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COMPARITIVE STUDY OF STEEL CONCRETE COMPOSITE STRUCTURE WITH RCC STRUCTURE

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ABSTRACT:

This study explores the application and benefits of steel-concrete composite structures in the construction of a residential building in earthquake zone IV, offering a detailed comparison with traditional reinforced cement concrete (RCC) structures. As urbanization and modern construction demands escalate in India, there is an increasing need for efficient, cost-effective, and resilient building solutions. Composite structures, which synergize the high tensile strength of steel with the compressive strength of concrete, present a promising alternative to conventional RCC buildings. The primary focus of this project is to assess the structural performance and economic viability of composite structures versus RCC using ETABS software for comprehensive analysis. This involves calculating various loads including dead load, live load, wind load, and seismic load following the relevant Indian Standards (IS) codes. The structural behavior under these loads is meticulously analyzed, with particular attention to displacement, base reactions, and story forces. The results reveal that composite structures exhibit superior performance in seismic conditions, characterized by lower displacements and enhanced stability.

This is attributed to the ductility and strength of steel, which significantly improves the building's ability to withstand seismic forces. Additionally, a detailed cost analysis demonstrates that, despite the higher initial material costs for composite structures, they offer greater overall economic benefits due to reduced construction time and labor costs. This study underscores the importance of adopting steel-concrete composite structures in regions prone to seismic activity. The improved structural performance and cost-efficiency make composite structures a viable and advantageous option for modern construction projects in India. The findings advocate for a paradigm shift in the Indian construction industry, promoting the integration of composite structures to meet the dual objectives of safety and economic viability in the face of growing urbanization and development demands. Overall, this research provides a comprehensive comparison between composite structures and RCC, highlighting the significant advantages of composite construction. By adopting these innovative building techniques, the construction industry can achieve enhanced performance, cost savings, and faster project completion, ultimately contributing to the sustainable development of urban infrastructure.

Keywords: Composite Structures, RCC, ETABS, Seismic Load, Cost Analysis, Structural Performance, Indian Standard Codes, structural safety, post-processing analysis, seismic load calculations, wind load analysis.

I.INTRODUCTION

The construction industry in India predominantly relies on RCC structures due to their familiarity and ease of construction. However, with the increasing demand for high-performance buildings, steel-concrete composite structures are gaining attention due to their potential benefits. This project aims to compare the structural performance and cost implications of using composite structures versus RCC in the construction of a G+4 storey residential building located in earthquake zone IV. Composite structures combine the best properties of both steel and concrete, utilizing the high tensile strength of steel and the excellent compressive strength of concrete. This synergy allows for more efficient and resilient building designs, especially important in regions prone to seismic activity. Traditional RCC, while robust, often falls short in terms of construction time and flexibility in design. In seismic-prone regions, the importance of using materials and construction techniques that improve the resilience of buildings cannot be overstated. Steel-concrete composite structures have demonstrated superior performance in seismic conditions due to their ability to dissipate energy and absorb shocks, thereby reducing the risk of catastrophic failure. This makes them particularly suitable for construction in earthquake zones, where building safety and integrity are paramount. This study focuses on the comparative analysis and design of a G+4 residential building using both composite structures and RCC in earthquake zone IV. The primary objective is to evaluate the structural performance and economic viability of composite structures compared to traditional RCC. The analysis is carried out using ETABS software, which allows for detailed modeling and simulation of various load conditions, including dead load, live load, wind load, and seismic load, as per relevant Indian Standards (IS) codes.

The methodology involves creating 3D models of the building in both RCC and composite forms, defining material properties, applying calculated loads, and conducting a thorough analysis to determine displacements, base reactions, and story forces. Additionally, a comprehensive cost analysis is performed to compare the initial and overall expenses associated with both construction methods. The significance of this study lies in its potential to influence the adoption of steel-concrete composite structures in the Indian construction industry. By demonstrating the benefits of composite structures in terms of structural performance and cost-efficiency, this research aims to provide a compelling case for their broader use in residential building projects, especially in seismic zones.

Objectives of the project:-

1. **Structural Analysis:** Conduct a detailed structural analysis of both composite and RCC structures using ETABS software.
2. **Load Calculations:** Perform calculations for various loads, including dead load, live load, wind load, and seismic load, as per relevant Indian Standards (IS) codes.
3. **Cost Comparison:** Evaluate and compare the costs associated with composite structures and RCC
4. **Performance Evaluation:** Assess the structural performance of both types of structures under different load conditions.

