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Experimental Study On Composite Encased Steel Beam With Different Guage And Sections

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Abstract
A composite encased steel beam is a structural element where a steel section is embedded within concrete. This integration enhances the strength, stiffness, and durability of the beam, making it an efficient choice for modern construction projects. The concrete provides compressive strength, while the steel contributes tensile strength, ensuring optimal structural performance.
The primary objective of this study is to evaluate the mechanical behavior of composite encased steel beams with different gauges and sections under various loading conditions. The experimental investigation involves material selection, mix design, beam casting, and testing of the specimens for load-bearing capacity, deflection, and failure modes. A comparative analysis is conducted between composite encased steel beams and conventional reinforced concrete beams to assess their performance advantages.
Through extensive research and experimental trials, significant improvements in strength, ductility, and deformation resistance have been observed in composite encased steel beams. The results demonstrate that increasing the steel gauge enhances the beam's ability to resist bending and shear forces. Additionally, the composite action between steel and concrete contributes to better load distribution and crack resistance, making it a viable alternative to traditional construction methods.
This study provides insights into optimizing the design of composite encased steel beams for future applications in high-rise buildings, bridges, and infrastructure projects. The findings serve as a foundation for further research on dynamic loading conditions, durability, and cost-effectiveness.
Keywords *composite encased, steel gauge, durability.*

INTRODUCTION

The construction industry continuously evolves to develop materials that improve structural performance, cost efficiency, and sustainability. Composite encased steel beams represent a breakthrough in structural engineering by combining the tensile strength of steel with the compressive strength of concrete. This fusion enhances the durability, stiffness, and load-bearing capacity of structural elements, making them an ideal choice for modern buildings, bridges, and other infrastructure projects.

Traditional reinforced concrete beams often exhibit limitations in terms of cracking, corrosion susceptibility, and long-term durability. The incorporation of steel encased within concrete mitigates these issues, offering improved resistance to bending, shear, and environmental impacts. Additionally, composite beams ensure better fire resistance and enhanced energy absorption, making them more reliable in seismic-prone areas.

The primary objectives of this research is to analyze the structural behavior of composite encased steel beams under axial and flexural loads and to compare the impact of different steel gauges and sections on overall beam performance. The deflection, crack propagation, and failure patterns through experimental testing will be assessed for recommending improvements for designing cost-effective, high-performance composite beams. The load-bearing capacity of composite beams under varying conditions will be assessed and the comparison of the performance of beams reinforced with 12 mm main bars and 8 mm stirrup will be made based on the results obtained.

This study aims to evaluate the performance of composite encased steel beams with different gauges and sections under various loading conditions. The research involves experimental testing to analyze parameters such as Load-bearing capacity, Deflection characteristics, Flexural and shear strength, Failure mechanisms The study will also provide insights into optimizing the design of composite encased steel beams, ensuring their effective implementation in structural engineering applications.

MATERIALS AND TESTING METHODS

The materials used in this study include both conventional concrete ingredients and alternative waste-derived materials. The materials chosen for this application were meticulously evaluated for their physical and chemical characteristics to guarantee optimal performance and compatibility in concrete.

Cement

In the present study, Ordinary Portland cement (OPC) of 43 grade conforming to IS:12269–2003 was used. Cement is a crucial binding material in concrete, responsible for strength and durability. The physical properties of cement are represented in below table.

Table 1 Cement Properties

Specific Gravity	3.13
Fineness	5% residue retained on a 90-micron sieve
Initial Setting Time	30 minutes
Final Setting Time	600 minutes
Compressive Strength (28 Days)	43 MPa

Fine Aggregate

The M sand as per the requirements of IS:383-1970 was used as fine aggregate in the present study. The following results were obtained upon testing of fine aggregates.

Table 2 Fine Aggregates Properties

Specific Gravity	2.52
Fineness Modulus	2.65
Water Absorption	1.2%
Bulk Density	1650 kg/m^3

Coarse Aggregate

Coarse aggregates from a local quarry crusher were used for the study. The following are the physical properties obtained after testing.

