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# "SEISMIC BEHAVIOR OF COMPOSITE STEEL-CONCRETE BEAMS IN HIGH-RISK EARTHQUAKE ZONES: AN ANALYTICAL APPROACH"

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***ABSTRACT*:**

This study investigates the seismic performance of composite steel-concrete beams in high-risk earthquake zones through a combination of analytical modeling and experimental testing. Composite beams, which combine the strengths of steel and concrete, are increasingly utilized in structural designs due to their superior load-bearing capacity and ductility. The research emphasizes the behavior of these beams under seismic loading, focusing on critical parameters such as energy dissipation, load transfer mechanisms, and failure modes. Advanced numerical simulations are conducted to model the nonlinear behavior of composite beams, validated through full-scale experimental testing. The findings highlight the influence of connection detailing, material properties, and beam geometry on seismic performance. The outcomes provide practical recommendations for optimizing composite beam designs, ensuring enhanced safety and structural resilience in earthquake-prone regions.

**Keywords**: seismic behavior, composite beams, steel-concrete structures, earthquake zones, analytical modeling, experimental testing, structural resilience, energy dissipation, nonlinear behavior, high-risk earthquake zones.

## INTRODUCTION

The seismic performance of structures plays a pivotal role in safeguarding human lives and infrastructure in earthquake-prone regions. Structural failures during earthquakes often lead to catastrophic consequences, including loss of life, economic disruptions, and long-term societal impacts.

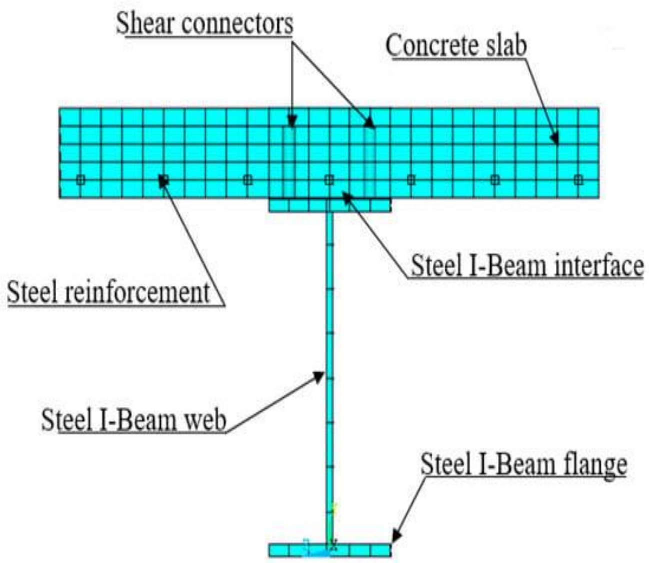


**Figure1.1: Strengthened Steel–Concrete Composite Beams**

To address these challenges, composite steel-concrete beams have emerged as an advanced engineering solution, leveraging the complementary properties of steel and concrete. Steel offers high tensile strength and ductility, while concrete provides excellent compressive strength and stiffness. Together, these materials form a synergy that enhances energy dissipation, structural integrity, and load-bearing capacity, making composite beams an indispensable choice in seismic-resistant construction. Despite the widespread adoption of composite beams, their seismic behavior remains a complex area of study influenced by various parameters, including material properties, connection detailing, beam geometry, and load conditions. While previous research has contributed to understanding these factors, most studies either rely on numerical simulations or experimental analyses in isolation. The need for a comprehensive approach that integrates analytical modeling and experimental validation is critical to capturing the nonlinear, dynamic behavior of composite steel-concrete beams under seismic loading conditions.

This research addresses this gap by adopting an analytical and experimental approach to evaluate the seismic behavior of composite steel-concrete beams in high-risk earthquake zones. Advanced finite element modeling techniques are employed to simulate the dynamic and nonlinear behavior of these beams under varying seismic intensities. These simulations are then validated through rigorous experimental testing of full-scale specimens, focusing on critical performance parameters such as energy dissipation, load transfer mechanisms, and failure modes.

The outcomes of this study aim to provide actionable insights into the seismic performance of composite beams, offering practical design recommendations to engineers and architects. By optimizing material use, connection designs, and structural configurations, this research seeks to enhance the resilience and reliability of composite structures in high-risk earthquake zones, ultimately contributing to safer and more sustainable built environments.

## PROBLEM STATEMENT

Seismic events pose a significant threat to the safety and stability of structures, particularly in high-risk earthquake zones. Composite steel-concrete beams are widely used in modern construction due to their superior strength, ductility, and energy dissipation capabilities. However, despite their advantages, the seismic behavior of these composite beams is not fully understood, especially when subjected to complex, nonlinear, and dynamic loading conditions typical of severe earthquakes.

Existing studies on composite beams primarily focus on isolated factors, such as material properties, connection designs, or beam geometry, often relying on either analytical modeling or experimental testing alone. This fragmented approach limits the ability to predict real-world performance accurately. Furthermore, the lack of validated design guidelines that account for the interaction of these factors under seismic loading increases the risk of structural failure in high-risk zones.

This research aims to address these gaps by investigating the seismic behavior of composite steel-concrete beams through a holistic approach that integrates advanced analytical modeling with experimental validation. By understanding the critical factors influencing their performance, this study seeks to develop practical recommendations to improve the design and resilience of composite structures in earthquake-prone regions.

### Goal of Dissertation

To investigate and enhance the seismic performance of composite steel-concrete beams in high-risk earthquake zones through analytical modeling and experimental validation, with the goal of developing optimized design guidelines for safer and more resilient structures.