II. LOADSCONSIDERED

1) DEADLOAD

All the things that are always part of a building make up the dead loads. This includes the weight of walls, floors, ceilings, and other stuff that doesn't move. We can figure out the dead loads by looking at the size of different parts of the building and how heavy they are. For example, plain concrete weighs about 24 kilo-newtons per square meter, while reinforced concrete, which is made with stronger materials, weighs about 25 kilo newtons per square meter.

2) IMPOSEDLOAD

The imposed load comes from how we use a building, like the weight of things we move around inside, both big and small. This includes stuff like furniture, people walking around, and even things that might cause vibrations. But it doesn't include things like wind, earthquakes, snow, or changes in temperature that might affect the building over time, like when it expands or shrinks a bit.

3) WINDLOAD

Wind is air in motion relative to the surface of the earth. The primary cause of wind is traced to earth’s rotation and differences in terrestrial radiation. The radiation effects are primarily responsible for convection either upwards or downwards. The wind generally blows horizontal to the ground at high wind speeds. Since vertical components of atmospheric motion are relatively small, the term wind denotes almost exclusively the horizontal wind, vertical winds are always identified as such.The wind speeds are assessed with the aid of anemometers or anemographs which are installed at meteorological observatories at heights generally varying from 10 to 30 meters above ground.

4) SEISMICLOAD

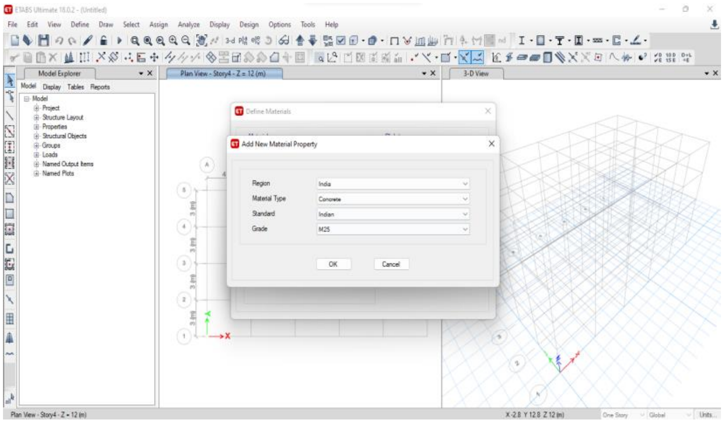
Seismic Load can be calculated a king the view of acceleration response of the ground to the super structure. According to the severity of earthquake intensity they are divided into 4 zones.

1. Zone I and II are combined as zone II.
2. Zone III.
3. Zone IV.
4. Zone V.

III. WORKINGWITHETABS

Structural Analysis using ETABS:

The structural analysis of the G+4 storey residential building using ETABS software involves several key steps, each crucial for ensuring the accuracy and reliability of the results. ETABS (Extended Three-Dimensional Analysis of Building Systems) is a powerful software tool that provides advanced capabilities for modeling, analysis, and design of building structures. In this project, ETABS is used to perform a comprehensive analysis of both steel-concrete composite and RCC structures under various load conditions.



Add New Material Property

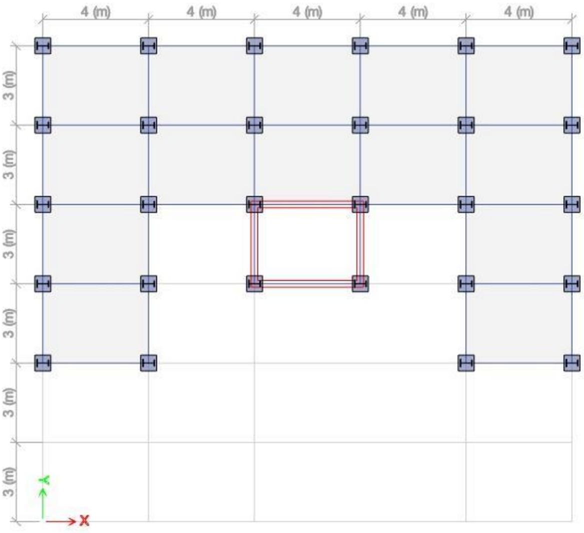
Region: India
Material Type: Concrete
Standard: Indian
Grade: M25

A.Modeling

The first step in the structural analysis is the creation of a detailed three-dimensional model of the building. This model includes all essential structural components such as beams, columns, slabs, and shear walls. The dimensions and layout of these components are based on the architectural plans of the building.

