ANALYSIS & DESIGN OF G+20 RESIDENTIAL BUILDING USING ETABS

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Abstract

Self-Compacting Concrete (SCC) addresses the challenges of poor compaction in traditional concrete, offering superior flowability without mechanical vibration. However, SCC's higher cost, due to superplasticizers and high cement content, can be mitigated using Supplementary Cementitious Materials (SCMs) like fly ash and silica fume. SCMs improve the mechanical strength and durability of concrete by refining its pore structure. Ternary blended concrete (TBC), combining two SCMs as partial cement replacements, optimizes these benefits while addressing individual SCM limitations.

Despite its advantages, SCC has poor tensile strength, impact resistance, and brittleness. Adding glass fibers, which enhance mechanical properties and reduce shrinkage cracks, mitigates these issues. This study evaluated the fresh, mechanical, and durability properties of TBC blends and glass fiber-reinforced SCC. Among the tested blends, TBC9, comprising 70% Ordinary Portland Cement, 20% fly ash, and 10% silica fume, demonstrated superior mechanical and durability properties.

Introducing alkali-resistant glass fibers to TBC9 improved splitting tensile strength by 17% and increased energy absorption, though higher fiber content reduced compressive strength. Overall, the optimal TBC9 blend with glass fibers enhanced SCC's tensile and impact strengths while maintaining workability and durability. These findings highlight the potential of TBC and fiber reinforcement to advance SCC applications in construction.

Key Words: *Self-Compacting Concrete (SCC), Ternary Blended Concrete (TBC), Supplementary Cementitious Materials (SCMs), Glass Fiber, Durability, Mechanical Properties, Workability.*

1.INTRODUCTION

Introduction

Self-Compacting Concrete (SCC) is an innovative type of concrete that flows under its own weight without requiring mechanical vibration, ensuring uniform compaction even in heavily reinforced or complex structural elements. Introduced in Japan during the late 1980s to address challenges such as poor compaction and labor shortages, SCC has gained prominence worldwide due to its ease of placement and enhanced durability. SCC's ability to flow through congested reinforcement zones without segregation is attributed to its unique mix design, which incorporates a higher percentage of fine aggregate relative to coarse aggregate (Hajime and Masahiro, 2003). The mix design is further optimized using superplasticizers and viscosity-modifying agents to achieve filling ability, passing ability, and segregation resistance, as described by Paulo Ricardo et al. (2019).

Although SCC offers several advantages, such as reduced noise pollution during placement and suitability for intricate architectural structures, its high cementitious content contributes to increased costs (EFNARC, 2005). Supplementary Cementitious Materials (SCMs) like fly ash and silica fume are often used to partially replace cement, reducing costs and improving durability. Fly ash, a by-product of coal combustion, and silica fume, derived from the silicon industry, contribute to pore refinement, strength enhancement, and environmental sustainability (Kavitha et al., 2015; Samahbhanja and Sengupta, 2003).

Additionally, the inclusion of fibers, such as alkali-resistant glass fibers, addresses SCC's inherent brittleness, low tensile strength, and poor impact resistance. These fibers improve mechanical properties and restrict crack propagation but must be optimally dosed to maintain SCC's workability (Rao et al., 2012). This study investigates the formulation of ternary blended SCC incorporating SCMs and fibers to improve the material's mechanical and durability properties while minimizing costs and addressing environmental concerns.

1.1SCOPE OF THE WORK

The scope of work for this project encompasses the comprehensive planning, static analysis, and design of a G+20 residential building located in Hyderabad. The primary objective is to create an efficient and safe structural design that adheres to Indian Standard Codes, specifically IS 456:2000 for the design and construction of reinforced concrete structures, and IS 1893 (Part 1): 2016 for seismic design considerations. The project involves a detailed examination of key structural elements such as beams, columns, slabs, and foundations to ensure their safety, strength, and stability under various loads.

The design process will begin with functional planning to ensure the building's layout is efficient for residential use, incorporating considerations for space utilization, aesthetics, and user needs. Static analysis will be performed using ETABS software to evaluate the building's response to different loads, including dead loads, live loads, and environmental factors such as wind and seismic forces. The seismic analysis will specifically address the building's behavior in a region prone to earthquakes, as per the guidelines set in IS 1893 (Part 1): 2016[11]

Following the analysis, detailed structural design of the building components will be carried out, focusing on the reinforcement details of beams, columns, and slabs, ensuring they can withstand the expected loads. Emphasis will be placed on structural detailing to prevent issues such as cracking, deformation, or failure, ensuring long-term durability and safety.