Table 3 Coarse Aggregate Properties

Specific Gravity	2.55
Water Absorption:	0.4 %
Bulk Density	1550 kg/m*
Impact Value	21%
Crushing Value	22%

Steel Sections

Steel sections play a crucial role in the structural performance of composite beams. These sections provide strength, stability, and load distribution in the composite system. The following types of steel sections were used:

Table 4 Steel Properties

Type	Shapes Used	Physical Properties
Cold-formed Steel (CFS)	I-section	Yield Strength: 250-350 MPa
	Hollow Rectangular Sections	Ultimate Tensile Strength: 410-500 MPa
	Thicknesses: 2.5 mm and 3 mm	Elongation: 12-16%

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Reinforcement

Steel reinforcement is essential in composite beams as it enhances their tensile strength and prevents cracking under applied loads. The reinforcement used in this study includes:

12 mm dia main bars with yield strength of 500 MPA, Ultimate strength of 550 MPa for the purpose of providing tensile strength and for resting the bending was used. Stirrups of 8 mm dia with yield strength of 415MPa for providing shear resistance was used. The study follows an experimental design approach, which includes Selection and characterization of raw materials, Mix proportioning and preparation of different concrete specimens, Casting and curing of test specimens and Comparative analysis of modified concrete properties against conventional concrete.

Mix Proportioning

Concrete mix design was carried out based on IS 10262:2019 for M30 grade concrete. The control mix followed a standard water-cement ratio of 0.45 with the following proportions:

Design Stipulations

- **Grade of Concrete:** M30
- **Type of Cement:** OPC 43 Grade
- **Maximum Nominal Aggregate Size:** 20 mm
- **Workability:** Slump of 75-100 mm
- **Exposure Condition:** Moderate
- **Method of Mixing:** Machine Mixing

Casting and Compaction

Beam Specimens

1. Material Preparation

o The materials were measured and mixed using the same method as for cubes and cylinders.

2. Casting

- Concrete was poured into 150mm × 200mm × 1000mm beam molds.
- The molds were vibrated to remove trapped air and compact the concrete.

3. Curing

- The beams were de-molded after 24 hours and immersed in a curing tank for 28 days.

Fig.1 Beam Specimens

Testing Procedures

Strength Tests

- **Flexural Strength (IS 516:1959):**

Beams tested under two-point loading.

Fig.2 Flexural Strength Test

Ductility factor

Experimental investigation is carried out on prepared specimens which are having dimensions of about 150mm × 200mm × 1000mm. All the specimens are casted and cured for 28days
Specimens are tested under universal testing machine by keeping dial gauge at the bottom,
loadings are applied on the specimens and corresponding deflection reading are noted. **Ductility factor (μ) = ΔU/ ΔY**
Were,
ΔU= ultimate deflection
ΔY=yield deflection

RESULTS AND DISCUSSIONS

The primary objective of current study was to analyze the load-bearing capacity, deflection, and structural behavior of composite encased steel beams with different gauge thicknesses and sections. The study compared the performance of these beams against traditional RCC beams to determine their efficiency and suitability for construction applications.
A total of five different beam types were cast and tested after a 28-day curing period. The beams were subjected to compressive strength tests and deflection analysis to assess their structural performance. The findings from these tests are discussed below.

Load-Bearing Capacity Analysis

The load-bearing capacity of the beams was evaluated under static loading conditions to determine the maximum force each beam could withstand before failure. The results are summarized as follows:

Table 5 Beam load bearing capacity Results

Beam Type	Thickness (mm)	Load Capacity (kN)
RCC Beam	12Ø main bar & 8Ø stirrups	144.5
I-Section Beam	2.5	112.4
I-Section Beam	3	421.28
Hollow Rectangular Beam	2.5	82.5
Hollow Rectangular Beam	3	130

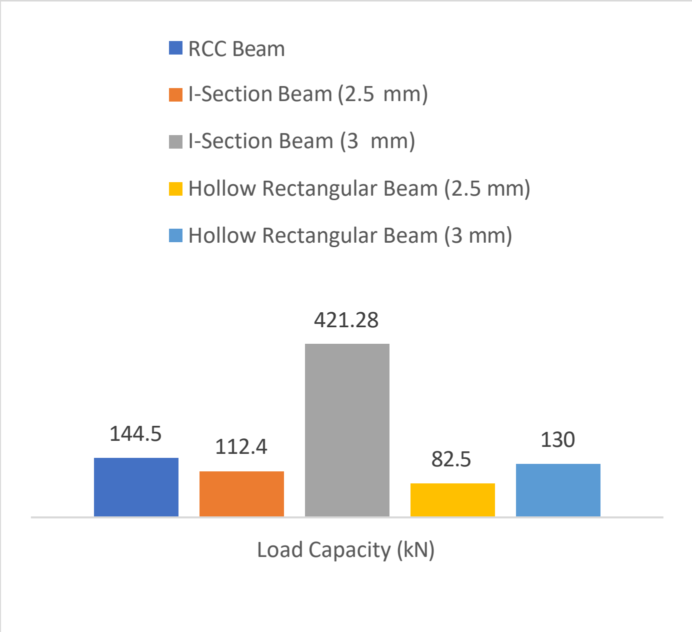

Fig 3 Load-Bearing Capacity

Deflection Performance

Deflection refers to how much a beam bends or deforms under loading. Lower deflection indicates higher stiffness and structural stability. The results are as follows:

Table 6 Beam deflection results

Beam Type	Thickness (mm)	Deflection (mm)
RCC Beam	12Ø main bar & 8Ø stirrups	1.7
I-Section Beam	2.5	1.2
I-Section Beam	3	3.7
Hollow Rectangular Beam	2.5	5.6
Hollow Rectangular Beam	3	1.7

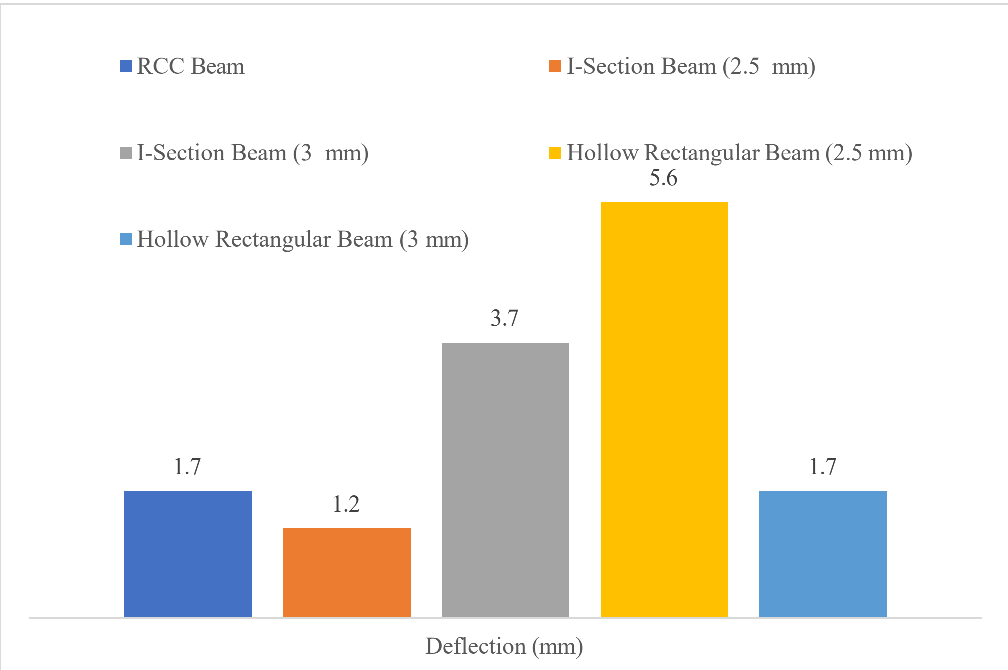

Fig 4 Deflection

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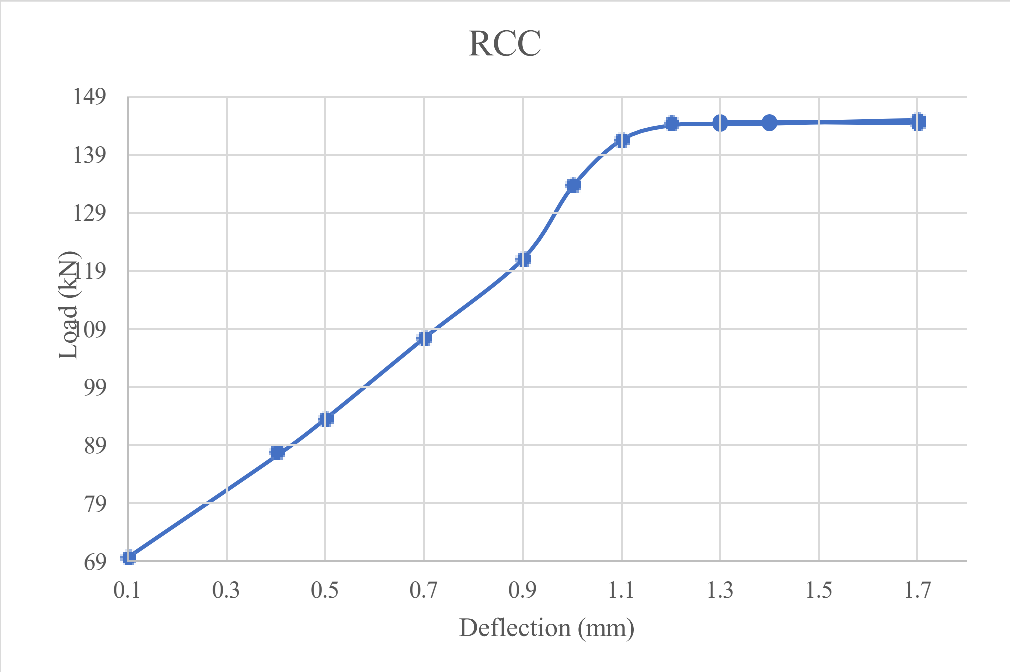