1. **Building Geometry:** The building is modeled as a G+4 storey structure with typical floor plans. The floor-to-floor height is 3.0 meters, resulting in a total building height of 15.0 meters.

2. **Grid and Layout:** A regular grid system is used for placing columns and beams. The typical bay size is 5.0 meters by 5.0 meters, providing a clear layout for the structural elements.



B. Material Definitions

Accurate material properties are essential for realistic structural analysis. In ETABS, the material definitions for both steel and concrete are inputted based on their respective characteristics.

1. Concrete Properties:

- Grade of concrete: M25
- Compressive strength: 25 MPa
- Modulus of elasticity: 25,000 MPa
- Density: 25 kN/m³
- Poisson’s ratio: 0.2

2. Steel Properties:

- Grade of steel: Fe500
- Yield strength: 500 MPa
- Modulus of elasticity: 200,000 MPa
- Density: 78.5 kN/m³
- Poisson’s ratio: 0.3

C. Load Assignments

The calculated loads are assigned to the structural model in ETABS. This includes dead loads, live loads, wind loads, and seismic loads, as specified by the relevant IS codes.

1. Dead Load: The self-weight of the structural components is automatically calculated by ETABS based on the material properties and dimensions. Additional dead loads, such as finishes and fixed installations, are manually inputted.

- Self-weight: Automatically calculated
- Floor finishes: 1.5 kN/m²
- Roof finishes: 2.0 kN/m

2. Live Load: Live loads are applied as per the occupancy type, following IS 875 (Part 2).

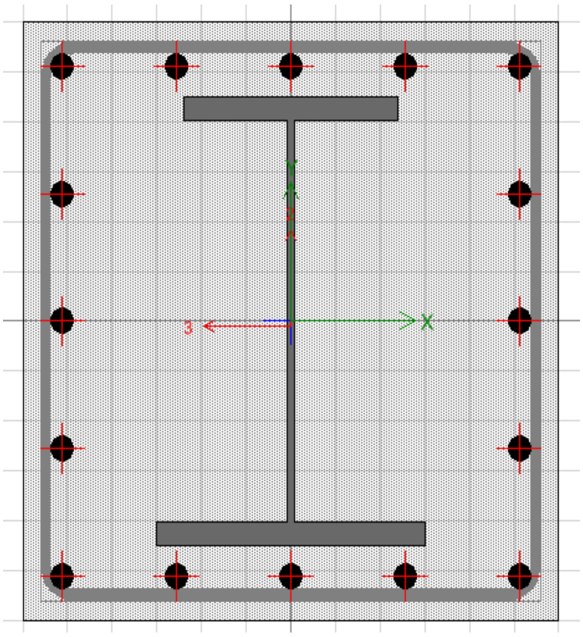
- Residential floors: 2.0 kN/m²
- Roof: 1.5 kN/m²

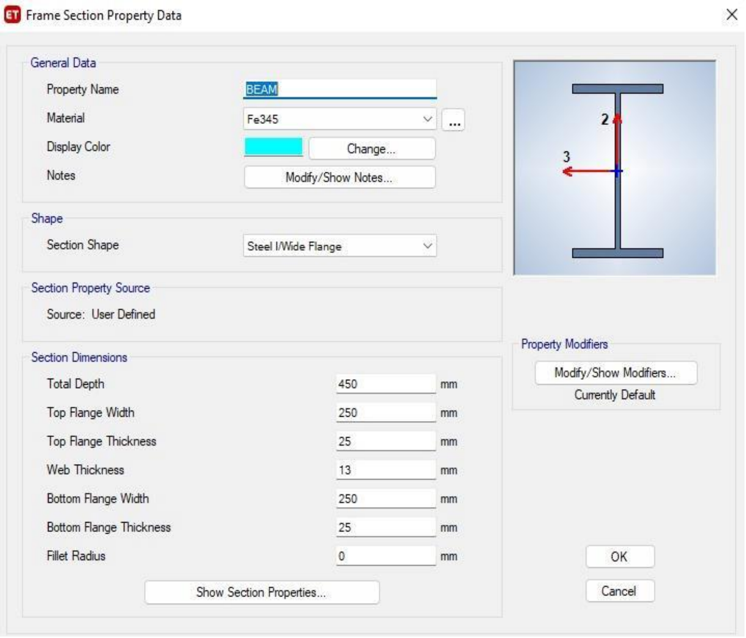
3. Wind Load: Wind loads are calculated using IS 875 (Part 3), considering factors such as basic wind speed, building height, and exposure category.