The project will also include the preparation of design calculations, drawings, and specifications for all key structural components. By addressing the structural integrity and functional requirements, the design will ensure the building meets all safety, performance, and regulatory standards, making it suitable for residential use in a seismic zone.

1.2 OBJECTIVES OF THE WORK

1. To model and analyze a 20-story reinforced concrete (R.C.) frame building located in Hyderabad using ETABS software for structural stability and design optimization.
2. To determine the building's response under various loads, including seismic and wind forces, and ensure compliance with relevant standards.
3. To design the foundation system (isolated and combined footings) and structural components, such as beams, columns, and slabs, using AutoCAD for precise detailing.
4. To evaluate and optimize the reinforcement detailing for beams, columns, and slabs to ensure durability and cost efficiency.

2.THEORY AND METHODOLOGY

The modeling process in ETABS begins by selecting the appropriate design code for the project, ensuring the structure adheres to the required standards. The user then sets the units of measurement for the model, typically in terms of metric units (e.g., Newtons, meters) for Indian standard code compliance. Once the units are defined, the structural layout of the G+20 residential building is created by defining the floor levels, columns, beams, and slabs, as well as any structural elements like walls and foundations[12].

The next step involves assigning material properties, such as the concrete strength (grade of concrete), reinforcement details, and the type of steel to be used, in accordance with the specifications outlined in Indian Standard codes. Section properties for beams, columns, and slabs are also defined, specifying dimensions, reinforcement types, and locations.

Support conditions are applied to model the real-life constraints, such as fixed, hinged, or roller supports, to simulate how the building reacts to loads. Load definitions, including dead loads, live loads, wind loads, and earthquake loads, are then assigned, in line with the relevant standards (IS 875, IS 1893). Finally, load combinations are set for analysis, which are essential for ensuring the structure can withstand different loading scenarios. Once all parameters are defined, the model undergoes static analysis to determine the building's response under various loads, and the results are verified for accuracy and compliance with the design codes. AutoCAD facilitates efficient drafting and visualization of 2D/3D models, offering features like powerful drafting tools, object analysis, and extensive plug-in support. It enables integration with various utilities and benefits from widespread training resources[14].

3.SOFT WARE USED:

AutoCAD, developed by Autodesk, is a leading CAD program for 2D and 3D design, widely used in engineering, construction, and architecture. ETABS, a powerful 3D modelling software, is used for the analysis and design of multi-story buildings, offering advanced features like seismic analysis, load calculations, and automated reinforcement design.

3.1DETAILS OF THE BUILDING

Type of building	:	R.C. Frame building
Number of floors	:	G + 20
Location of building	:	Hyderabad
Total height of the building number of columns	: :	63m from ground level Total 24
Depth of foundation	:	3 m below ground level
Type of footing	:	Isolated footing & Combined footings
Plinth level	:	0.5m above ground level
Size of beams	:	0.3m x 0.45m
Size of columns	:	0.5m x 0.5m
Thickness of slab	:	150mm
Type of walls	:	Ordinary clay brick walls
Wall thickness	:	6" (outer wall) and 4.5" (inner wall)
Type of Staircase	:	Dog legged Staircase
Grade of concrete	:	M 30
Grade of Steel	:	Fe 500