### Importance of Composite Steel-Concrete Beams in Earthquake Engineering

- Explain the structural benefits of composite beams, such as improved strength, ductility, and energy dissipation.
- Provide examples or case studies where composite beams have proven effective or raised concerns in seismic conditions.
- Describe the importance of optimizing these beams to enhance the seismic performance of buildings and bridges.

### Objectives of the Study

- To study the interaction between steel and concrete elements under seismic loads.
- To analyze the failure mechanisms of composite beams during earthquakes.
- To propose design improvements to improve seismic resistance.


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**Scope and Limitations**

- Define the scope of the study, such as the types of composite beams analyzed (e.g., particular dimensions, materials, or connection methods).
- Clarify limitations like the range of seismic intensities tested, assumptions in analytical modeling, or constraints of the experimental setup.
- Highlight the focus on structural performance rather than ancillary factors (e.g., cost analysis or long-term durability).

## RESEARCH METHODOLOGY

The research methodology for this study integrates both analytical and experimental approaches to comprehensively investigate the seismic behavior of composite steel-concrete beams. The methodology begins with an extensive literature review to examine existing studies on the seismic performance of composite beams, focusing on analytical modeling techniques, experimental testing methods, and the key parameters that influence performance. The review helps identify the gaps in the current understanding of the nonlinear behavior of composite beams under seismic loading conditions.

Following the literature review, advanced finite element models (FEM) will be developed to simulate the seismic behavior of composite steel-concrete beams. These models will incorporate various factors such as material properties, connection details, and beam geometries, allowing for a detailed investigation of the beams' response to seismic forces. Parametric analyses will be conducted to study the impact of different variables such as material composition, loading intensities, and boundary conditions on the overall seismic performance.

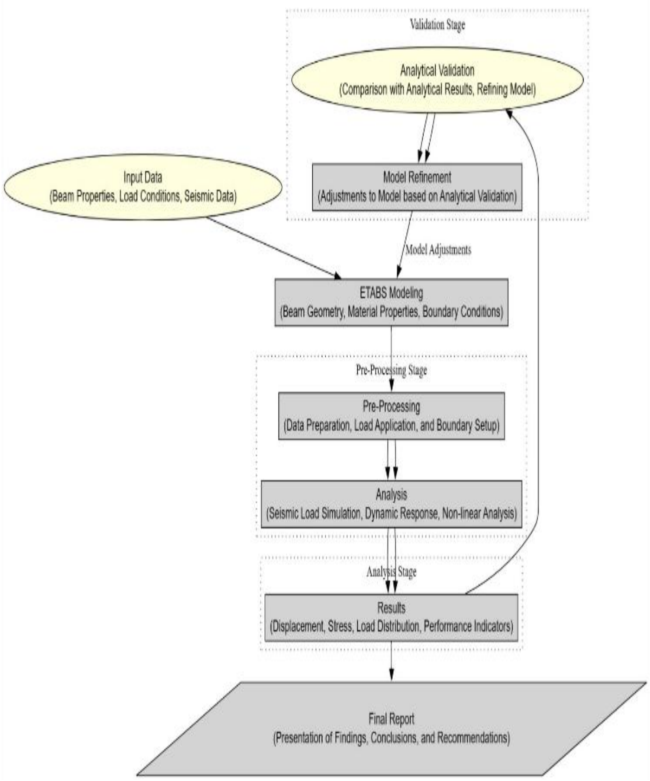


**Figure1.2: Research Methodology**

To validate the analytical models, full-scale composite steel-concrete beam specimens will be designed and fabricated for experimental testing. These specimens will be subjected to simulated seismic loading using specialized testing equipment such as shake tables or cyclic loading setups. Key performance parameters, including energy dissipation, load transfer, ductility, and failure modes, will be measured during the testing phase.

The results of the experimental tests will then be compared with the predictions from the analytical models to assess their accuracy and reliability. Any discrepancies will be addressed by refining the numerical models, and additional simulations will be performed to improve the predictions.

Data from both the experimental testing and the simulations will be analyzed to identify patterns and determine the critical factors that influence the seismic performance of composite steel-concrete beams. The effectiveness of different connection designs, material combinations, and structural configurations in enhancing seismic resilience will be evaluated.

Based on the findings from both the analytical and experimental phases, practical design guidelines will be developed. These guidelines will aim to optimize the design of composite steel-concrete beams for improved seismic performance while considering cost-effectiveness, sustainability, and safety.

Finally, the research findings will be documented and shared through academic publications, industry seminars, and design codes, providing valuable insights for engineers and architects involved in the design of earthquake-resistant structures. This comprehensive methodology ensures a thorough understanding of the seismic behavior of composite beams, contributing to the advancement of safer, more resilient infrastructure in high-risk earthquake zones.

## DESIGN & MODELLING

The design and modeling phase of this study focuses on developing a robust framework to simulate and evaluate the seismic performance of composite steel-concrete beams. This phase combines detailed design considerations with advanced computational modeling to ensure accurate representation of the composite beam behavior under seismic loading.

The first step in the design process involves selecting the appropriate beam geometry, material properties, and connection details that are representative of real-world applications in high-risk earthquake zones. Composite steel-concrete beams are typically designed with a steel section (such as an I-beam) that is connected to a concrete slab, with the two materials working together to resist loads. The design will incorporate varying beam dimensions, connection configurations, and material strengths to investigate their influence on seismic behavior.