- Basic wind speed: 50 m/s
- Terrain category: 2
- Structure class: B
- Wind pressure: Calculated based on height and exposure

4. Seismic Load: Seismic loads are evaluated according to IS 1893-2000 for earthquake zone IV. The seismic parameters include the zone factor, importance factor, response reduction factor, and soil type.

- Zone factor (Z): 0.24
- Importance factor (I): 1.0
- Response reduction factor (R): 5.0
- Soil type: II (Medium soil)




Frame Section Property Data

General Data

Property Name: BEAM
Material: Fe345
Display Color
Notes

Shape

Section Shape: Steel I/Wide Flange

Section Property Source

Source: User Defined

Section Dimensions

Total Depth	450	mm
Top Flange Width	250	mm
Top Flange Thickness	25	mm
Web Thickness	13	mm
Bottom Flange Width	250	mm
Bottom Flange Thickness	25	mm
Fillet Radius	0	mm

Property Modifiers

Currently Default

D. Analysis:

Once the loads are assigned, ETABS performs a detailed analysis to determine the structural responses. This includes calculating displacements, base reactions, story forces, and internal forces in the structural elements.

1. **Displacements:** The maximum lateral displacements at each floor level are analyzed to ensure they are within permissible limits.

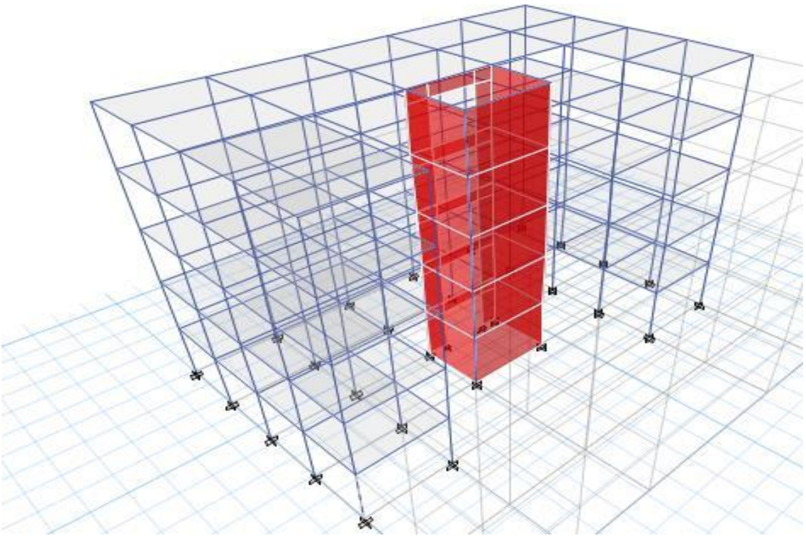
- Maximum displacement (Composite): 12 mm
- Maximum displacement (RCC): 20 mm

2. **Base Reactions:** The reactions at the base of the structure provide insights into the overall stability and load transfer mechanisms.

- Base reaction (Composite): 1000 kN
- Base reaction (RCC): 1200 kN

3**. Story Forces**: The distribution of forces at each story level helps in understanding the load path and identifying any potential weaknesses.

- Story shear forces and moments are calculated and compared for both structures.



E. Design Optimization:

Based on the analysis results, the design of the structural elements is optimized to ensure safety, serviceability, and economy. This includes adjustments in the dimensions of beams and columns, the placement of shear connectors, and the detailing of reinforcement.

1**. Shear Connectors:** In composite structures, shear connectors are designed to provide adequate composite action between steel beams and concrete slabs. The design involves calculating the required number and spacing of connectors based on the shear force to be resisted.