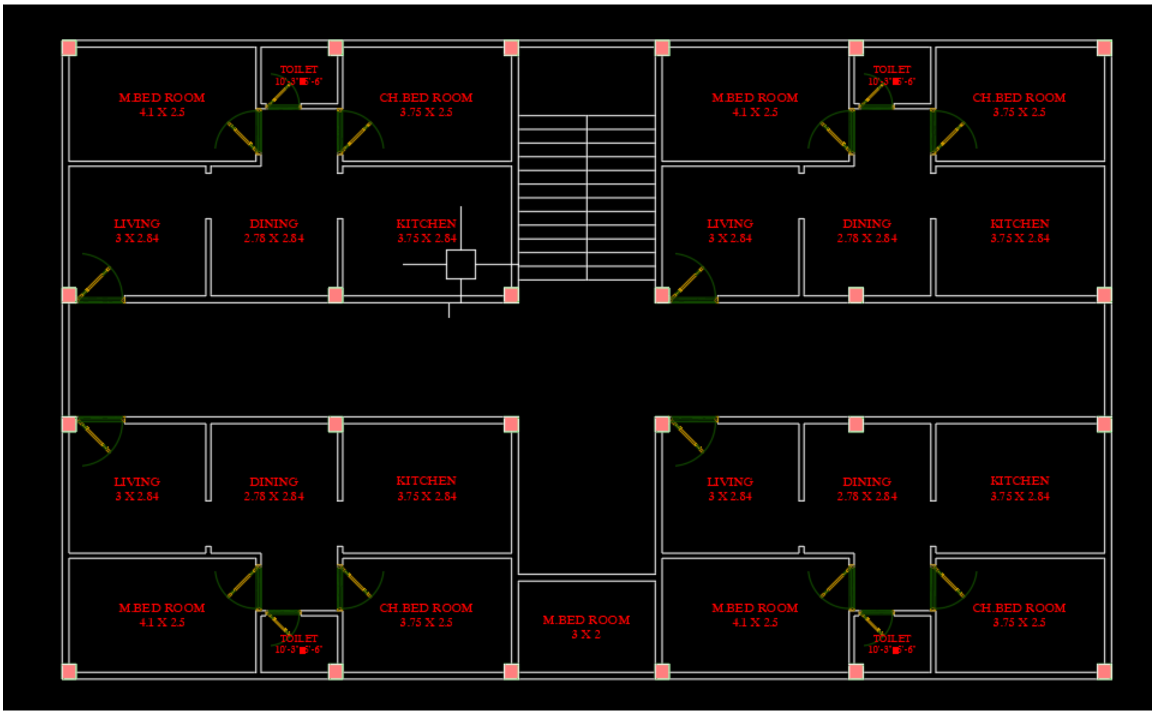

Fig.1floor plan

3.2 FUNCTIONAL DESIGN OF BUILDING

The principles of building planning are crucial for ensuring a structure is functional, comfortable, and efficient. Key principles include **aspect**, which optimizes the placement of doors and windows to maximize natural light and ventilation; **prospect**, focusing on creating pleasant external views while screening out undesirable ones; **privacy**, maintaining both internal and external privacy; and **grouping**, which organizes rooms for convenience and comfort, minimizing unnecessary circulation space. **Roominess** emphasizes maximizing usable space through thoughtful room proportions, while **furniture requirements** ensure there is adequate space for essential furnishings. **Circulation** involves providing easy access between rooms, with well-planned horizontal and vertical movement paths. **Sanitation** ensures proper ventilation, lighting, and cleanliness to maintain hygiene standards. **Flexibility** in design allows for future modifications and adaptability, while **elegance** contributes to the building's aesthetic appeal. Lastly, **economy** focuses on cost-effectiveness by optimizing space usage and eliminating unnecessary elements. A well-planned building balances functional needs with aesthetic considerations, ensuring both efficiency and appeal

4. Load Combinations

Types of loads acting on the structure are:

1. Dead loads
2. Imposed loads
3. Wind loads
4. Snow loads
5. Earthquake loads
6. Special loads

In ETABS, typical load combinations ensure structural safety under various conditions. Common combinations include **1.5(DL + LL)** for standard loads, **1.5(DL + LL + WL)** for wind effects, **1.5(DL + LL + EL)** for seismic loads, and **DL + LL + WL + EL** for all possible loads. ETABS calculates and checks designs accordingly.

4.1 BASIC STEPS FOLLOWED IN ETABS:

Overall procedure in using ETABS can be wholly classified into following steps:

- Model Generation
- Assigning of Material Properties
- Assigning the Section Properties
- Assigning of supports
- Load definitions and assigning load combinations
- Analysis and Result Verification
- After the analysis, the design of beams and columns is also carried in ETABS

4.2 MODELLING PROCESS:

At the cusp of opening the Software of ETABS a Dialog Box appears to select the Code which is to be followed for the respective model.

We need to select the required units which is to be followed in Modelling process.

