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Effect of Seismic Load on Behavior of RCC and Composite Structure Analysis using STAAD Pro

Kawade Dhananjay Sunil[1], Solat Shubham Namdeo[2], Wakchaure Gayatri Kisan[3], Warade Aditya Umesh[4], Prof. S. R. Wale[5]
Department of Civil Engineering[1-5]
Amrutvahini College of Engineering, Sangamner, A. Nagar, MH

Abstract: *This study investigates the comparative behavior of Reinforced Cement Concrete (RCC) and composite structures under seismic loading using STAAD Pro software. With the growing need for efficient and resilient buildings in earthquake-prone regions, understanding the dynamic performance of different structural systems has become essential. The project involves the modeling of an 8-story (G+7) building in two configurations—RCC and composite—while maintaining consistent geometry, loading conditions, and support constraints to ensure an accurate comparison. Seismic loads are applied based on IS 1893:2016 standards, and both static and dynamic (response spectrum) analyses are performed. Key structural parameters such as base shear, story drift, displacement, and natural frequencies are recorded and analyzed. The results highlight significant differences in structural performance, with composite structures generally exhibiting reduced displacements and improved energy dissipation due to the synergistic interaction between steel and concrete. This study not only demonstrates the advantages of composite construction in seismic regions but also emphasizes the importance of advanced structural modeling and dynamic analysis in modern design practices.*

Keywords: Seismic analysis, RCC structures, Composite structures, STAAD Pro, Structural dynamics.

I. INTRODUCTION

In the field of structural engineering, understanding the response of buildings to seismic forces is of paramount importance, particularly in regions that are prone to earthquakes. Earthquakes introduce dynamic and unpredictable loads that can severely compromise the integrity of structures. Hence, designing buildings to be earthquake-resistant is a critical aspect of modern civil engineering. Seismic analysis allows engineers to evaluate a building's response to earthquake-induced loads and design appropriate structural elements to resist those forces efficiently. Earthquake-resistant design focuses not only on preventing structural collapse but also on ensuring serviceability, occupant safety, and minimal damage during seismic events. With the advancement of computational tools and building codes, it is now feasible to conduct comprehensive seismic assessments of various structural systems [1].

Reinforced Cement Concrete (RCC) structures have traditionally dominated construction in India and many parts of the world due to the availability of raw materials and cost-effectiveness. RCC combines the compressive strength of concrete and the tensile strength of steel, forming a durable construction material suitable for various types of buildings. However, under seismic conditions, RCC structures may show limitations such as high dead weight, reduced flexibility, and delayed construction timelines. Moreover, the seismic performance of RCC structures is highly sensitive to factors like mass distribution, stiffness irregularities, and ductile detailing. Earthquakes demand that these structures not only resist static and gravity loads but also dynamic lateral forces, which require special attention in their design and detailing [2].

In contrast, composite structures—typically consisting of steel beams and columns combined with concrete slabs—offer an innovative solution to overcome the limitations of conventional RCC construction. The integration of steel and concrete in composite members capitalizes on the beneficial properties of both materials, providing enhanced strength, ductility, and energy absorption. Composite structures also tend to be lighter in weight than traditional RCC systems,

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reducing seismic mass and, consequently, the forces induced during an earthquake. Moreover, their faster construction process, facilitated by prefabricated steel components, is particularly advantageous in urban high-rise developments [3]. To evaluate the seismic performance of both RCC and composite structures accurately, software tools like STAAD Pro are employed. STAAD Pro enables engineers to model complex geometries, apply various load conditions, and perform both linear and non-linear dynamic analyses. It supports compliance with international and national design codes such as IS 1893:2016 for seismic design, which classifies India into different seismic zones and prescribes corresponding response spectra, design coefficients, and structural performance criteria. By simulating earthquake scenarios using response spectrum analysis or time-history analysis, STAAD Pro allows for a detailed comparison of structural behavior under dynamic loading [4].

The significance of this research lies in the comparative study of RCC and composite structures when subjected to seismic forces. The primary focus is on evaluating parameters like base shear, inter-story drift, maximum displacement, and natural frequencies to determine which structural system offers better seismic resilience. The choice of structural system significantly influences the cost, construction time, safety, and serviceability of the building. Therefore, understanding how different materials and structural systems respond to seismic forces is essential for selecting the most efficient and secure design, particularly for multi-story and high-rise buildings in seismic zones [5].

