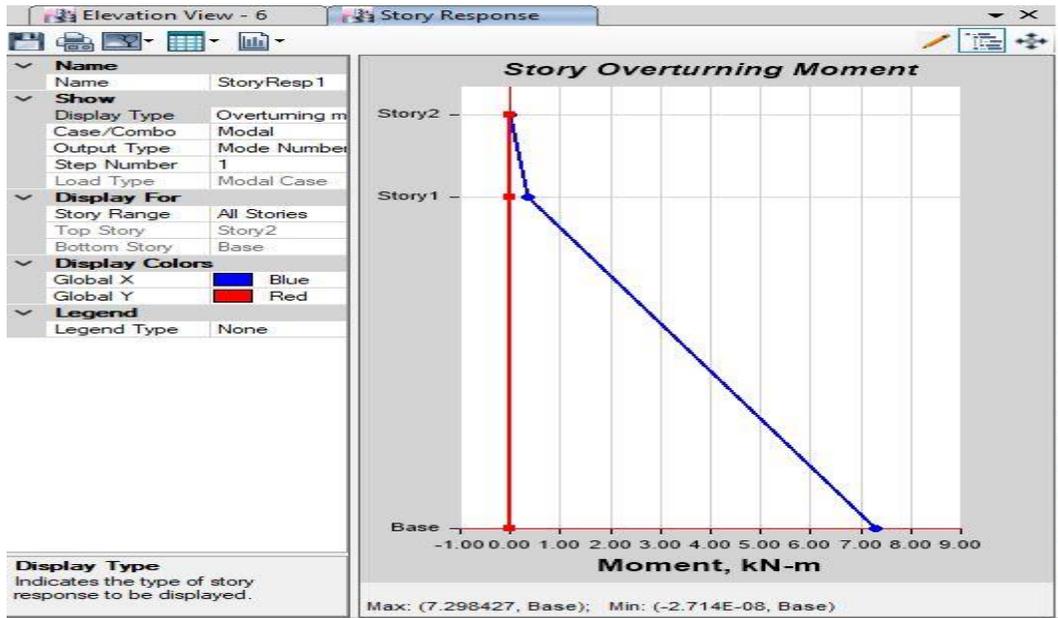


Figure 5: Maximum overturning moment is 7.298 and minimum is -2.714E

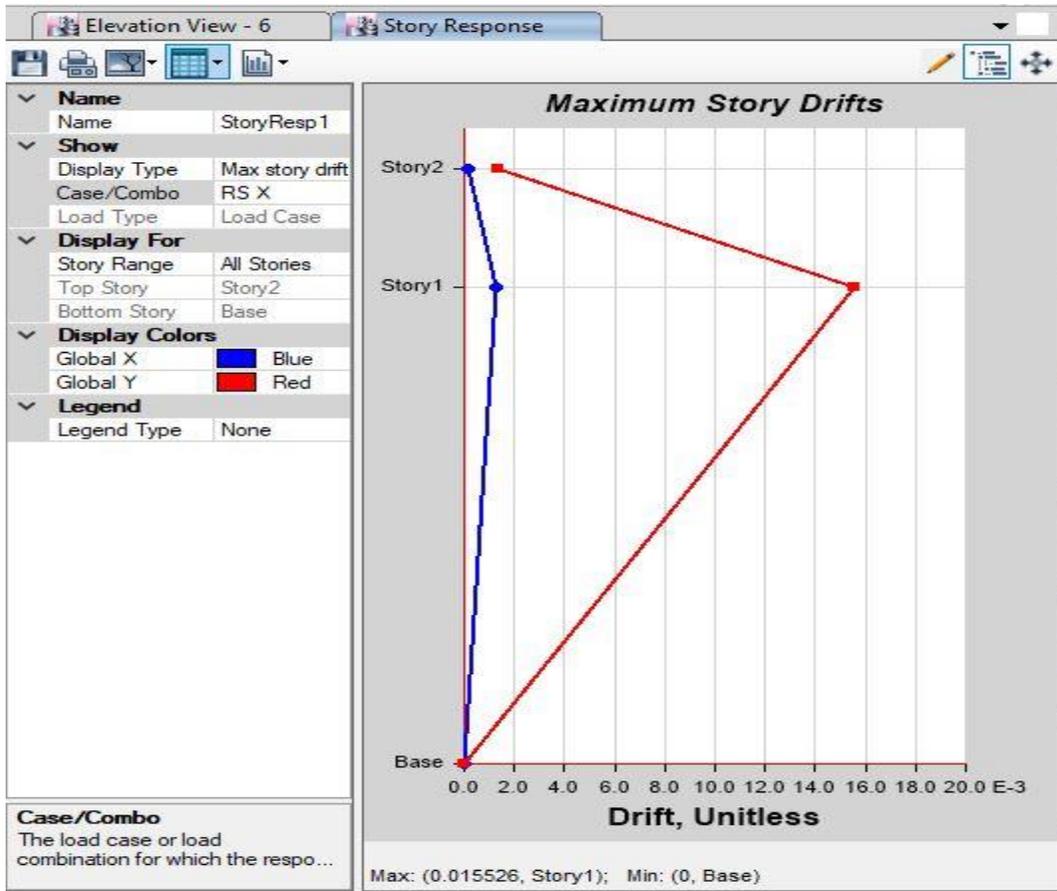


Figure 6: Maximum Storey Drift is 0.0155mm

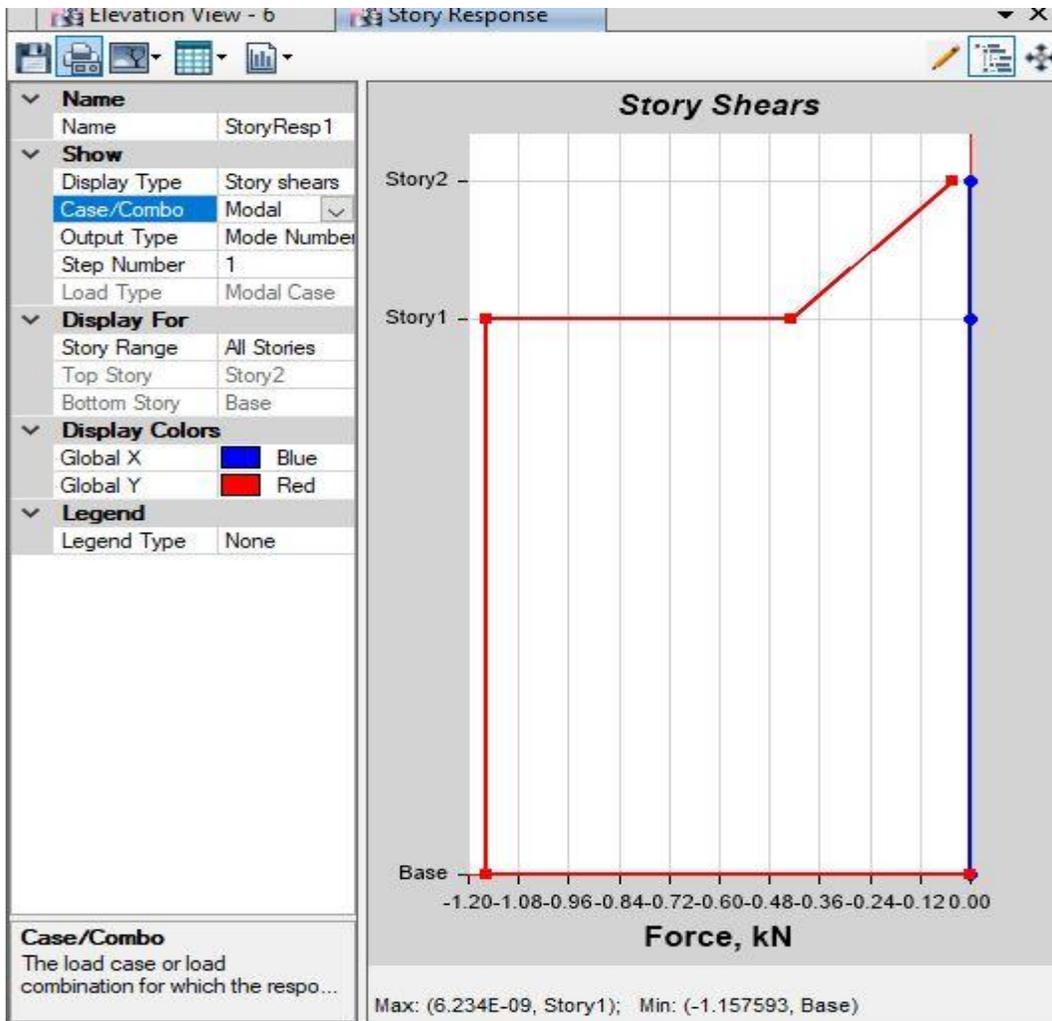


Figure 7: Maximum storey shear is 6.234E-09 and minimum is -1.157593

Table 2: Summary of Member Properties

Member	Section provided
Top chord	ISA 200*200*25
Bottom chord	ISA 200*200*25
Web member	ISA 200*200*25
Column	ISWB 600@145.1 kg
Purlin	ISB 48*82*5.4

Table 3: Summary of Results

Maximum Storey Displacement	95.575mm
Maximum Overturning Moment	7.298
Minimum Overturning Moment	-2.714E
Maximum Storey Drift	0.0155mm
Maximum Storey Shear	6.234E
Minimum Storey Shear	-1.157593

CE 3.3.7

The project was successfully completed within the stipulated time frame of four months and the final structure met all the design requirements and standards, providing a safe and functional industrial warehouse capable of withstanding seismic forces in zone II. This project was a significant milestone in my engineering career, allowing me to apply theoretical knowledge to a practical, real-world problem and it enhanced my understanding of structural engineering principles, seismic design, and the use of advanced software tools like ETABS and the experience also improved my project management skills, particularly in planning, execution, and quality control.

SUMMARY

CE 3.4.1

I undertook this project as part of my course in Construction Engineering and Management. This project, which had lasted from [REDACTED], focused on designing and analyzing an industrial warehouse using ETABS software. The project had aimed to address the need for well-designed industrial warehouses in [REDACTED], particularly in seismic zones like [REDACTED], so first I conducted a comprehensive literature review and used ETABS for seismic analysis to ensure the warehouse could withstand earthquakes. The project involved calculating displacements, shear, and overturning moments using the Response Spectrum method and I meticulously planned, designed, and analyzed the structure, collaborating with my batchmates and supervisor to validate the design against Indian Standards. Hence, the final design met all safety and performance criteria, providing a robust and stable warehouse and this project significantly enhanced my understanding of structural engineering, seismic design, and advanced software tools.