Fig 5 Load v/s deflection for RCC beam

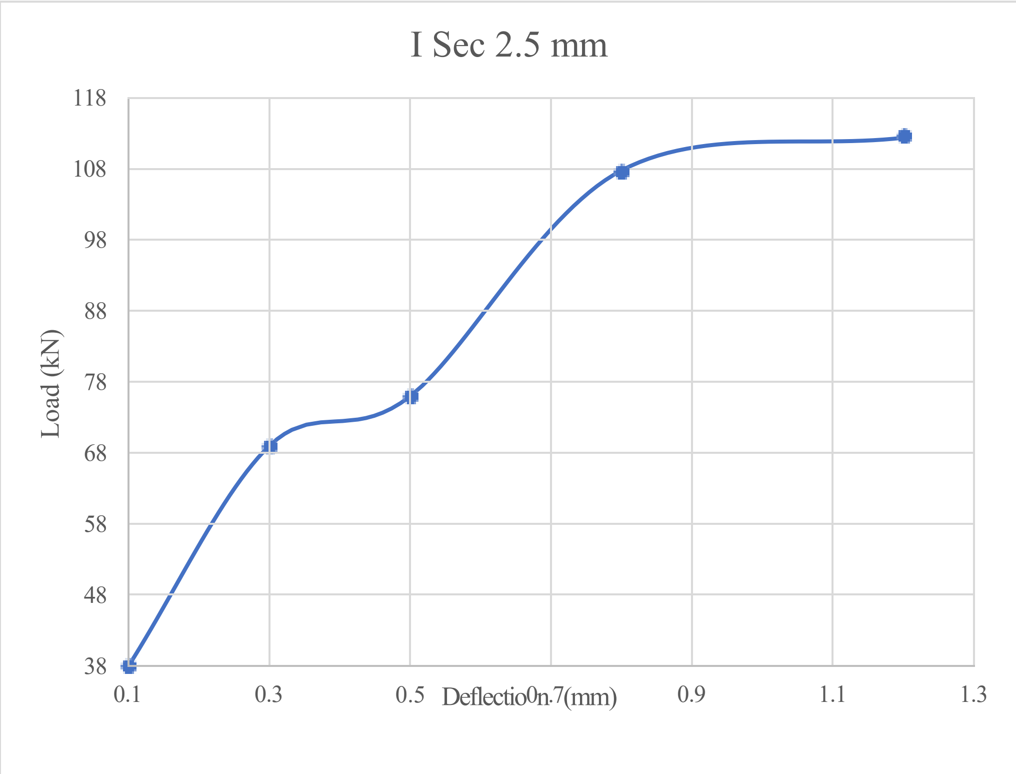

Fig 6 Load v/s deflection for I Sec (2.5 mm) beam

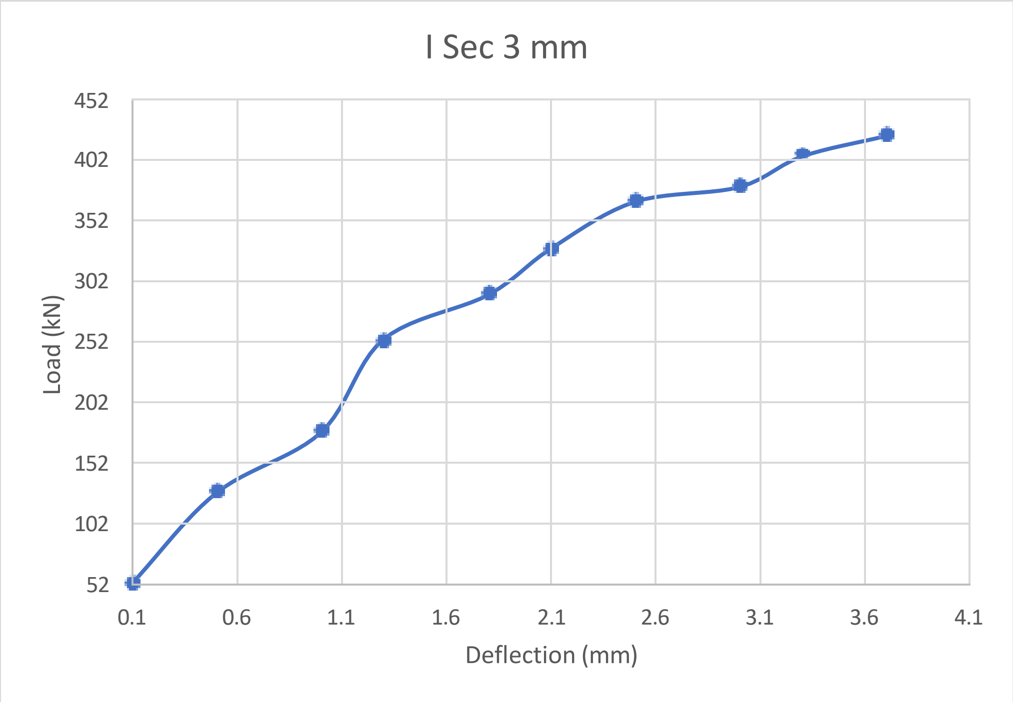