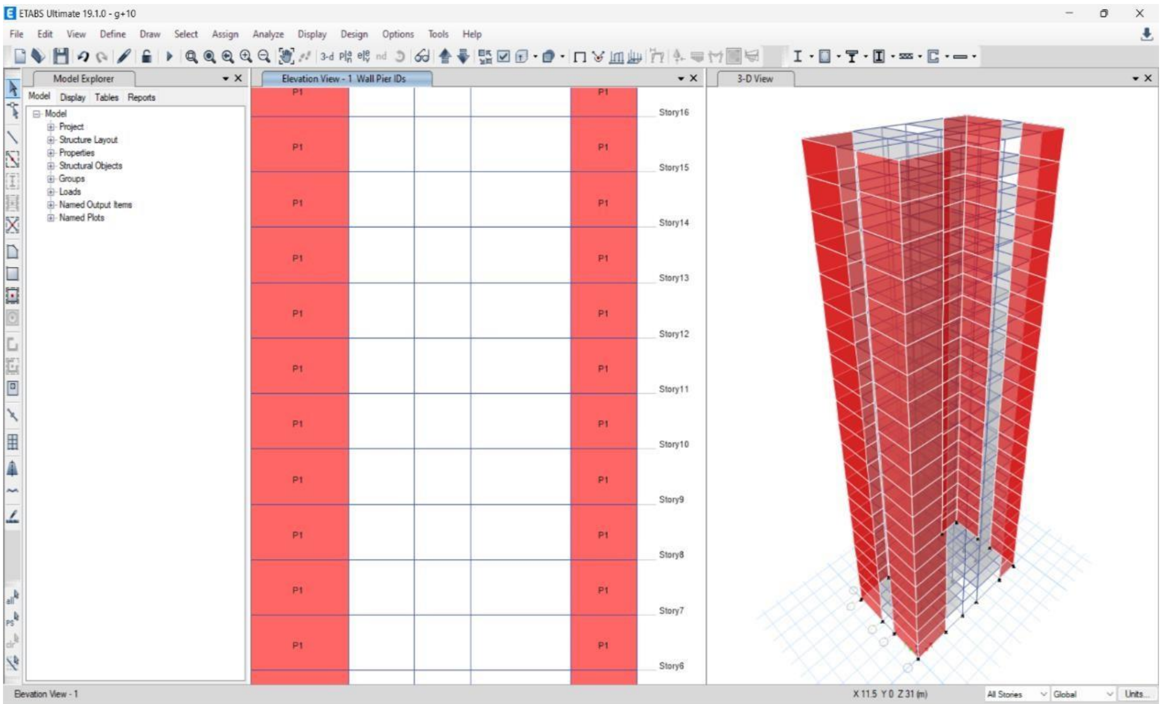

Fig.2 Floor wise load

The image showcases ETABS software analyzing a high-rise structure. Red-highlighted wall piers ("P1") are displayed in the elevation and 3D views, spanning multiple stories. These structural elements are critical for lateral load resistance, such as seismic or wind forces. ETABS provides efficient visualization and precise design optimization for building stability