For the modeling phase, advanced finite element analysis (FEA) techniques will be employed to simulate the structural response of the composite beams under seismic loading. The beams will be modelled using a combination of linear and nonlinear elements to capture the complex interactions between the steel and concrete components. The nonlinear modeling will account for material behavior under cyclic loading, as well as potential failure mechanisms such as yielding, cracking, and bond-slip between the steel and concrete.

The modeling process will also consider the boundary conditions and load profiles representative of seismic events. A range of seismic loadings, including varying intensities and frequencies, will be applied to the model to assess the beam's response under different earthquake scenarios. The material properties will be defined using realistic values based on standard design codes, with particular attention paid to the strength and ductility of both steel and concrete in seismic conditions.

The connection detailing, which is critical to the overall seismic performance of composite beams, will be incorporated into the model. Various connection types, such as shear studs or welded connections, will be examined to determine their effectiveness in transferring loads between the steel and concrete components during seismic events.

Once the model is established, a series of parametric studies will be conducted to explore the impact of different design variables, such as beam geometry, material properties, and connection types, on the seismic behavior. The findings from the numerical simulations will be used to identify the optimal design parameters for maximizing the seismic resilience of composite steel-concrete beams.

The design and modeling phase will be followed by validation through experimental testing, where full-scale composite beams will be tested under controlled seismic conditions. The experimental


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## 1. Composite Structure Design Steps

### G+20 Composite Structure Plan for ETABS

### 1. General Description

- Structure Type: G+20 composite building.
- Purpose: Commercial/Residential.
- Foundation Type: Raft foundation/pile foundation.
- Seismic Zone: Zone III (as per IS code, modify based on location).
- Wind Speed: 44 m/s (adjust based on site conditions).

### 2. Materials Properties

Concrete:

- Grade: M40 (for columns) and M30 (for slabs).
- Density: 25 kN/m³.
- Poisson's Ratio: 0.2.

Steel:

- Grade: Fe500 (for rebar).
- Structural Steel: FE250
- Density: 78.5 kN/m³

### 3. Geometry

Grid Dimensions:

- Grid Spacing: 3 m x 3 m.
- Number of Bays: 8 x 11.

Story Heights:

- Ground Floor Height: 3 m.
- Typical Floor Height: 3 m.
- Total Height: 63.3 m.

Structural Components:

- Columns: Composite concrete-filled I sections.
- Beams: Concrete Beam.
- Slabs: Concrete Slab

### 4. Loading

Dead Loads:

- Self-weight of the structure (calculated automatically by ETABS).
- Floor Finish: 1.5 kN/m².
- Partition Wall Load: 7.3 kN/m².

Live Loads:

- Residential: 2 kN/m².

Wind Load:

- Design as per IS 875 Part 3.
- Basic Wind Speed: 44 m/s.

Seismic Load:

- Design as per IS 1893:2016.
- Zone Factor (Z): 0.16 (Zone III).
- Importance Factor (I): 1.0.
- Response Reduction Factor (R): 5.0 (for composite moment-resisting frame).

### 5. ETABS Model Setup

Step 1: Define Material Properties

- Input properties for concrete and steel.

Step 2: Define Section Properties

- Columns: Composite concrete-filled I sections.
- Beams: Concrete Beam
- Slabs: Concrete Slab.

Step 3: Define Load Patterns and Combinations


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- Load Patterns: Dead, Live, Wall Load, Sunk Load, Wind, Seismic.
- Load Combinations: Auto-generate as per IS 456:2000.

Step 4: Assign Loads

- Apply loads to slabs, beams, and columns.
- Define diaphragms at each floor for lateral load transfer.

Step 5: Assign Boundary Conditions

- Fix supports at the base.
- Define foundation stiffness based on soil-structure interaction.

Step 6: Run Analysis

- Check displacements, base shear, and member forces.
- Optimize composite sections based on results.

**6. Design Details**

Columns:

- Sizes: 530 mm x 530 mm with steel I section.

Beams:

- Sizes:
- Design Check: Verify moment and shear capacities.

Slabs:

- Thickness: 150 mm
- Reinforcement: Mesh of 8 mm dia bars @150 mm c/c.

**7. Detailing and Connections**

- Shear Connectors: Welded studs for beam-slab interaction.
- Beam-to-Column Connections: Bolted or welded as per design requirements.
- Expansion Joints: Provide as per building length.

**8. Deliverables**

- ETABS model file (.edb) with applied loads, material properties, and section assignments.
- Design reports including:
    - Member capacities.
    - Floor-wise deflection checks.
    - Story Displacement
    - Story Drift
    - Overturning Moment
    - Story Acceleration

