Comparative Study on Seismic Analysis of (G+11) R.C.C. and Steel-Concrete Composite Buildings using ETABS

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Abstract: **Reinforced Concrete (RCC) structures have long been the preferred choice in the Indian construction sector due to their cost-effectiveness and ease of construction. However, with the growing demand for high-rise buildings and enhanced seismic safety, steel–concrete composite systems have gained increasing acceptance because of their favorable strength-to-weight ratio, improved ductility, and superior performance under lateral loads.**

This study investigates and compares the seismic behaviour of a G+11 storey RCC frame and an equivalent composite frame structure located in Seismic Zone III. Both structural models were designed to resist identical gravity loads, with beam and column members modeled either as RCC or composite sections. Seismic analysis was carried out using the Response Spectrum Method in ETABS, in accordance with IS 1893:2016 provisions. Key parameters considered in the comparative evaluation include fundamental natural time period, storey displacements, storey drift, base shear, storey mass, and overall stiffness characteristics.

The results indicate that the composite structure exhibits a lower seismic weight, reduced displacements and inter-storey drifts, and a shorter natural time period compared to the conventional RCC structure. These characteristics collectively demonstrate the enhanced seismic performance and stability of composite frames.

The findings emphasize the potential of composite construction as a viable alternative to traditional RCC systems in earthquake-prone regions, offering engineers a practical basis for selecting structural systems that ensure safety, efficiency, and resilience in high-rise construction.

Keywords: Seismic Analysis, Shear Wall, Response Spectrum Analysis, ETABS, Reinforced Cement Concrete, Multistorey Building

I. INTRODUCTION

Structural analysis is a fundamental branch of civil engineering concerned with assessing the stability, safety, and efficiency of buildings and infrastructure. It provides engineers with the necessary tools to evaluate how structures respond to various loads, ensuring that they can withstand both everyday service conditions and extreme events such as earthquakes or windstorms. One of the key challenges in this field is the analysis of structures of composite structures, which display irregularities in geometry, mass distribution, and stiffness. Such irregularities complicate load transfer mechanisms and can result in torsional effects, uneven displacements, and increased vulnerability under seismic loading. Understanding and accurately analyzing these behaviors is therefore crucial for designing safe and reliable structural systems.

Composite Construction

Steel–concrete composite construction is a structural system in which steel and concrete are combined to function as a single unit. In columns, this is achieved by encasing steel sections in concrete or filling hollow steel sections with concrete, thereby enhancing strength and stiffness. For beams, an RCC or profiled steel deck slab is structurally connected to the steel beam through shear connectors, which ensure proper interaction between the two materials. This composite action improves stiffness, load-carrying capacity, and overall seismic performance. Despite these advantages, adoption in India remains limited due to a lack of awareness and perceived complexity in design. However, research and practical applications highlight that composite structures offer faster construction, improved durability, superior stability, and cost efficiency when properly designed.

Elements of Composite Construction

Key components of composite construction include composite beams, composite columns, shear connectors, and profiled decking. A composite beam consists of a steel section integrated with a concrete slab, connected through shear connectors that transfer shear forces and prevent separation at the interface. Composite columns, formed by encasing or filling steel sections with concrete, exhibit higher axial load capacity, stiffness, and seismic resistance. Shear connectors, such as studs or bars welded to steel beams, play a crucial role in ensuring effective force transfer and composite action. Additionally, composite floors using profiled steel decking are widely used in high-rise buildings due to their rapid construction and efficiency, though specific Indian standards for their design are yet to be established.

Figure 1. Composite Structure

Aim of Study

- To model and analyse a G+11 RCC building and an equivalent Steel-Concrete Composite building using ETABS, following IS 1893 (Part 1): 2016 guidelines.
- To evaluate and compare the seismic response of both structures in terms of Storey displacement, Storey drift, Base shear, Fundamental time period.
- To study the effect of material properties (RCC vs. composite) on the overall seismic performance of the buildings.
- To evaluate the advantages of using steel-concrete composite construction over conventional RCC in seismic-prone regions.
- To provide recommendations for selecting appropriate structural systems based on performance under seismic loading.

II. LITERATURE REVIEW

Rahul Patel et al. (2025) carried out a comparative seismic analysis of G+12 RCC and steel–concrete composite buildings using ETABS software under identical loading conditions. The Response Spectrum Method was applied, and the results revealed that composite frames experienced lower lateral displacements, reduced base shear, and enhanced ductility compared to RCC structures, thereby establishing their greater suitability for seismic regions.