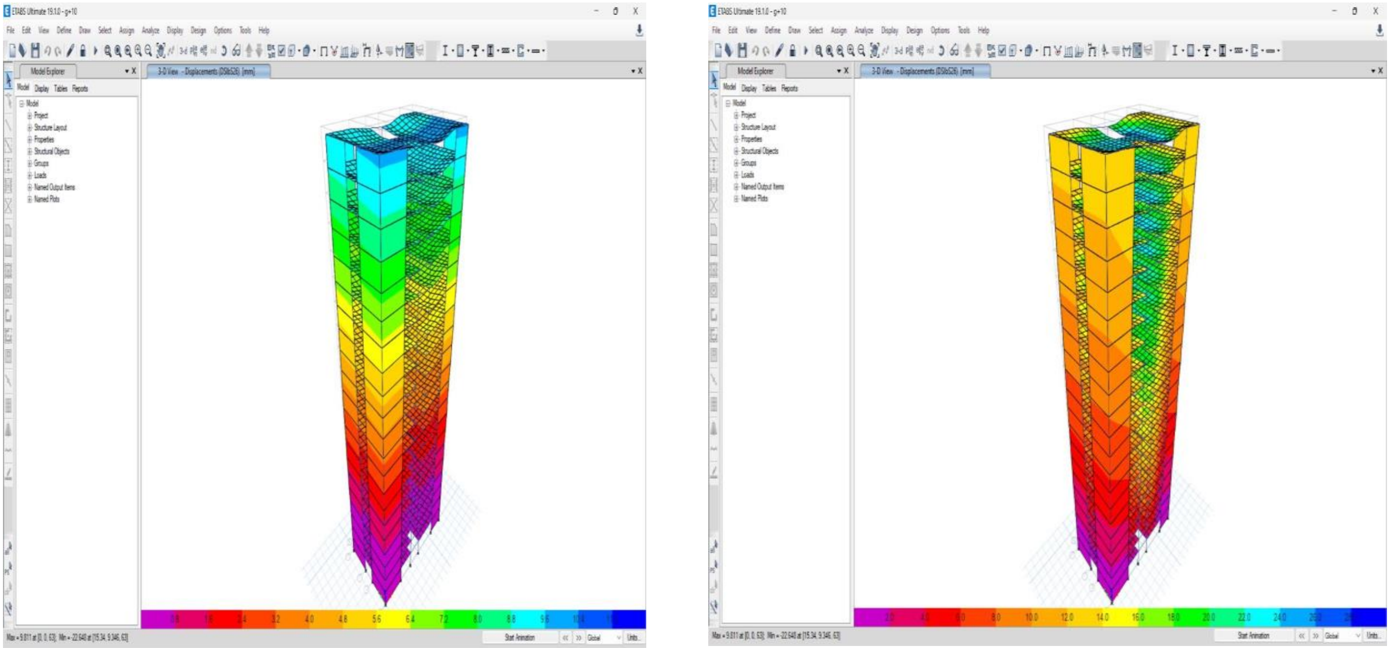

Fig.3Concrete Frame Load

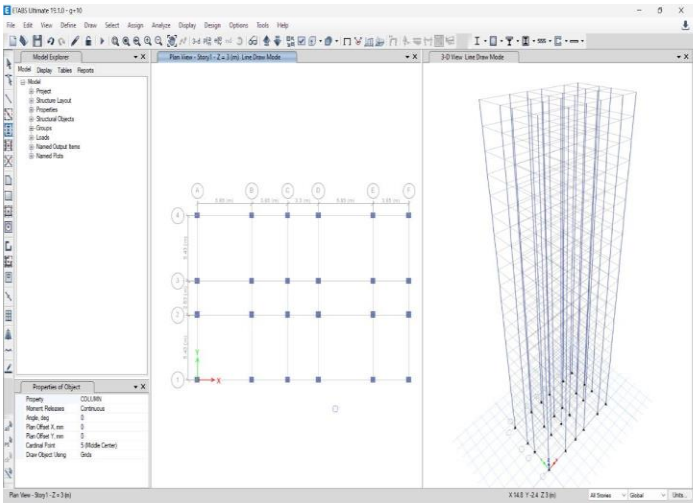

Fig.4 load on column

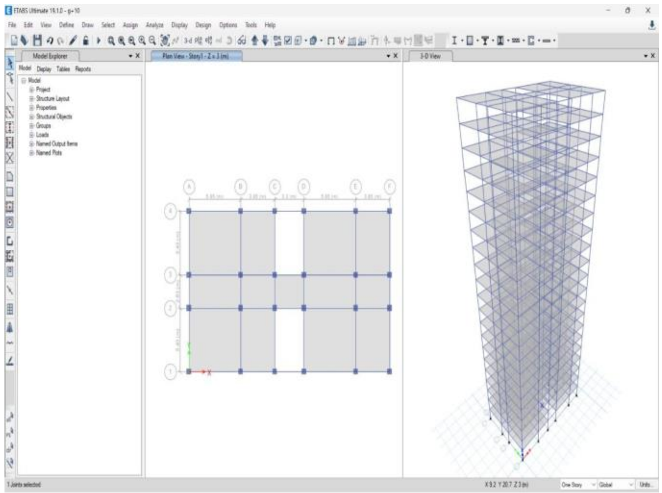

Fig.5 load on beam

- **Loads on Columns**: Columns in ETABS are subjected to dead load, live load, seismic load, wind load, and load combinations. ETABS calculates axial loads, bending moments, and shear forces on columns, considering interactions between these forces. Seismic and wind loads are evaluated based on the building's location and geometry.
- **Loads on Beams**: Beams carry dead loads (self-weight, slab, partitions), live loads (occupancy, furniture), and other external loads like seismic and wind forces. ETABS distributes floor loads to beams and generates bending moment and shear force diagrams. Load combinations and point or distributed loads are considered to ensure the beam's safety under different loading scenarios.

This ETABS analysis demonstrates structural design under various load cases, showing deformation through a color-coded gradient. Engineers evaluate minimum and maximum displacements to ensure safety and compliance. By analyzing load combinations, performing detailed calculations, and verifying structural checks, they optimize the building’s stability, strength, and resilience under real-world conditions.

The Deflected shape of the structure is shown below.

The deflected shape of a structure indicates the deformation resulting from applied loads, showing displacements at

various points. It reveals critical areas of stress concentration, potential instability, and structural performance. Evaluating this result ensures design adequacy, safety compliance, and identifies the need for reinforcement to maintain structural integrity.