**Plan and 3D Elevation**

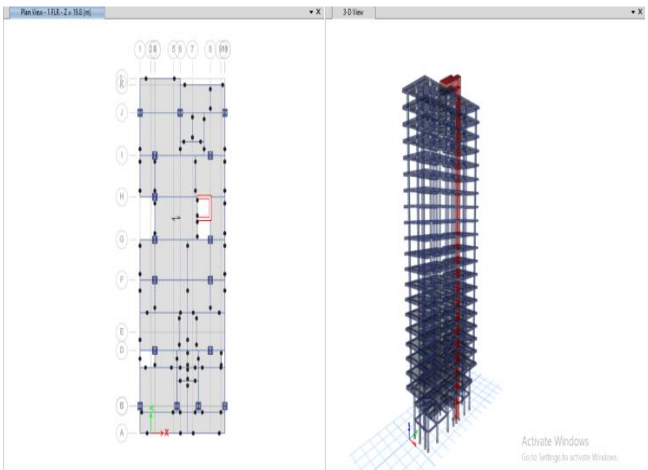

**Figure1.3: Plan and 3D Elevation**

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**Load Pattern**

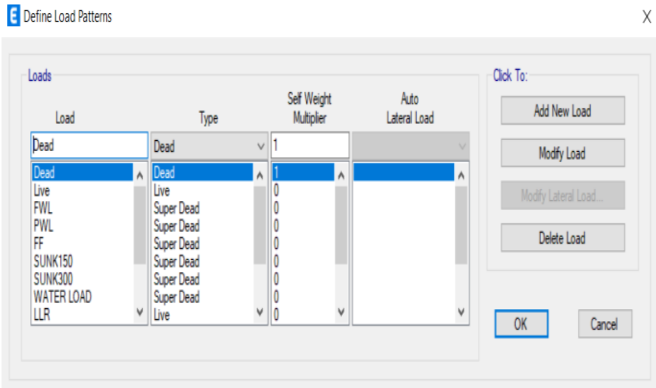


Figure1.4: Load Pattern

**Material Properties**

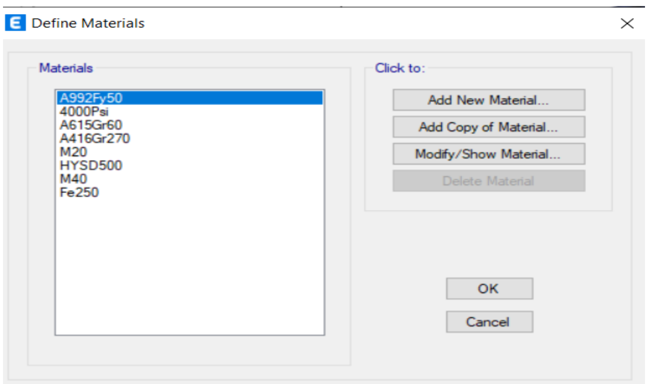


Figure1.5: Material Properties

**Load Cases**

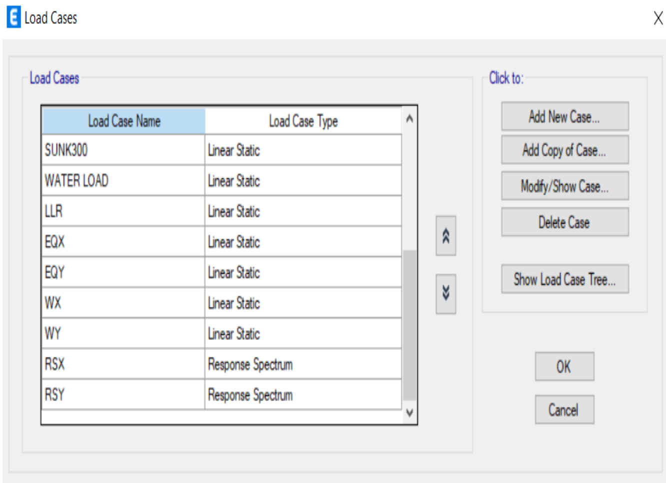


Figure1.6: Load Cases

**5.5 Model Mode Shapes**



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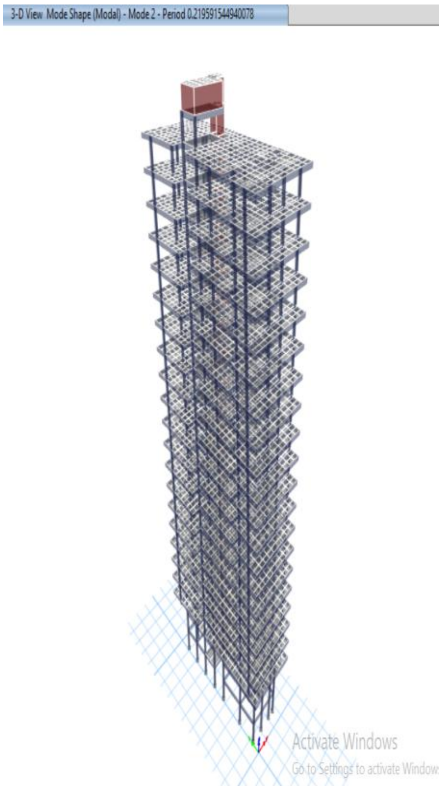