Ultimately, the goal of this study is to generate a comprehensive and comparative analysis that will aid engineers, architects, and policymakers in making informed decisions when designing earthquake-resistant buildings. As seismic design codes evolve and the demand for safer infrastructure increases, such research becomes a valuable resource for advancing structural engineering practices. In doing so, this study contributes to the broader mission of reducing the devastating impact of earthquakes on human life and the built environment.

PROBLEM STATEMENT

The study aims to address the lack of comparative analysis on the seismic performance of RCC and composite structures, focusing on identifying which system offers greater efficiency and safety under earthquake loading conditions.

OBJECTIVE

- To compare the seismic performance of RCC and composite structures using STAAD PRO.
- To evaluate structural parameters such as displacement, base shear, and story drift under seismic loads.
- To identify the advantages and limitations of each structural system in earthquake-prone zones.
- To analyze the behavior of structures under different load combinations as per IS 1893:2016.
- To recommend the more efficient structural system for high-rise construction in seismic areas.

II. LITERATURE SURVEY

1. **Analytical Investigation of Composite Structure in Comparison of RCC Structure**

Vrunda R. Laddha et al. (2021) conducted a comparative analysis of G+7 RCC and composite structures using ETABS software. The study focused on parameters such as storey displacement, base shear, and time period under seismic and wind loads. The findings indicated that composite structures exhibited superior performance due to reduced self-weight and increased ductility, making them more suitable for high-rise buildings in seismic zones.

2. **A Comparative Study on Seismic Performance of RCC and Composite Structures in Different Seismic Zones by Response Spectrum Method**

RenukaHullikashi and Chidananda G. (2023) analyzed RCC and composite structures across seismic zones II to V using response spectrum analysis as per IS 1893:2016. The study revealed that composite structures demonstrated lower storey displacement, drift ratio, and base shear compared to RCC structures, attributed to their higher stiffness and reduced mass, thereby enhancing seismic performance.

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3. **Comparative Study of RCC, Steel, and Composite Structures by Using ETABS Software**
ShaikhMustaqueem A. (2019) performed a comparative study on G+12 RCC, steel, and composite frames using ETABS. The research highlighted that composite structures offer advantages such as lower self-weight, higher ductility, and better seismic behavior compared to RCC and steel structures. The study concluded that composite frames are more efficient in terms of construction time, material cost, and seismic performance.

4. **Comparative Study on Seismic Behaviour of Composite and RCC Plan Irregular Structures**
Mohammed AkifUddin and M. A. Azeem (2020) investigated the seismic behavior of G+15 plan irregular RCC and composite structures using response spectrum analysis. The study found that while RCC structures exhibited higher stiffness, composite structures had reduced base shear and base moments due to their lower dead weight, suggesting that composite structures are advantageous in seismic regions.

5. **Evaluation of RC, Composite, and RC + Composite Structures under Seismic Loading – A Comparative Study**
Abdul Rahman et al. (2022) evaluated the seismic performance of various structural systems, including RCC, composite, and hybrid structures. The study concluded that composite structures, due to their inherent ductility and reduced mass, performed better under seismic loads, making them a preferable choice for high-rise constructions in earthquake-prone areas.

III. METHODOLOGY

Background Study
Objective: To gather relevant information on the seismic performance of RCC and composite structures.
Step 1.1: Review recent research papers, textbooks, and technical reports that examine the seismic behavior of RCC and composite structures under various loading conditions.
Step 1.2: Analyze seismic codes, such as IS 1893 (India), and their guidelines for seismic design and performance evaluation.
Step 1.3: Study structural dynamics, focusing on seismic behavior, including response spectrum analysis and time-history analysis.

Defining Project Objectives
Objective: To establish specific aims for the project and identify performance indicators.
Step 2.1: Define performance parameters to evaluate the behavior of the structures under seismic loads, including maximum displacement, inter-story drift, base shear, and natural frequency.
Step 2.2: Define the specific seismic response objectives such as stability, displacement behavior, and energy dissipation.

Structural Modeling and Configuration Selection
Objective: To create detailed and comparable models for RCC and composite structures.
Step 3.1: Choose the building type and configuration. For consistency, consider a G+7 (8-story) building with identical geometry and plan dimensions for both RCC and composite models.
Step 3.2: Define the cross-sections, dimensions, and material properties for RCC and composite structures.
RCC Model: Include columns, beams, and slabs designed using reinforced concrete material properties.
Composite Model: Use steel columns and beams with concrete slabs or metal decking as composite sections.
Step 3.3: Establish the boundary conditions, including fixed or pinned supports and uniform material properties across models.

