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Hybrid Structure: Combining Steel and Concrete for Optimal Performance

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Abstract
This Study Explores the Potential of Hybrid Structures Combining Steel and Concrete to Enhance Structural Performance, Sustainability, And Efficiency in Modern Construction. Steel Offers Excellent Tensile Strength and Flexibility, While Concrete Provides Superior Compressive Strength and Durability. By Synergizing These Materials, Hybrid Systems Can Optimize Load-Bearing Capacity, Reduce Construction Time, And Improve Resistance to Environmental Stresses. The Research Aims to Develop Innovative Design Techniques, Streamline Construction Processes, And Promote Eco-Friendly Practices. Expected Outcomes Include Improved Structural Integrity, Cost-Effectiveness, And Broader Applications in Infrastructure, Contributing to Sustainable and Resilient Built Environments.

Keywords: Hybrid Structures, Structural Performance, Steel, Concrete, Eco-Friendly Practices, Structural Integrity, Durability

I. INTRODUCTION

A hybrid structure combines steel and concrete to leverage the strengths of both materials. Steel provides high tensile strength and flexibility, while concrete offers excellent compressive strength and durability. Together, they enhance load-bearing capacity, reduce structural weight, and improve resistance to vibrations and environmental factors. This synergy is commonly used in bridges, high-rise buildings, and industrial structures for better performance and cost efficiency.

Steel and concrete are two of the most used materials in the construction industry. Individually, each material has its own set of advantages and limitations. Steel is Known for its high tensile strength, ductility, and speed of erection, while concrete is appreciated for its excellent compressive strength, durability, and fire resistance. However, when used together in a strategically engineered system, they complement each other's weaknesses and enhance overall performance.

Concrete structure has good integrity and elasticity, and steel structure is a structure with steel as the main raw material, these two technologies are widely used in construction projects and directly affect the overall quality and efficiency of the building. The strong support and bearing capacity of concrete and steel structures can provide more reliable safety for construction projects. At present, concrete projects mainly utilize their compressive load-bearing properties, so it is necessary to ensure its tensile stress range to prevent cracks. Steel structure mainly utilizes the elasticity and tensile properties of steel materials, so it is necessary to ensure the performance, integrity, and corrosion resistance of the steel structure connection location to prevent damage to the steel structure and stress concentration causing damage. Therefore, it is necessary to improve the concrete and steel structure construction technology can effectively improve the construction quality. How to use concrete and steel structures more effectively, give full play to the advantages of both, and overcome their respective deficiencies at the same time has become an urgent problem to be solved in the current field of construction engineering, which not only requires engineers and technicians to have an in-depth understanding and mastery of the construction technology of concrete and steel structures but also requires them to be able to apply flexibly in practice to ensure the safety and durability of the project while ensuring the construction quality.

II. LITERATURE SURVEY

[1] The research paper titled "Comparative study of Reinforced Concrete frame structure & SteelConcrete composite structure ssubjected to static and dynamic loading" authored by Parag P. Limbare, Prof. P.A. Dode focuses structure combines the advantages of steel structure and reinforced concrete Structure, with high bearing capacity, good ductility, and strong wind and earthquake resistance. In The past 10 years, the steel-concrete hybrid structure has been widely used in my country, which has Good economic benefits and broad development space.

[2] The research paper titled "Design and analysis of steel-concrete composite structure" authored by Radomir Folic, Mirjana Malesev, Vlastimir Radonjani focuses crack resistance of the hybrid steel fiber-reinforced beams significantly improved. When the large cracks are formed, more energy is dissipated because of the presence of hooked-end fibers, which have excellent pull-out resistance. The addition of hooked-end and micro-steel fibers in a hybrid form reduces the crack spacing in the range of 16–45%, respectively, to concrete strength and volume fraction of fibers. Similarly, the width of the crack was also reduced by 25–75%.

[3] The research paper titled "Comparative Analysis of RCC and Steel-Concrete-Composite (B+G+ 11 Storey) Building" authored by Mr. Nitish A. Mohite Mr. P.K. Joshi Dr. W. N. Deulkar focusesThe addition of hooked-end and micro-steel fibers in the hybrid form into the RCC increases the ductility ratio in the range of 50–85.4%, respectively, to the concrete strength and volume of the fiber.