**Figure1.7: Model View for Mode Shape-1**


**Figure1.8: Model View for Mode Shape-1**

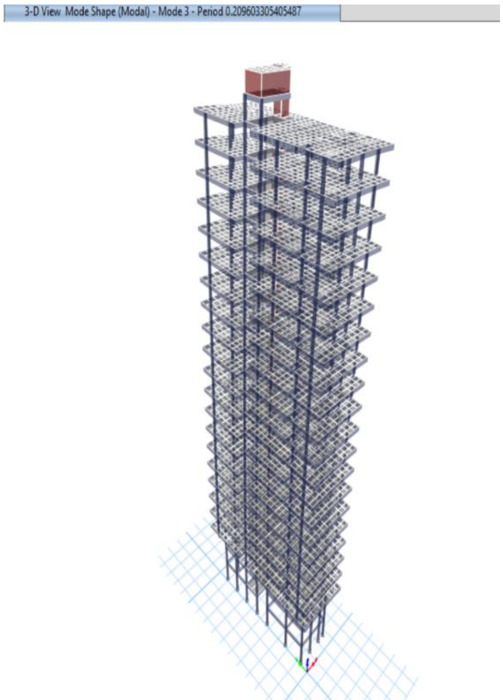


**Figure1.9: Model View for Mode Shape-1**

**Bending Moment Diagram**

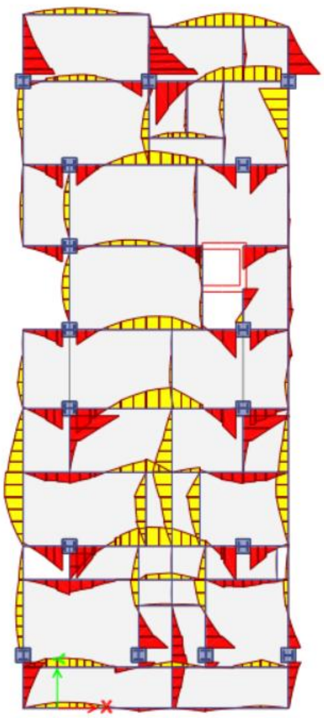

**Figure1.10: Bending Moment Diagram**

### 5.7 Shear Force Diagram

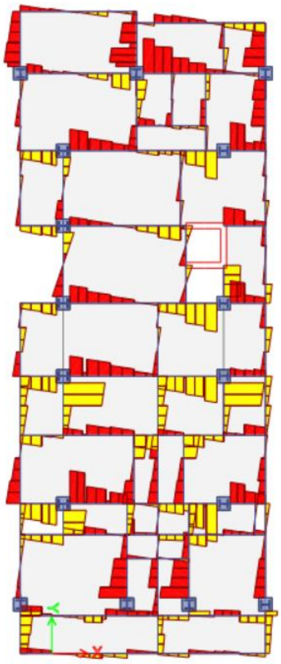

**Figure1.11: Shear Force Diagram**

### Torsion of Model

**Figure1.12: Torsion of Model**


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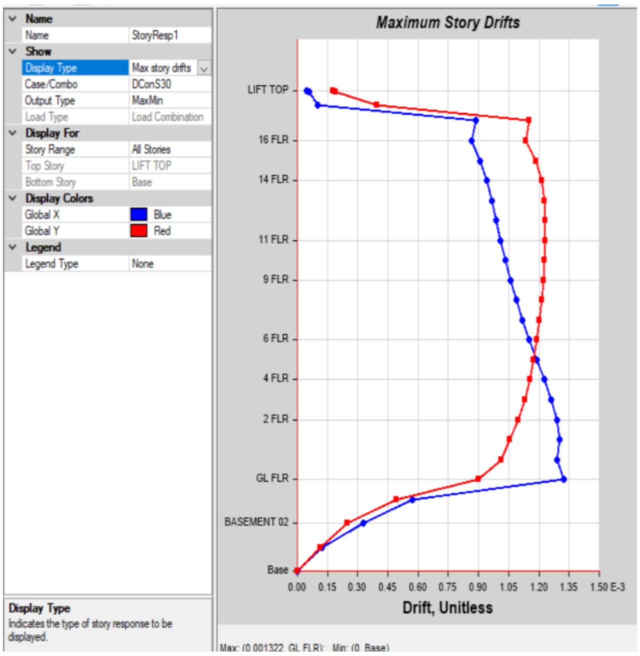
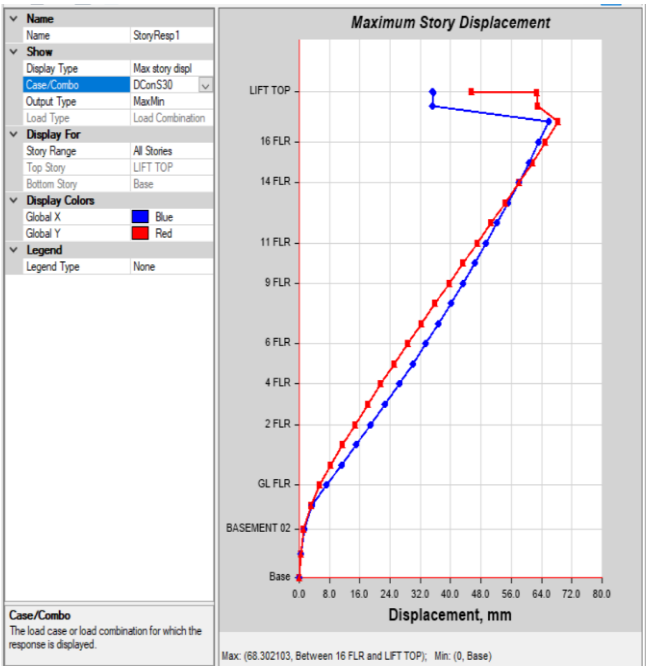
**Software Results Parameter**
**Maximum Story Drift**




**Graph1.1: Maximum Story Drift**

Story drift is the relative displacement between two consecutive stories due to lateral loads such as wind or seismic forces. It is an essential factor in structural design, as excessive drift can cause damage to structural and non-structural components. Graph 5.1: Maximum Story Drift illustrates the variation of story drift across different levels of the structure, highlighting the areas of maximum lateral displacement.