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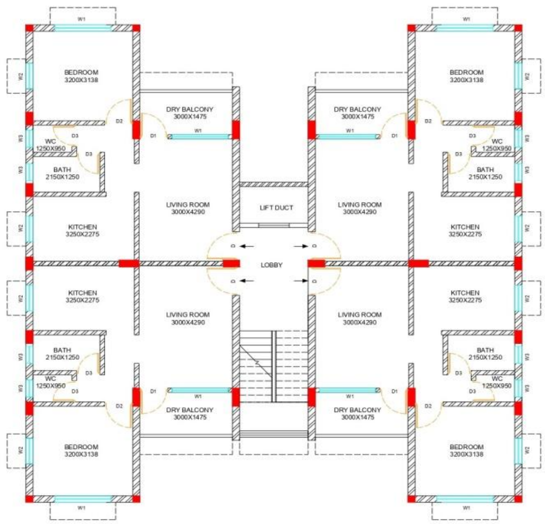

Fig. No.:1. G+7 first floor plan

Load Definitions and Seismic Loading

Objective: Accurately define seismic loads and other relevant loads for realistic analysis.

Step 4.1: Define static loads based on building codes, including dead load (self-weight) and live load.

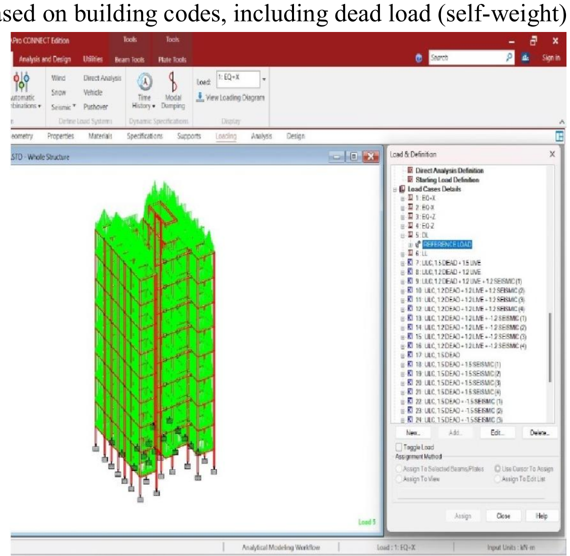

Fig. No.: 2. DL on Structure

Step 4.2: Define seismic load parameters such as seismic zone factor, importance factor, response reduction factor, and soil type as per IS 1893 (India).

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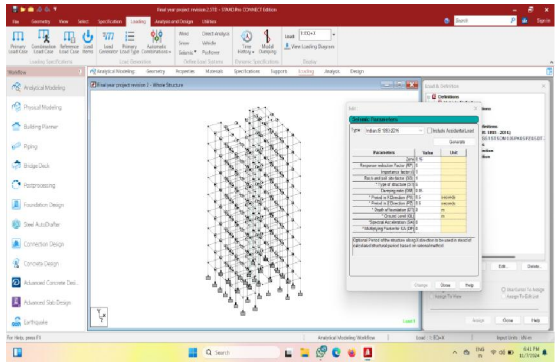

Fig. No.: 3. Seismic load on Structure

Step 4.3: Specify load combinations, including dead load + seismic load, live load + seismic load, and other relevant combinations.

Step 4.4: Configure response spectrum analysis parameters in STAAD PRO for seismic load application.

STAAD PRO Model Development

Objective: To build, define, and simulate structural models for both RCC and composite configurations using STAAD PRO software.

Step 5.1: Set up two models in STAAD PRO: one for RCC and one for composite structures.

Step 5.2: Define material properties for both models:

RCC Model: Concrete properties based on IS 456 (Indian standard for reinforced concrete).

Composite Model: Combination of steel and concrete material properties.

Step 5.3: Assign sectional properties for beams, columns, slabs, and any composite decking.

Step 5.4: Apply load definitions, boundary conditions, and supports.