Fig 7 Load v/s deflection for I Sec (3 mm) beam

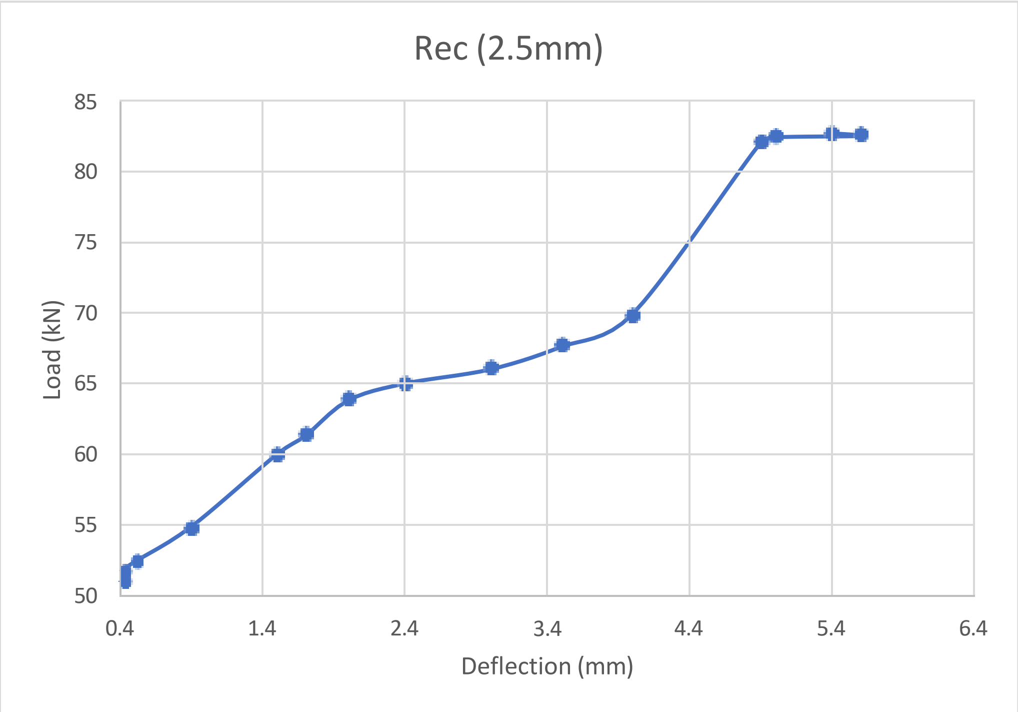

Fig 8 Load v/s deflection for Rec (2.5 mm) beam

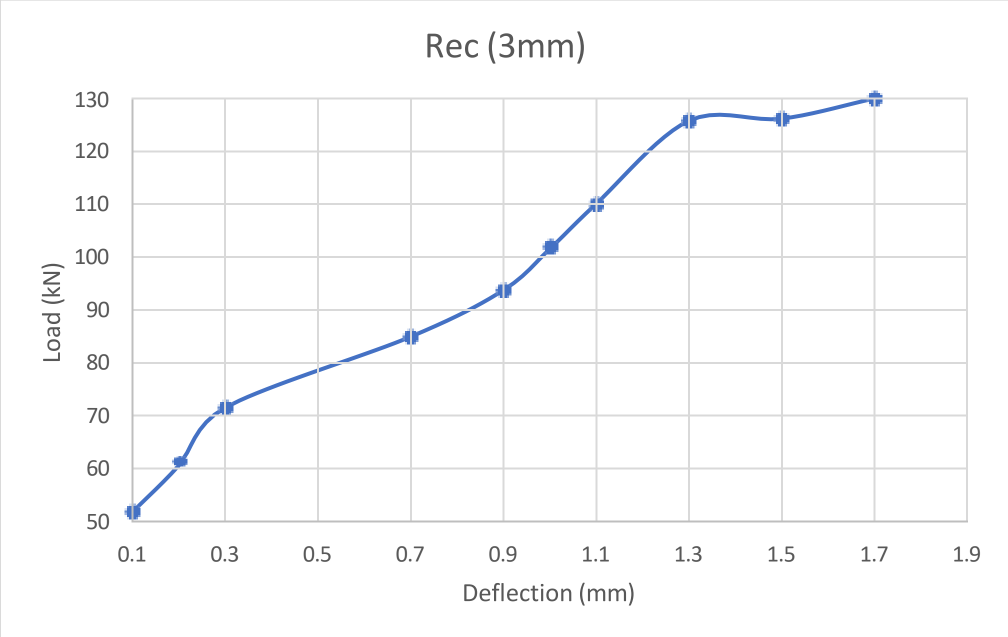