**Maximum Story Displacement**




**Graph1.2: Maximum Story Displacement**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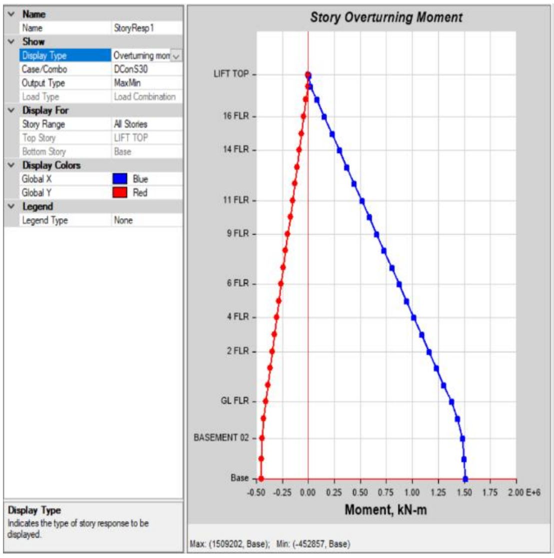
Story displacement represents the absolute movement of a story from its original position due to external forces. This parameter is crucial in assessing the overall stability and flexibility of the structure. Graph 5.2: Maximum Story Displacement provides a visual representation of how the displacement varies across different stories, indicating the extent of movement under applied loads.

**Overturning Moment**




**Graph1.3: Overturning Moment**

Overturning moment is the rotational force exerted on the structure due to lateral loads, which can lead to instability if not properly countered by the foundation and resisting elements. Higher overturning moments indicate increased vulnerability to overturning, especially in high-rise buildings and slender structures. Graph 5.3: Overturning Moment presents the distribution of overturning moments along the height of the structure, helping engineers ensure adequate stability measures are in place.

## RESULTS AND ANALYSIS BASED ON SEISMIC PARAMETER

**Maximum Story Displacement (mm)**

**Table1.1: Maximum Story Displacement (mm)**

| Maximum Story Displacement (mm) | |
|---|---|
| **Story** | **Displacement (mm)** |
| LIFT TOP | 45.473 |
| OHTTOP | 62.782 |
| OHTBTM | 62.87 |
| TERRECE | 68.302 |
| 16 FLR | 64.938 |
| 15 FLR | 61.534 |
| 14 FLR | 57.977 |
| 13 FLR | 54.344 |
| 12 FLR | 50.666 |
| 11 FLR | 46.971 |
| 10 FLR | 43.277 |
| 9 FLR | 39.593 |
| 8 FLR | 35.929 |
| 7 FLR | 32.291 |
| 6 FLR | 28.686 |
| 5 FLR | 25.121 |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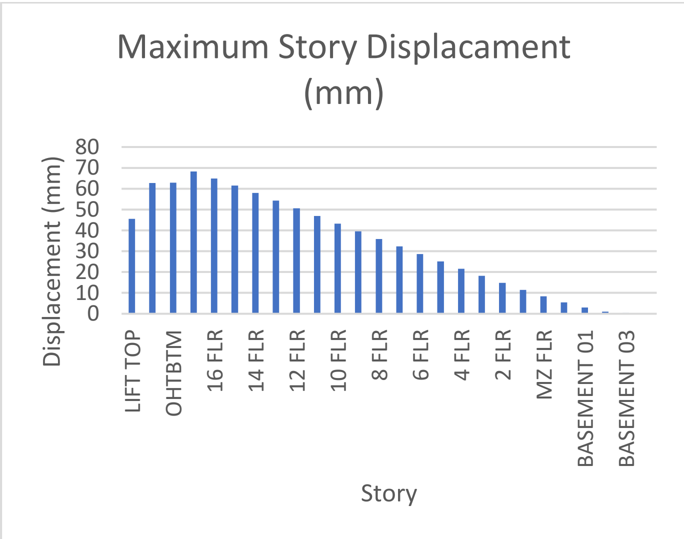
| | |
|---|---|
| 4 FLR | 21.604 |
| 3 FLR | 18.146 |
| 2 FLR | 14.763 |
| 1 FLR | 11.483 |
| MZ FLR | 8.356 |
| GL FLR | 5.457 |
| BASEMENT 01 | 3.057 |
| BASEMENT 02 | 1.029 |
| BASEMENT 03 | 0.406 |
| Base | 0 |




**Graph1.1: Maximum Story Displacement (mm)**

Above 6.1 Graph Shows Maximum Story Displacement (mm),

Story displacement is the total lateral movement of a structure at different levels due to applied lateral forces such as wind or seismic loads. It is a key factor in structural analysis as excessive displacement can lead to structural instability and damage to both structural and non-structural components.

The displacement values recorded at different stories of the structure indicate how the building responds to these forces. The displacement increases as we move from the base to the top of the structure, with the **maximum displacement recorded at the terrace level (68.302 mm)**.

The displacement pattern follows a logical trend, where lower levels experience lesser displacement due to the restraining effect of the foundation and higher stiffness, while upper stories exhibit greater displacement due to increased flexibility and cumulative lateral deflection.

The displacement data for various levels is as follows:

- **Lift Top (45.473 mm)** – The lift top experiences moderate displacement, which is lower than the terrace but still significant.
- **OHT Top & Bottom (62.782 mm & 62.87 mm)** – The overhead tank structure experiences considerable displacement, indicating the effect of lateral forces on elevated water tanks.
- **Terrace Level (68.302 mm) – Maximum Displacement** – The highest displacement is observed at the terrace level, as it is the topmost free-standing part of the structure.
- **Floor Levels (1st to 16th)** – Displacement values gradually reduce from **64.938 mm (16th floor) to 11.483 mm (1st floor)**, showing a steady decrease in deflection.
- **Mezzanine & Ground Floor (8.356 mm & 5.457 mm)** – The displacement at these levels is significantly lower, indicating their proximity to the foundation.