[4] The research paper titled "Comparative study of Reinforced Concrete frame structure & Steel-Concrete composite structure subjected to static and dynamic loading" authored by Renavikar Aniket V. Suryawanshi Yogesh focuses on the use of hybrid concrete construction means that a percentage of the frame is manufactured by a skilled workforce in a weatherproof factory, resulting in faster construction and better quality.

[5] The research paper titled "Advanced design of composite steel-concrete Structural element" authored by Dr. D. R. Panchal focuses on A high proportion of the work for a hybrid concrete construction project is carried out in the precast factory. On site, the use of hybrid concrete construction helps ensure that each safety plan is drafted on the individual project's merits.

[6] The research paper titled "Comparative study of R.C.C, steel and composite (G+30 storey) building" authored by D. R. Panchal And P.M. Marathe focuses on the use of concrete has additional benefits in assessing whole-life costs, a factor important to owner-occupiers and PFI operators. For example, the thermal mass of concrete can moderate energy demands in cooling and heating buildings.

III. METHODOLOGY AND DISCUSSION

Scope of the Project:

- Material Selection and Integration
- Structural Design and Analysis
- Performance Evaluation

Objective of the Project:

- To analyze the Hybrid structure

- To compare the Hybrid structure with respect to Steel and RCC Structure

Problem Statement:
Develop a design framework for a hybrid structure that strategically combines steel and concrete to enhance structural performance.

IV. VALIDATION

Question: Analysis of framed structure of beam size 230mm x500mm column size 300mm x 300mm floor height 4m take grade of concrete 25 and fe415

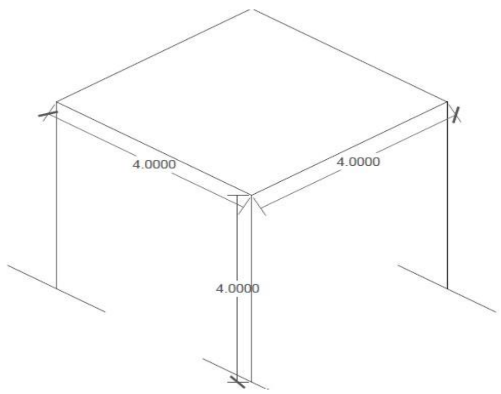


Fig.No.01

Solution:
Beam size = 230 × 500 mm
Column size = 300 × 300 mm
Grade of concrete = M25
Grade of steel = Fe415

Step1: Calculate UDL from slab
Assuming slab thickness = 150 mm = 0.15m
Unit weight of RCC = 25 kN/m^3
Load from slab = 0.15 × 25 = 3.75 kN/m^2
Beam spacing = 3m
∴ UDL on beam = 3.75 × 3 = 11.25 kN/m

Step2: Analyze continuous Beam

$$\frac{wl^2}{8} = \frac{11.25 \times 3.5^2}{8}$$

MB = Mcenter = $\frac{wl^2}{12}$ = 17.23 kN/m

∴ Span AB = $\frac{11.25 \times 4^2}{12}$ = 15 kN/m

∴ Span BC = $\frac{11.25 \times 2^2}{12}$ = 8.437 kN/m

Total = 15 + 8.437

= 23.437 kN/m

∴ Maximum bending moment = $\frac{wl^2}{8} - \frac{wl^2}{12}$

= 17.23 – 23.437 = -6.307 N/m

Step 3: Shear force at support

Shear at A & C

$V = \frac{WL}{2}$

At A = $\frac{11.25 \times 4}{2}$ = 22.5 kN/m

At C = $\frac{11.25 \text{ x } 3}{2}$ = 16.875 kN/m

∴ Total = 22.5 + 16.875

= 39.37 kN/m

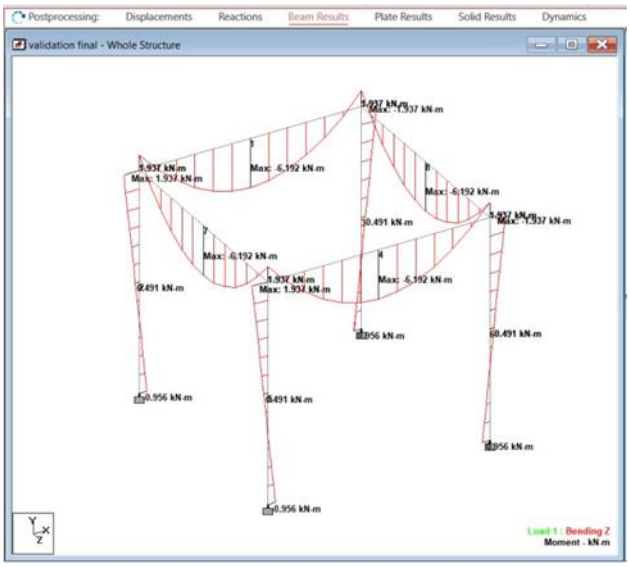


Fig.No.02

Maximum Shear Force and Bending Moment in STAAD Pro:

V. Analysis of Structure

Planning Approach:

The project was carried out in multiple stages to ensure a comprehensive analysis:

- Literature review and understanding of hybrid structures.
- Selection of a standard building layout.
- Structural modelling using STAAD Pro.
- Analysis and comparison based on design displacement, material usage, and cost.

Model Design Strategy:

Three separate structural models were developed:

Model 1: Steel Structure – Entire framework designed using steel members.

Model 2: RCC Structure – Conventional RCC design for all beams, columns, and slabs

Model 3: Hybrid Structure – A combination of steel columns and RCC beams/slabs.

The Bending moment (BM) obtained using the classical manual method is -6.307 kN/m, while the value obtained from "STAAD Pro" software is -6.192 kN/m.
The close agreement between these results validates the accuracy and reliability of the software.

Planning Tools and Software:

- STAAD Pro was chosen as the primary software due to its robust capabilities in structural analysis and design.
- AutoCAD was used for drafting initial layouts.

AUTOCAD TYPICAL FLOOR PLAN:

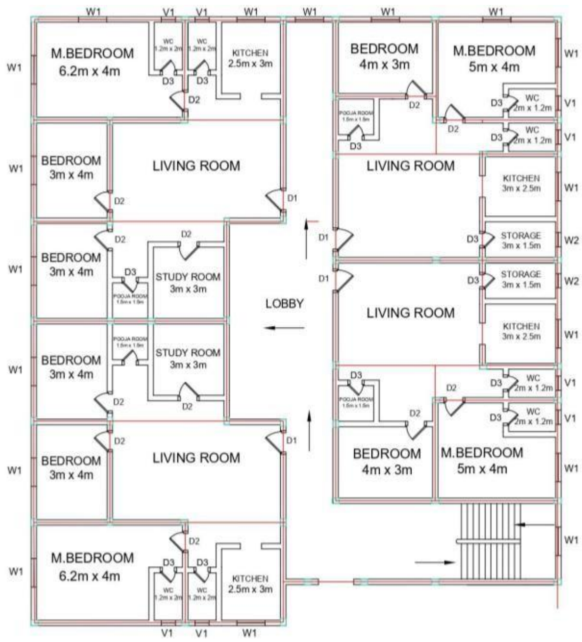


Fig. No.03 AutoCAD Plan

STAAD Pro G+30 Design (With Supports and 3D Rendering View):

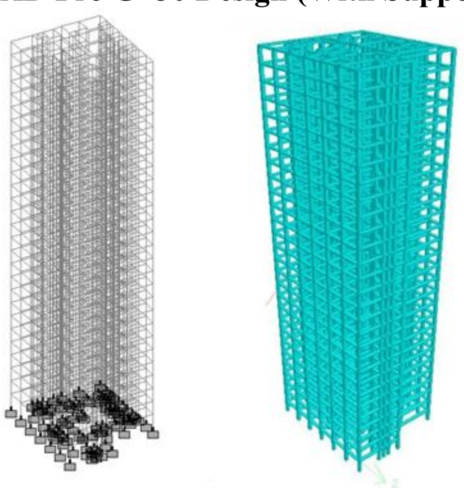


Fig.No.04 Staad Pro

VI. SPECIFICATIONS AND DETAILS OF THE STRUCTURE

Materials Used

Concrete:
M30 grade concrete has been adopted for all structural elements, ensuring adequate strength and durability suitable for moderate to severe exposure conditions.

Steel Reinforcement:
High yield strength deformed bars of Fe415 grade have been used for all RCC elements as per IS 1786.

Is Codes Used:

1. IS 456:2000 – Plain and Reinforced Concrete – Code of Practice
Used for RCC design (slabs, beams, columns, footings) in STAAD.