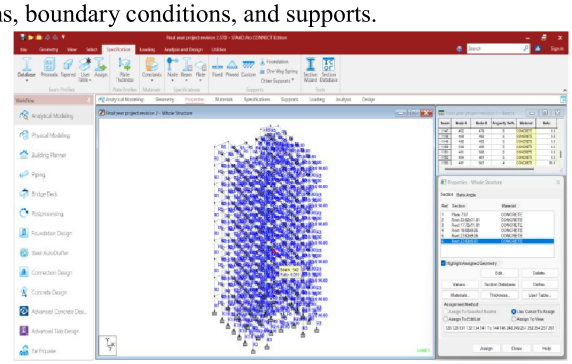

Fig. No.: 4. material properties

Analysis Setup

Objective: To configure STAAD PRO for performing static and dynamic analysis under seismic conditions.

Step 6.1: Perform static analysis on both models to assess the behavior under gravity loads alone (dead load + live load).

Step 6.2: Configure dynamic analysis settings to simulate seismic conditions.

Response Spectrum Analysis: Apply the response spectrum method to simulate the structure's behavior under seismic loading based on spectral data.

Time-History Analysis (Optional): If required, configure a time-history analysis to capture more detailed seismic behavior and dynamic response.

Step 6.3: Ensure models are fully meshed, particularly at junctions where different materials interact, such as steel beams and concrete slabs.

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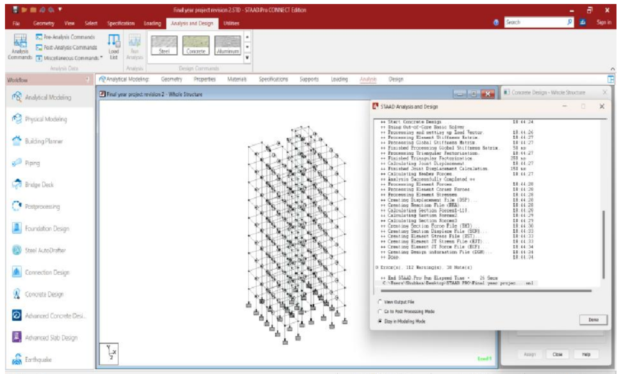


Fig. No.:5. Analysis of Model

Simulation and Analysis in STAAD PRO

Objective: To simulate the seismic behavior of both RCC and composite models.

Step 7.1: Run the response spectrum analysis for both models, ensuring that all load combinations are considered.

Step 7.2: Record key results such as:

Displacement and Drift: Maximum displacement and drift at the top floor.

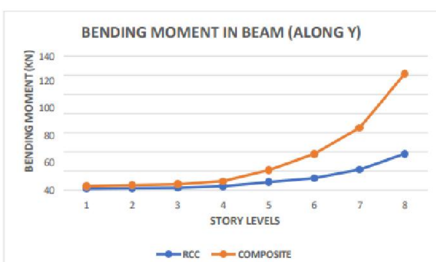
Base Shear and Overturning Moment: Calculate base shear and overturning moments for both models.

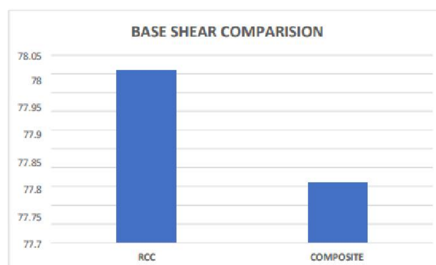
Stress and Strain Distribution: Analyze the stress and strain distribution across key structural elements.

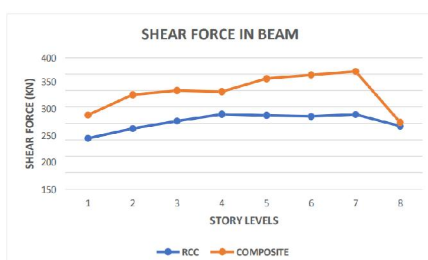
Modal Analysis: Record modal frequencies and mode shapes to understand dynamic behavior.

Step 7.3: Compare the results of the RCC and composite structures with design code requirements (e.g., permissible drift limits).

