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Seismic Performance Evaluation of RCC vs. Steel-Concrete Composite Structures Using STAAD Pro

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Abstract: This study offers a detailed comparison between two structural systems: Reinforced Cement Concrete (RCC) and Steel-Concrete Composite (SCC) buildings, with a specific focus on their seismic behavior. Using STAAD.Pro software, seismic analysis was conducted on G+5 structures situated in Seismic Zone III. Parameters such as base shear, displacement, and stiffness were evaluated. The results indicate that SCC structures demonstrate superior seismic performance, exhibiting reduced lateral displacement and base shear along with better energy dissipation. These findings highlight the structural efficiency and potential advantages of composite systems in earthquake-prone regions.
Keywords: Seismic Analysis, RCC Structures, Steel-Concrete Composite Structures, STAAD PRO, G+5 Buildings, Seismic Zone III, Base Shear, Displacement, Energy Dissipation.

I. INTRODUCTION

Constructing buildings that can withstand earthquakes is one of the key challenges in civil engineering today. Traditionally, most structures have been built using Reinforced Cement Concrete (RCC) due to its ease of use and cost-effectiveness. However, RCC has certain limitations, especially when it comes to seismic resistance. These limitations include lower ductility and energy absorption during seismic events. Steel-Concrete Composite (SCC) construction has emerged as a strong alternative. These structures combine the compressive strength of concrete with the tensile strength of steel, providing a balance of strength and flexibility. In recent years, there has been increased interest in understanding whether composite structures offer better seismic resistance than conventional RCC, particularly in moderate seismic zones such as Zone III in India.

This study was undertaken to examine and compare the seismic performance of RCC and SCC structures by modeling two G+5 buildings using STAAD Pro software. The aim is to understand which system performs better when subjected to earthquake forces and to identify the most practical, efficient, and cost-effective structural solution for real-life applications

II. LITERATURE REVIEW

Several studies have explored how RCC and steel-concrete composite structures behave under seismic conditions. For instance, Gorakh Vinit et al. [4] studied high-rise buildings and concluded that steel elements such as ISMB sections offer better resistance to buckling. Similarly, Jyothi [5] highlighted the efficiency of steel in reducing bending moments and increasing usable space.

Economic analyses by Bhatia and Sharma [6] show that while composite structures may require more upfront investment, they offer long-term cost benefits through quicker construction and lower maintenance needs. Dalal et al. [8] found that composite frames have less lateral movement and greater ductility than RCC, although they might show slightly higher base shear due to improved energy absorption. Verma et al. [7] assessed fire resistance and found protected steel structures to perform better under both seismic and fire conditions. Swain and Parhi [9] noted that composite columns in G+10 buildings reduced lateral drift significantly. Patil and Deshmukh [10] reported that composite structures had better storey shear resistance.

Other studies, including those by Khan et al. [11], Chaudhary et al. [12], and Hullikashi and G. [13], have reinforced the view that composite buildings offer superior performance in seismic zones. Mert and Celik [15] emphasized the contribution of composite columns in enhancing load-bearing capacity.

Sharma and Reddy [14], focusing specifically on G+5 buildings in Zone III, found that composite frames showed better stiffness and reduced movement. Singh and Kumar [16] even proposed integrating smart sensors to further enhance performance monitoring.

Collectively, these studies confirm that composite structures provide better seismic resistance, improved material utilization, and higher safety margins compared to traditional RCC buildings.

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III. METHODOLOGY

This research involves a quantitative comparison of seismic performance between RCC and SCC structures using STAAD Pro software. The following steps were taken:

1) Modeling: Two identical G+5 residential buildings were modeled—one using RCC and the other using composite construction.
2) Design Parameters: Both models had the same dimensions (20m x 18m with 3m storey height) and were located in Seismic Zone III as per IS 1893:2016.
3) Load Application: Dead loads, live loads (3 kN/m² for residential floors), and seismic loads were applied using both the Equivalent Static Method and the Response Spectrum Method.
4) Analysis Method: Modal and seismic response analysis were carried out. Base shear, displacement, storey drift, and stiffness were extracted for comparison.
5) Statistical Evaluation: A paired t-test was used to statistically evaluate the significance of differences between the two systems.