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- **Basement Levels** – The displacement continues to decrease as we go deeper into the structure, with **Basement 03 experiencing just 0.406 mm** of movement, showing its rigidity and stability.
- **Base (0 mm)** – At the base, there is no displacement, as expected, since it is the fixed reference point of the structure.

**Maximum Story Drift**

**Table1.2: Maximum Story Drift**

| **Maximum Story Drift** | |
|---|---|
| **Story** | **Story Drift** |
| LIFT TOP | 0.000177 |
| OHTTOP | 0.00019 |
| OHTBTM | 0.000394 |
| TERRECE | 0.001152 |
| 16 FLR | 0.001134 |
| 15 FLR | 0.001186 |
| 14 FLR | 0.001213 |
| 13 FLR | 0.001227 |
| 12 FLR | 0.001232 |
| 11 FLR | 0.001232 |
| 10 FLR | 0.001229 |
| 9 FLR | 0.001222 |
| 8 FLR | 0.001213 |
| 7 FLR | 0.001202 |
| 6 FLR | 0.001189 |
| 5 FLR | 0.001173 |
| 4 FLR | 0.001154 |
| 3 FLR | 0.001129 |
| 2 FLR | 0.001097 |
| 1 FLR | 0.001054 |
| MZ FLR | 0.001012 |
| GL FLR | 0.000898 |
| BASEMENT 01 | 0.000491 |
| BASEMENT 02 | 0.000246 |
| BASEMENT 03 | 0.000113 |
| Base | 0 |

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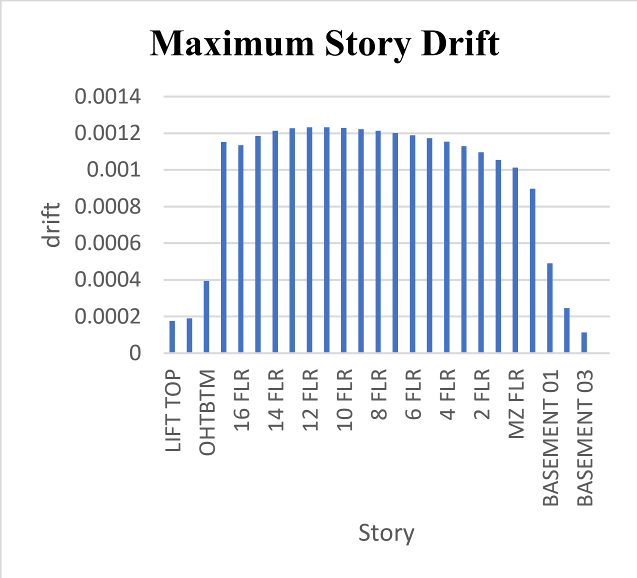



**Graph1.2: Maximum Story Drift**

Story drift refers to the relative lateral displacement between two consecutive stories due to lateral forces such as wind or seismic loads. It is an important parameter in structural design as excessive drift can lead to damage in structural and non-structural components, affecting the overall stability of the building.

Analysis of Story Drift at Different Levels

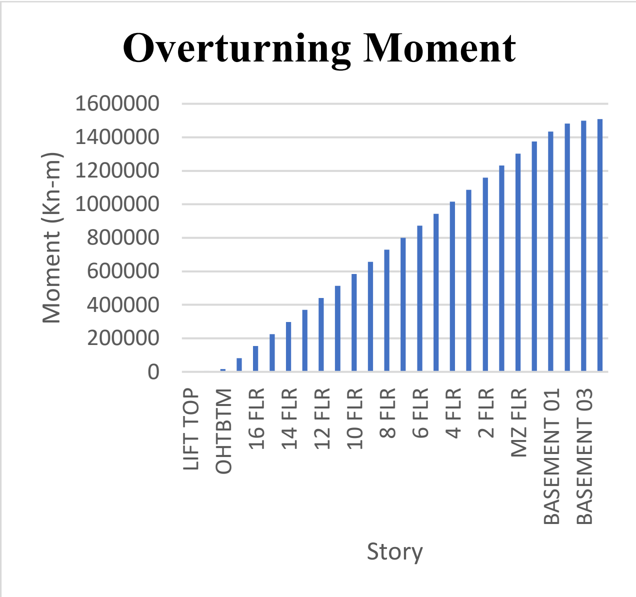
- Lift Top (0.000177) – The story drift is minimal at the topmost structural point, as it is a free-standing section with lesser resistance to lateral loads.
- Overhead Tank (OHT Top & Bottom: 0.00019 & 0.000394) – The drift increases slightly due to the added mass of the water tank but remains within a controlled range.
- Terrace (0.001152) – A noticeable increase in drift is observed, marking the transition to the main structural portion of the building.
- Middle Floors (1st to 16th Floor, Peak at 12th Floor: 0.001232) – The highest story drift occurs around the 12th floor (0.001232), after which it gradually decreases. This is expected, as mid-level floors generally exhibit the most flexibility in response to lateral forces.
- Lower Floors (Mezzanine & Ground Floor: 0.001012 & 0.000898) – The drift values reduce as the structure gains more rigidity from the foundation.
- Basement Levels – The drift continues to decline, with Basement 03 showing a minimal drift of 0.000113, approaching zero at the base (0.000).