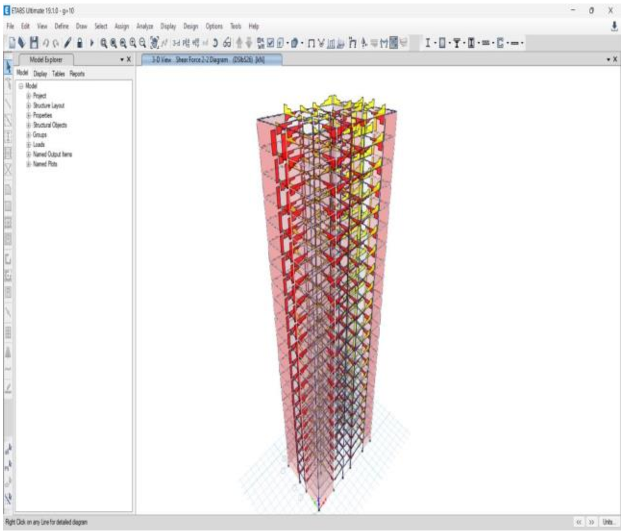

Fig-6 checking Load 1

Fig.7 design data

Checking load involves verifying that a structure can safely withstand applied forces, including dead loads, live loads, wind, and seismic forces. This process ensures load distribution is within design limits, preventing overstressing or failure. Accurate load checks are vital for safety, structural efficiency, and compliance with engineering standards and codes.

The Design results after the Design calculations are shown below.

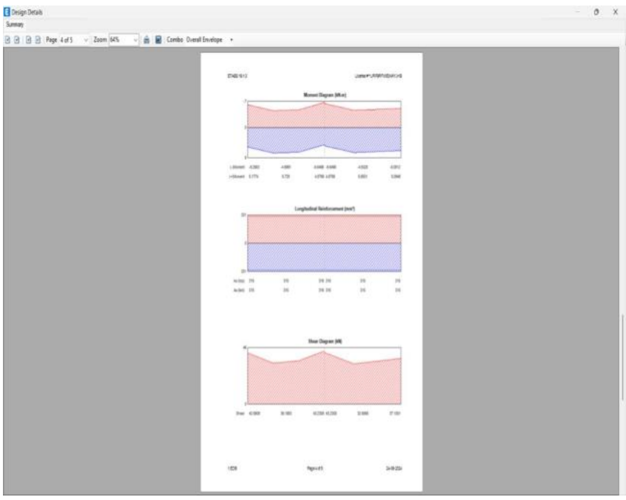

Fig.8 Design Data 1

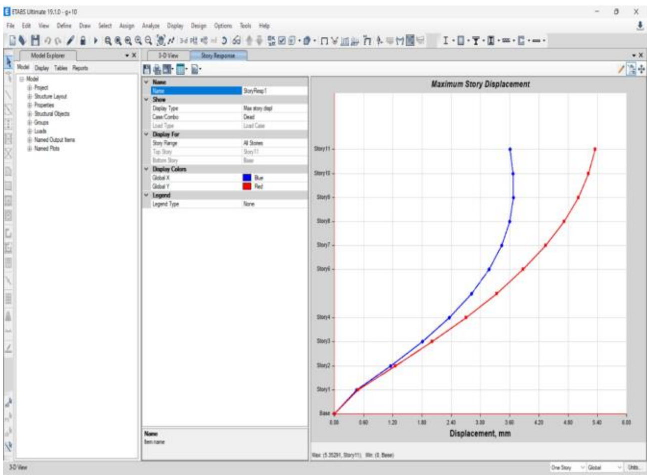

Fig.9 Design Data 3

The Story Response for the entire building in both the X and Y direction are as below. We can check whether the Story displacement is within the permissible limits or not.

5.CONCLUSION

The future of the study involves a deeper understanding of structural behavior and optimization of building designs. Analyzing forces, stresses, and deflections will be crucial to ensure the building's safety and stability under various loading conditions. The use of advanced software like ETABS will continue to play a significant role in designing efficient structural systems, focusing on improving earthquake resistance through the application of seismic design principles. Further research will explore the interaction of structural elements like beams, columns, and slabs, with an emphasis on material selection and dimension optimization. Additionally, advancements in sustainable materials like AAC blocks will be studied for reducing overall load and improving performance.

5.1 **FUTURE OF WORK**

Analyzing forces: Analyzing the forces, stresses, strains, deflections, and bending moments of the building

Designing the structural system: Designing the structural system of the building using software like ETABS

Making the building earthquake resistant: Designing the building to be resistant to seismic forces and earthquakes

Learning about structural elements: Learning about the parameters of structural elements like beams, columns, and slabs

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