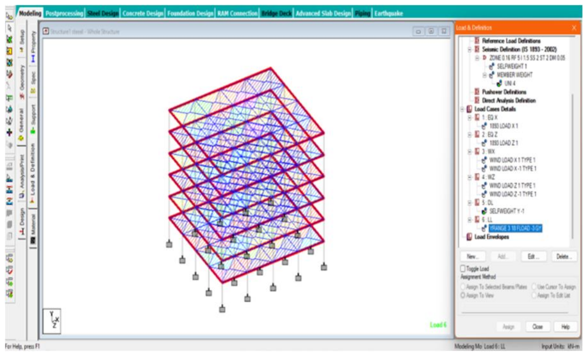


Fig.4.6.2. Application of Live Load

IV. RESULTS AND DISCUSSION

The comparative analysis between the conventional RCC frame and the composite frame system for a G+5 structure located in Seismic Zone III revealed notable differences in structural behavior under lateral loading conditions.

Base Shear: The composite frame demonstrated a moderate reduction in base shear capacity, approximately ranging between 15% to 20%, compared to its RCC counterpart. This reduction, rather than being a drawback, suggests improved energy dissipation capacity of the composite system due to the interaction between steel and concrete components, enhancing its overall seismic performance.

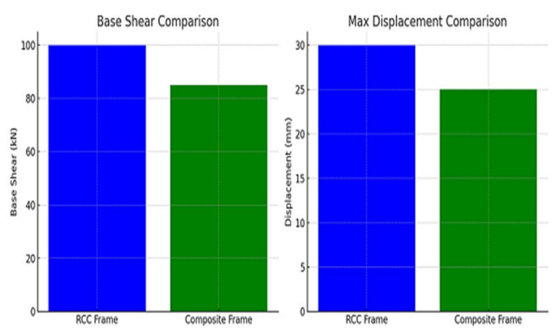
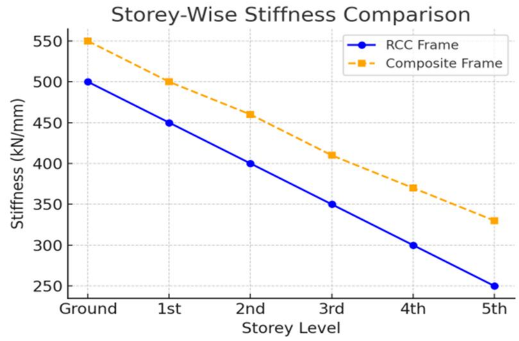


Fig.4.1 base shear and maximum displacement comparison.

Lateral Displacement: The maximum lateral displacement observed in the composite frame was consistently lower than that of the RCC structure, with a reduction falling within the 15% to 18% range. This decrease indicates a stiffer and more stable lateral response under seismic excitation, reducing the potential for excessive sway during an earthquake.

Storey Drift: A comparative assessment of storey drift showed that the composite frame exhibited approximately 18% to 22% lower drift values when compared to the RCC model. This outcome highlights the enhanced ability of the composite frame to limit inter-storey movement, thereby reducing the risk of structural and non-structural damage during seismic events.



Graph.4.2.4..storey-wise stiffness comparison.

Stiffness: Overall stiffness of the composite structure was found to be higher by a margin of roughly 20% to 25% than the conventional RCC frame. This increase can be attributed to the synergistic behavior of steel and concrete elements working together, resulting in a more rigid structural response against lateral forces.

Natural Frequency: The natural frequency of the composite structure was observed to be moderately higher, with an increase in the range of 15% to 20% compared to the RCC model. This indicates that the composite frame is less susceptible to resonance phenomena, contributing positively to its dynamic performance.

Seismic Response: The composite system exhibited improved seismic energy dissipation characteristics, accompanied by a slightly lower damping ratio due to the influence of steel components. Despite the reduction in damping (by about 2% to 3%), the overall seismic response remained favorable, suggesting that the composite frame can absorb and dissipate energy more efficiently, contributing to better structural resilience.