**Maximum Overturning Moment (Kn-m)**

**Table1.3: Maximum Overturning Moment (Kn-m)**

| Maximum Overturning Moment (Kn-m) | |
|---|---|
| | |
| Story | Overturning Moment |
| LIFT TOP | 312.3319 |
| OHTTOP | 5428.834 |
| OHTBTM | 16868.7689 |
| TERRECE | 82132.4308 |
| 16 FLR | 153927.5555 |
| 15 FLR | 225722.6802 |
| 14 FLR | 297517.8049 |
| 13 FLR | 369312.9297 |

| | |
|---|---|
| 12 FLR | 441108.0544 |
| 11 FLR | 512903.1791 |
| 10 FLR | 584698.3038 |
| 9 FLR | 656493.4286 |
| 8 FLR | 728288.5533 |
| 7 FLR | 800083.678 |
| 6 FLR | 871878.8027 |
| 5 FLR | 943673.9275 |
| 4 FLR | 1015469.052 |
| 3 FLR | 1087264.177 |
| 2 FLR | 1159059.302 |
| 1 FLR | 1230854.426 |
| MZ FLR | 1302649.551 |
| GL FLR | 1374444.676 |
| BASEMENT 01 | 1434818.785 |
| BASEMENT 02 | 1482753.861 |
| BASEMENT 03 | 1498463.371 |
| Base | 1509202.096 |




**Graph1.3: Maximum Overturning Moment (Kn-m)**

Overturning moment is a crucial parameter in structural analysis, representing the rotational force exerted on a building due to lateral loads such as wind and seismic forces. It is a measure of the tendency of the structure to overturn and is countered by the foundation and structural stability measures like shear walls and bracing systems.

The overturning moment is highest at the base (1,509,202.096 kN-m) and gradually reduces as we move upwards, indicating the cumulative effect of lateral forces acting on the structure. This pattern is expected, as lower levels bear the total overturning force from the upper stories.

Analysis of Overturning Moments at Different Levels

- Lift Top (312.3319 kN-m) – The overturning moment at the highest structural point is minimal, as this level does not contribute significantly to the base moment.
- Overhead Tank (OHT Top & Bottom: 5,428.834 kN-m & 16,868.7689 kN-m) – The moment increases due to the mass and elevation of the water tank, which adds to the lateral force impact.
- Terrace (82,132.4308 kN-m) – At this level, overturning effects become more significant as the cumulative moment from the above stories adds up.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- Upper Floors (1st to 16th Floor) – The overturning moment consistently increases as we move downward, reaching 1,230,854.426 kN-m at the 1st floor, indicating the growing force that the structure must resist.
- Mezzanine and Ground Floor (1,302,649.551 kN-m & 1,374,444.676 kN-m) – The moment continues to rise, approaching its peak at the basement levels.
- Basement Levels – The overturning moment reaches its highest near the base, with Basement 03 experiencing 1,498,463.371 kN-m, just below the final maximum at the base (1,509,202.096 kN-m).
- Base (1,509,202.096 kN-m) – Maximum Overturning Moment – At the base, the total overturning moment is at its peak, as it accumulates the rotational forces from all levels above.

## CONCLUSION

The expected outline for the review paper begins with an **Introduction**, where the background of seismic challenges in earthquake-prone regions will be introduced, emphasizing the importance of composite steel-concrete beams in earthquake-resistant design. This section will also define the objectives of the review and outline the structure of the paper to guide the reader through the content.

The paper will then move to a section on the **Seismic Behavior of Composite Steel-Concrete Beams**, exploring the fundamental properties of both steel and concrete in composite beams, and how they interact under seismic loading. It will examine key factors influencing seismic performance, such as material properties, connection detailing, and beam geometry, as well as the energy dissipation and load-bearing capabilities of these beams during seismic events.

Next, the **Analytical Modeling of Seismic Behavior** section will review the numerical methods used for modeling composite beams, particularly finite element analysis, and discuss the challenges in capturing nonlinear behavior under seismic loading. The section will also examine previous studies that have used analytical models to predict the seismic performance of composite beams and how these models have been validated through experimental data.

Following this, the **Experimental Testing of Composite Beams** section will review the various experimental methods used to evaluate the seismic performance of composite beams, such as cyclic loading tests, shake table tests, and full-scale specimen testing. Key performance parameters like energy dissipation, failure modes, and ductility will be discussed, along with findings from past research that have contributed to understanding composite beam behavior under seismic loads.

The paper will also address **Design Guidelines and Standards**, providing an overview of current design codes and standards for composite steel-concrete beams in seismic zones. This section will analyze the strengths and limitations of existing guidelines and offer recommendations for improving the seismic design of composite beams, drawing on case studies of real-world applications.

The review will then explore the **Gaps and Challenges in Current Research**, identifying areas where understanding of composite beam behavior under seismic loading is limited. It will discuss challenges in both modeling and experimental validation and highlight areas that require further investigation to improve seismic resilience.

In the **Future Research Directions** section, the paper will propose areas for future studies aimed at enhancing the seismic performance of composite beams. This will include advancements in computational modeling techniques, experimental methodologies, and innovations in materials and design strategies for improved seismic resilience.

The review will conclude with a **Conclusion** summarizing the key findings, discussing their implications for the design and performance of composite steel-concrete beams in seismic regions, and offering final thoughts on improving the seismic safety of structures using composite beams.


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