IV. RESULT AND DISCUSSION







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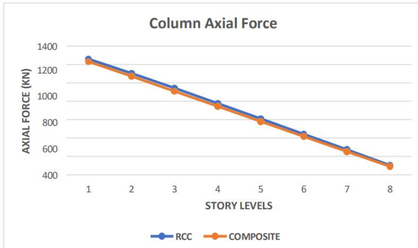

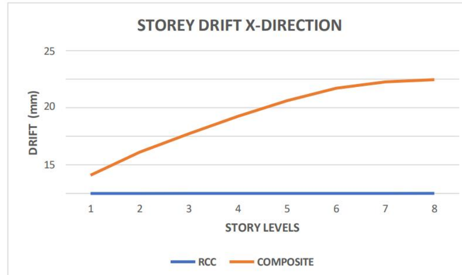

This section presents and interprets the findings from the seismic analysis of both RCC and composite (steel-concrete) structures modeled and analyzed using STAAD PRO. The comparison is based on several performance indicators, including maximum displacement, inter-story drift, base shear, and natural frequencies. The goal is to assess how each structural system responds to seismic loading and to identify which performs more efficiently in terms of strength, stiffness, and overall behavior under earthquake conditions.

1. Maximum Displacement

The RCC structure experienced a higher maximum lateral displacement at the top story compared to the composite structure.

Composite structures, due to their higher stiffness from steel elements, showed a reduced lateral sway.

Observation: The maximum top story displacement for RCC was approximately **20–25% higher** than that of the composite structure under the same seismic load combinations.

Implication: Reduced displacement in composite structures indicates better resistance to lateral movements during an earthquake.

2. Inter-Story Drift

The inter-story drift was calculated for each level.

Composite structures exhibited lower drift ratios, maintaining values well within the acceptable limits defined by IS 1893.

RCC structures showed increased drift, especially in mid-height stories.

Observation: Composite structures provided better control of lateral deformation, leading to enhanced comfort and safety during seismic events.

3. Base Shear

Base shear is the total lateral force at the base of the structure due to seismic action.

RCC buildings recorded slightly higher base shear than composite buildings.

This is attributed to the greater mass of RCC structures, leading to higher inertial forces.

Observation: Composite structures benefit from reduced seismic mass due to lighter steel sections, thus attracting less seismic force.

4. Mode Shapes and Natural Frequencies

The first three natural modes were studied for both models.

Composite structures had higher natural frequencies, indicating stiffer behavior.

RCC structures exhibited lower frequencies, which may lead to resonance with seismic frequencies in certain conditions.

Observation: Higher natural frequencies in composite systems help them avoid synchronization with predominant earthquake frequencies, improving their performance under seismic excitation.

5. Stress and Strain Distribution

Stress concentration was well-distributed in composite members due to steel's ductility and strength.

RCC elements showed higher local stress concentrations, especially at beam-column joints.

Composite structures demonstrated more uniform stress flow, contributing to improved energy dissipation.

Implication: Enhanced ductility and better energy absorption in composite structures reduce the likelihood of brittle failure.

6. Load Combination Behavior

Under different load combinations (e.g., DL+LL+EQ, DL+EQ), composite structures consistently performed better in terms of lateral stiffness and strength.

The moment-carrying capacity of composite beams allowed for efficient transfer of loads with reduced deformation.

7. Overall Structural Performance Comparison

Parameter	RCC Structure	Composite Structure
Max Displacement	Higher	Lower (~20–25% less)
Inter-Story Drift	Moderate to High	Low
Base Shear	Higher	Lower
Natural Frequency	Lower	Higher
Stress Distribution	Localized	More Uniform
Seismic Performance	Acceptable	Superior

The comparative study reveals that composite structures have superior seismic performance in several key areas. Their reduced weight leads to lower base shear forces, while their increased stiffness results in smaller displacements and drifts. These factors make composite structures more desirable in high-seismic zones. On the other hand, RCC structures, though robust and widely used, tend to suffer from larger deformations and heavier mass, which can amplify seismic effects.

The results confirm the growing preference for composite structures in modern construction, especially in seismic-prone areas. However, the design and detailing of connections in composite structures require careful attention to ensure proper interaction between steel and concrete components.

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V. CONCLUSION

This study comprehensively analyzed and compared the seismic performance of RCC and composite structures using STAAD PRO, focusing on key parameters such as displacement, inter-story drift, base shear, and natural frequencies. The results revealed that composite structures, due to their higher stiffness and lower seismic mass, exhibited superior behavior under earthquake loads with reduced lateral displacements and better energy dissipation. In contrast, RCC structures showed higher base shear and deformation due to their heavier weight and lower natural frequencies. Therefore, composite construction offers a more efficient and resilient solution for buildings in seismic-prone regions, making it a preferable alternative to conventional RCC systems for modern infrastructure.

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