Anjali Sharma et al. (2025) involved a nonlinear dynamic analysis of a G+15 composite structure featuring concrete-filled steel tubular (CFST) columns, designed in accordance with IS 1893:2016. The findings showed that CFST columns significantly improved energy dissipation and lateral stiffness. Overall, the study confirmed that composite frames provide superior seismic performance, particularly in high-rise applications.

N. Tiwari and M. Kulkarni (2024) evaluated the seismic performance of RCC and composite structures across seismic Zones II to V using ETABS analysis. Results indicated that composite structures performed more efficiently in high-risk seismic zones, with notable reductions in base shear and inter-storey drift. Conversely, RCC buildings exhibited higher vulnerability, particularly in Zones IV and V.

Shubham Verma et al. (2024) researched a G+10 irregular-plan composite structure was analyzed using Finite Element Method (FEM) tools. The study highlighted the effectiveness of composite columns in controlling torsional irregularities and improving lateral stability. Results demonstrated that steel–concrete composite frames provided greater resistance to the adverse effects of irregular geometries compared to conventional RCC systems.

Varunkumar Veerapandian et al. (2023) focused on the superior confinement behaviour of composite columns in comparison to traditional RCC columns. The researchers developed an Artificial Neural Network (ANN) model capable of predicting the ultimate axial load capacity of circular composite columns regardless of the type of confining steel tube. The ANN model was trained and validated using a comprehensive experimental database, including real-time testing, and supplemented with a user-friendly graphical interface to assist engineers in quickly estimating axial strengths.

Gaurav Swami et al. (2023) examined the performance of composite modular buildings utilizing CFST columns under progressive collapse scenarios. Using validated numerical models of CFST columns and semi-rigid frames, the analysis simulated both column and module removal cases in a ten-storey modular structure. Nonlinear dynamic and static pushover results indicated that CFST columns improved buckling resistance. Furthermore, corner module removal was identified as the most critical due to shear failure at inter-module joints. The authors recommended dynamic amplification factors (DAF) of 1.65 for corner modules and 1.2 for edge or internal modules.

S. M. Priok Rashid and Alireza Bahrami (2023) analyzed the role of fiber-reinforced polymer (FRP) and carbon fiber-reinforced polymer (CFRP) as external confinement materials in steel–concrete composite thin-walled columns (SCTWCs). Findings showed that fiber wrapping enhanced the interaction between steel tubes and concrete cores, significantly improving axial strength. CFRP confinement was especially effective, increasing load-carrying capacity by up to 30% and mitigating local buckling in steel tubes. The study provides valuable insights into the application of FRP systems for improving the seismic performance of composite columns.

Nikhil Patil et al. (2023) explored the growing use of modular precast composite systems in India, integrating cold-formed light-gauge steel with precast Ferrocement panels. These systems provide a sustainable alternative to RCC construction by reducing carbon emissions, speeding up construction, and minimizing labor and material transportation requirements. The approach was successfully applied to a G+5 residential project. Additionally, laboratory testing under varying thermal conditions was conducted to assess thermal performance, demonstrating potential benefits for energy efficiency and occupant comfort in urban housing.

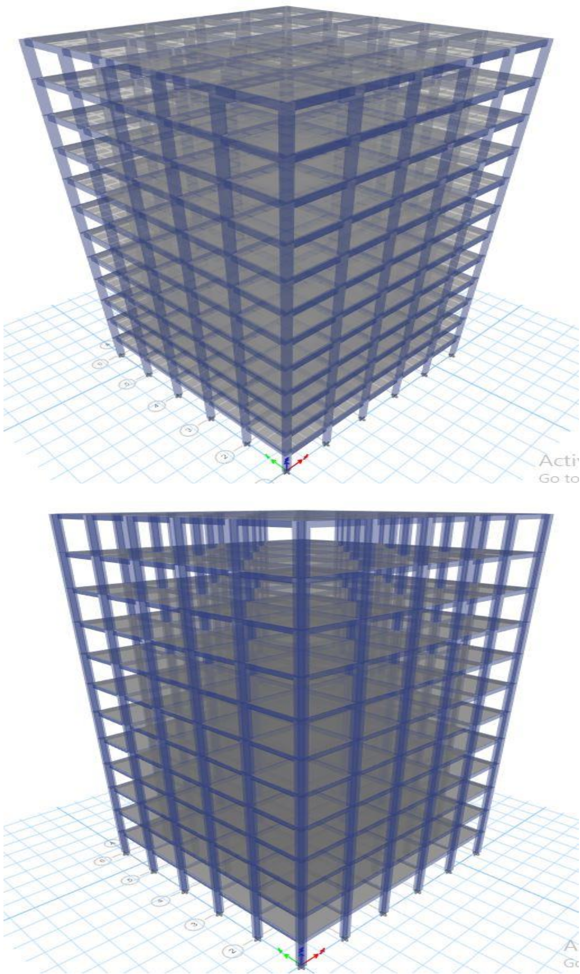
Yuchen Song et al. (2023) introduced a nonlinear fiber beam–column (FBC) model for analyzing partially encased composite (PEC) columns in high-rise buildings. The model accounts for material nonlinearity, concrete confinement, and local buckling effects using a fiber-discretized Euler-Bernoulli beam formulation. Stress redistribution due to local and post-local buckling was addressed through the Generalized Effective Width Method (GEWM). Validation through numerical simulations confirmed the model's accuracy in predicting concentric and eccentric loading behavior as well as global buckling. Compared to conventional 3D finite element analysis, the FBC model offered substantial reductions in computational demand while maintaining reliability.