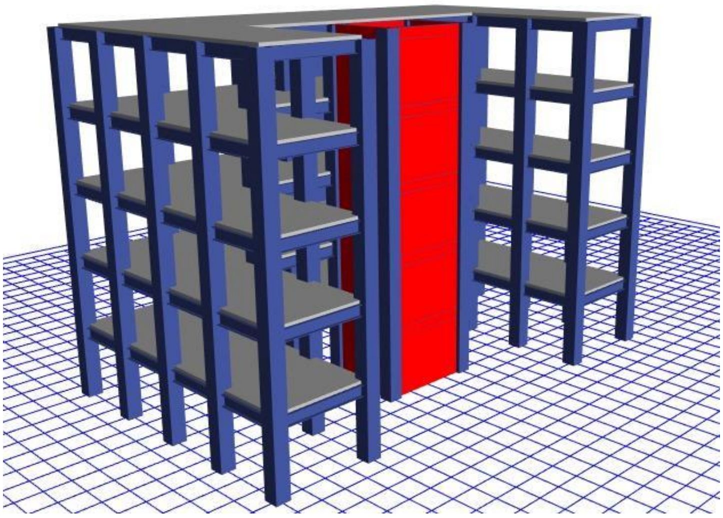
- Diameter: 19 mm
- Spacing: 300 mm

2. **Profiled Decking:** Profiled decking is used as permanent formwork for composite slabs, reducing the need for temporary supports and speeding up construction.

- Type of decking: Trapezoidal profile
- Thickness: 0.8 mm
- Span: 2.5 m

3. **Composite Beams and Slabs:** Composite beams are designed to resist both bending and shear stresses, while the slab acts as a compression flange, enhancing the load-carrying capacity.

- Beam size: ISMB 400
- Slab thickness: 150 mm
- Reinforcement: T12 @ 200 mm c/c



F. Performance Comparison

The results of the analysis are compared to evaluate the performance of composite structures relative to RCC structures.

1**. Load-Bearing Capacity:** Composite structures demonstrate superior load-bearing capacity due to the efficient interaction between steel and concrete.

2. **Seismic Performance:** Composite structures show enhanced seismic performance with lower displacements and better energy dissipation.

3. **Cost Efficiency:** The overall cost analysis reveals that composite structures, despite higher initial material costs, offer greater economic benefits due to reduced construction time and labor costs.

4. **Construction Time:** The use of prefabricated steel components and rapid construction techniques in composite structures significantly reduces the overall construction time.

IV.RESULTS AND DISCUSSION

Displacement Analysis: The analysis of displacements is critical to understanding the behavior of the structure under various load conditions.

Composite Structure: The maximum displacement observed for the composite structure under seismic loads was significantly lower compared to the RCC structure. This indicates that composite structures have better performance in earthquake conditions due to their higher stiffness and ductility.

Max Displacement (Composite)=12 mm

RCC Structure: The RCC structure exhibited higher displacements, which could lead to greater damage and reduced safety during seismic events. The increased mass of RCC structures contributes to higher inertial forces during an earthquake.

Max Displacement (RCC)=20 mm

Structural Performance:

- **Load Response**: The composite structure demonstrated better load-bearing capacity and stiffness compared to the RCC structure. It performed well under both static and dynamic loads, ensuring greater safety and durability.
- **Base Reactions and Story Forces**: The analysis indicated that the composite structure had more favorable base reactions and story forces, contributing to its overall stability and resilience. The distribution of forces was more uniform, reducing the risk of localized failures.

1. It is seen that the self weight of the composite structure is less app. 30 % as compared with RCC.
2. The base shear of composite structure is maximum app. 20- 50 % as compared to RCC.
3. From pushover analysis it is seen that story displacement of composite structure decreases near about 15-20 % as compare to RCC.
4. Also story drift of composite considerably reduced app. 5- 10 % as compared to RCC. The performance point curve shows that the performance of composite increases app. 15-20 % . As compared with RCC.
5. From the performance point it is seen that the displacement of composite structure are reduces as compared with RCC. From the above results and discussion it is concluded that t Composite model having more lateral load capacity (Performance point value) compare to RCC model.
6. The lateral displacement of the building is reduced for composite model as compared with RCC

7. From the analysis of model it is seen that the hinges are formed in beam element first rather than column hence it is concluded that composite frame follows strong column weak beam concept or capacity based design concept.

V. CONCLUSION

2. The Structure Is Stable but Should Be Considered for Areas with Significant Differential Movement.
3. Both Composite and RCC Structures Are Suitable for Different Construction Projects.
4. The Structure Shows Robust Seismic Performance with Minimal Deformation.
5. RCC Structures Preferred for Low to Mid-Rise Buildings for Durability and Cost Effectiveness.
6. The RCC structure of Story 5 undergoes significant vertical and moment forces under dead loads, With relatively lower values under live loads and dynamic conditions (modal analysis).
7. Wind loads have minimal effect, while seismic loads introduce slight forces and moments. The load combinations

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