2. IS 800:2007 – General Construction in Steel – Code of Practice
Used for steel structure design (trusses, steel frames, purlins).

3. IS 875 (Part 1 to 5):1987/2015 – Code of Practice for Design Loads
Part 1: Dead Loads
Part 2: Imposed (Live) Loads

VII. RESULTS AND DISCUSSION

This study evaluates the performance of a hybrid (composite) structure, which integrates the beneficial properties of both steel and concrete, and compares it against conventional RCC and steel structures.

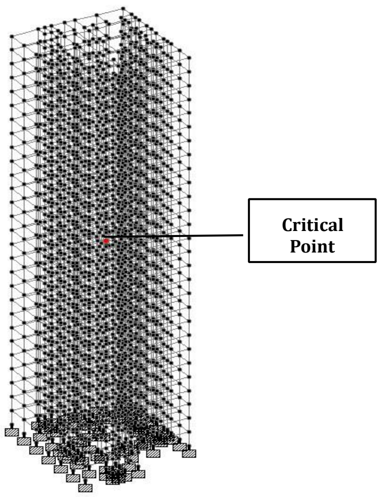
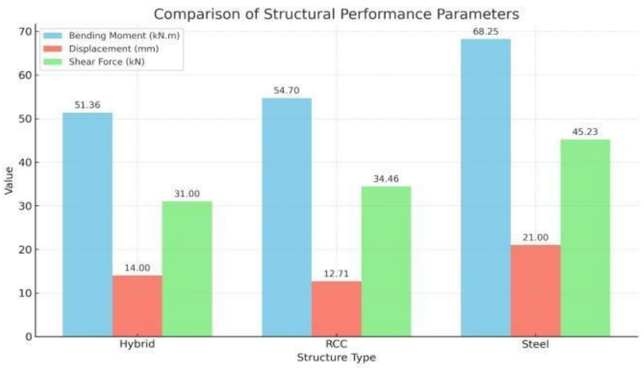


Fig.No.05 Critical Point

Performance Parameters Comparison:

[1] The hybrid structure recorded a **Bending Moment** of 51.36 kN.m, which is slightly less than that of RCC (54.695 kN.m) and significantly lower than the steel structure (68.25 kN.m).
This reflects its capability to resist internal moments effectively while optimizing material usage.
[2] In terms of **Displacement**, the hybrid system exhibited a value of 14 mm, falling between RCC (12.71 mm) and steel (21 mm), indicating a favourable balance between stiffness and ductility.
[3] The **Shear force** in the hybrid structure was measured at 31 kN, which is lower than RCC (34.458 kN) and steel (45.23 kN).
This lower shear value highlights its enhanced resistance to lateral and torsional effects.

Overall, the composite system offers a desirable balance of strength, durability, and design flexibility, making it a promising choice for modern structural applications.



The above bar graph shows comparing Bending Moment, Displacement, and Shear Force across Hybrid, RCC, and Steel structure

Discussion:

[1] The analysis of structural parameters—bending moment, displacement, and shear force—along with a comparative evaluation of key performance factors clearly demonstrates the efficiency and viability of hybrid (composite) structures. By combining the strength of steel with the compressive capability of concrete, the hybrid structure achieves a balanced performance profile.
[2] It offers moderate displacement, indicating controlled deflection, and shows lower shear force compared to RCC and steel structures, reflecting better resistance to lateral loads. Although the bending moment is slightly lower than RCC, it is within a safe and acceptable range, ensuring structural stability. Additionally, the composite system benefits from faster construction, moderate weight, high durability, and design flexibility, making it a versatile and practical choice for high-rise buildings and complex architectural forms.
[3] In discussion, the hybrid structure optimally utilizes materials to achieve structural efficiency, safety, and sustainability, and performance-enhancing alternative to traditional RCC and steel structures in modern construction.
In discussion, the hybrid structure optimally utilizes materials to achieve structural efficiency, safety, and sustainability, and performance-enhancing alternative to traditional RCC and steel structures in modern construction. Prediction accuracies increase through the evaluation of critical variables that include student grades in addition to their attendance records and socioeconomic backgrounds. Using logistic regression with neural networks in combination produces the implemented technology establishes early warning systems to stop students from dropping out. The selection of algorithm relies on attributes from

the dataset while specific models work best according to different characteristics. These models show exceptional performance with smaller datasets and these models demonstrate very good results in complex data environments.

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