III. METHODOLOGY

The study considers a G+11 multi-storey building, modeled in two different configurations. Model 1 represents a Reinforced Cement Concrete (RCC) moment-resisting frame, while Model 2 represents a steel–concrete composite frame with composite beams and columns. For a fair comparison, both models are designed with identical dimensions and geometry. The detailed building specifications, including structural configuration, material properties, and key characteristics adopted for the analysis, are presented in Table 1.

Table 1 Geometrical Data

Descriptions	Parameter
Number of Stories	(G+11)
Frame	Moment Resisting Frame
Height of building	36
Height of each story	3.0 m
Foundation Depth	3.2 m
Plan of the building	20m × 20 m
Floor Diaphragm	Rigid
Grade of Concrete	M30
Grade of reinforcing Steel	Fe550 for main steel Fe415 for distribution steel
Grade of structural steel	Fe345
Seismic Zone factor (Z)	0.16 (III Zone)
Soil Type	Medium soil
Importance factor	1
Response reduction factor	5
Damping Ratio	0.05
Modal Combination Method	CQC
Combination Type	SRSS
Diaphragm Eccentricity	0.05 for all diaphragm
Wall Load of 230mm width	13 kN/m
Shell load on floors	2 kN/m^2
Shell load for Floor Finish	1.5 kN/m^2
RCC Beam	300 x 450 mm
RCC Column	300 x 650 mm
Composite Beam	ISMB 500x500 With ISMB350
Composite Column	ISMB 500x500 With ISMB400



a) Model-1 b) Model-2

Figure 2 Extruded View of Structures

IV. RESULT AND DISCUSSION

The analytical results from ETABS reveal that steel-concrete composite structures exhibit superior seismic performance compared to conventional RCC structures in Seismic Zone III. The fundamental time period of the composite building is lower, reflecting higher stiffness and better resistance to seismic vibrations, though it results in slightly higher base shear. Storey displacements and inter-storey drifts are consistently smaller in the composite system, remaining well within IS 1893:2016 limits and demonstrating improved lateral stability. In contrast, RCC buildings show larger displacements and reduced stiffness, making them less effective under earthquake loading. From a practical standpoint, while composite construction may involve higher initial material costs due to steel, it significantly reduces overall construction time through prefabrication and faster assembly, leading to economic benefits when life-cycle costs and early occupancy are considered. Thus, composite structures provide a balanced advantage of seismic safety, serviceability, and construction efficiency over RCC systems.

Results of Storey Displacement

The displacement graph shows that the RCC frame experiences significantly higher lateral displacements, reaching up to 85 mm at the top storey, whereas the composite frame maintains much lower values, with a maximum of about 13 mm. This clearly demonstrates the superior lateral stiffness and seismic control of the composite structure compared to the RCC structure.

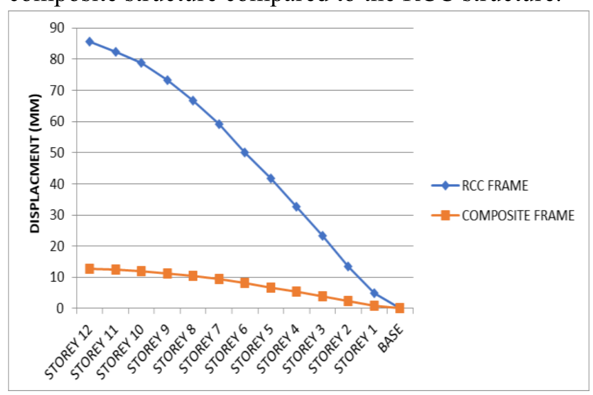


Figure 3. Storey displacement of Both Models

Results of Storey drift

Drift, which represents the relative displacement between two consecutive storeys, is a critical parameter in evaluating both structural safety and non-structural integrity under seismic loading. In the present study, it is observed that both RCC and composite models satisfy the permissible drift limits as prescribed by IS 1893:2016, ensuring adequate serviceability and stability of the structures.