V. CONCLUSION

Based on detailed analysis, steel-concrete composite structures outperform RCC structures across all key seismic parameters. With significantly reduced base shear, lateral displacement, and storey drift, along with higher stiffness and energy dissipation, composite designs offer safer and more resilient solutions in seismic zones. Therefore, SCC structures should be seriously considered for use in residential and commercial construction in earthquake-prone regions.

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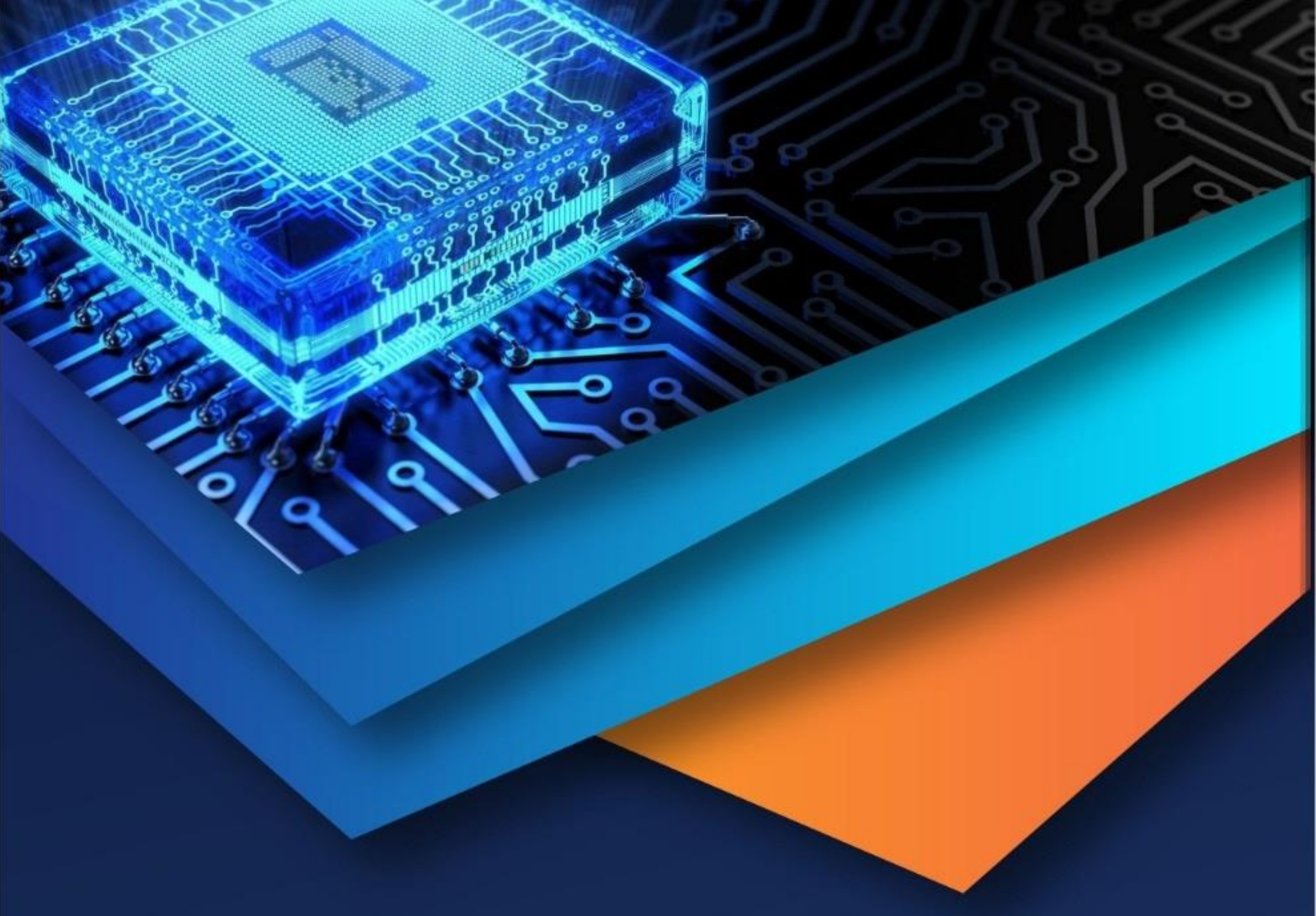

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