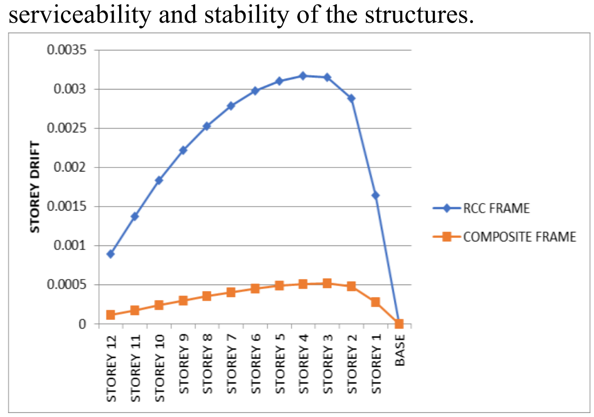


Figure 4. Storey drift of of Both Models

Results of Storey Shear

The storey shear values decrease progressively from the base to the top floors in both RCC and composite structures, primarily due to the reduction in cumulative seismic weight at higher levels. RCC buildings exhibit consistently higher shear values throughout the height because of their greater mass, with the maximum storey shear reaching approximately 1900 kN, compared to 745 kN in the composite structure. Moreover, the graphical comparison highlights that the RCC building experiences a sharper reduction in shear at upper storeys, whereas the composite structure demonstrates a smoother variation, indicating a more uniform and efficient distribution of seismic forces along the height of the building.

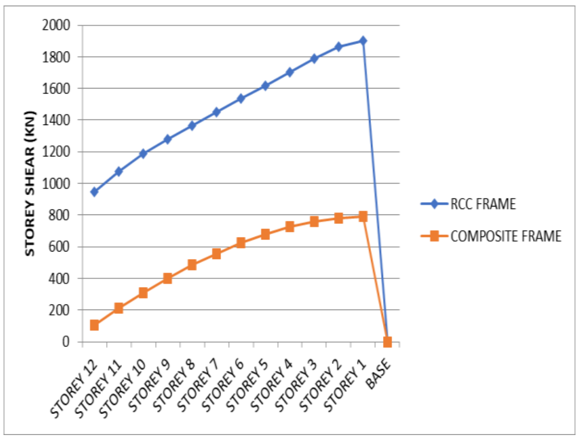


Figure 5. Storey Shear of Both Models

Weight of Structure

The weight of RCC and Stee structure are as follows:

Table 2 Weight of Structure

S.No	Structure System	Weight(kN)
1	RCC Frame	52701
2	Composite Frame	45560

V. CONCLUSION

This Analysis and design results of G+11 storey Composite, and R.C.C Structure has been studied and represented here. The comparison results of these building models are as follows.

- Seismic Performance

The composite building demonstrates a lower fundamental time period compared to the RCC building, signifying greater flexibility and improved capacity for seismic energy dissipation. Additionally, due to its lighter weight, the composite structure experiences lower base shear than the RCC structure, thereby reducing the seismic forces transmitted to the foundation.

- Storey Displacement and Drift

Both displacement and inter-storey drift are found to be higher in the RCC structure than in the composite structure, though they remain within the permissible limits prescribed by IS 1893:2016. The inherent flexibility of composite systems enhances ductility, thereby improving overall seismic resilience.

- Structural Weight

Composite buildings are considerably lighter than RCC structures owing to the use of structural steel sections in combination with concrete, which reduces the overall seismic demand on the structure.

- Construction Cost

While the unit cost of steel is higher than that of concrete, the overall expenditure for a composite structure can be comparable or slightly less than that of RCC. This is achieved through reduced formwork requirements, faster construction processes, and lower labour intensity.

- Construction Time

Composite structures can be executed in a much shorter timeframe, with project durations reduced by nearly 25%. This advantage makes them especially suitable for urban and industrial projects where timely completion is a priority.

- Practical Feasibility

The incorporation of prefabricated steel elements in composite construction ensures superior quality control, reduced on-site material wastage, and enhanced safety during execution, making the system highly practical and efficient for modern construction practices.

VI. FUTURE SCOPE OF WORK

- Performance of composite buildings under non-linear dynamic (time history) analysis.
- Comparative study for irregular structures or buildings with core-wall systems.
- Life cycle cost analysis including maintenance and durability aspects.
- Use of advanced composite materials like FRP (Fiber Reinforced Polymers).

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