Fig 9 Load v/s deflection for I Sec (2.5 mm) beam

Linear regression analysis

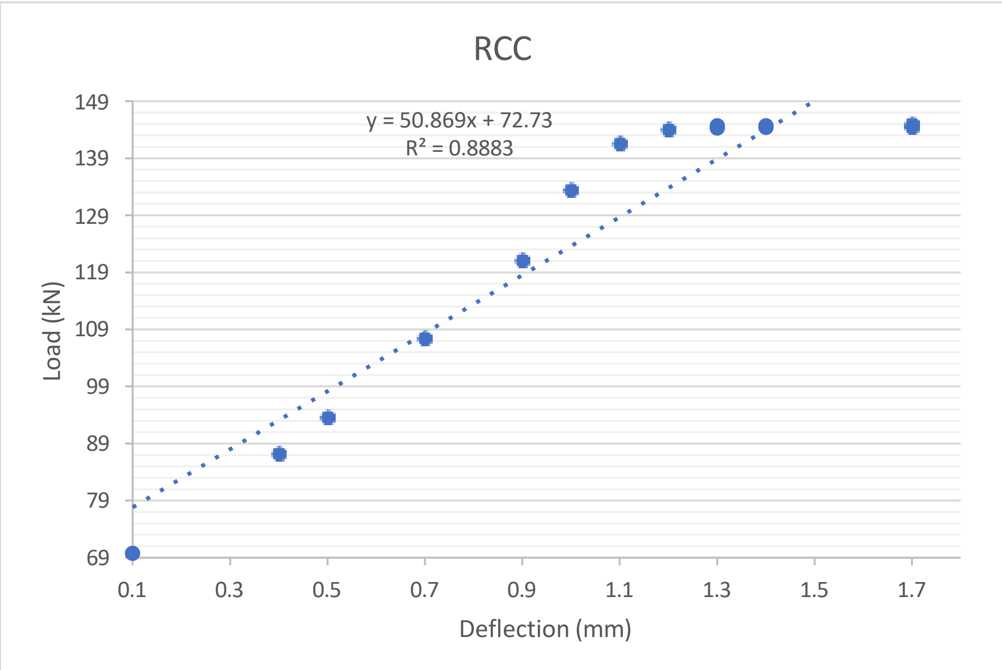

Fig 10 Regression analysis for RCC beam

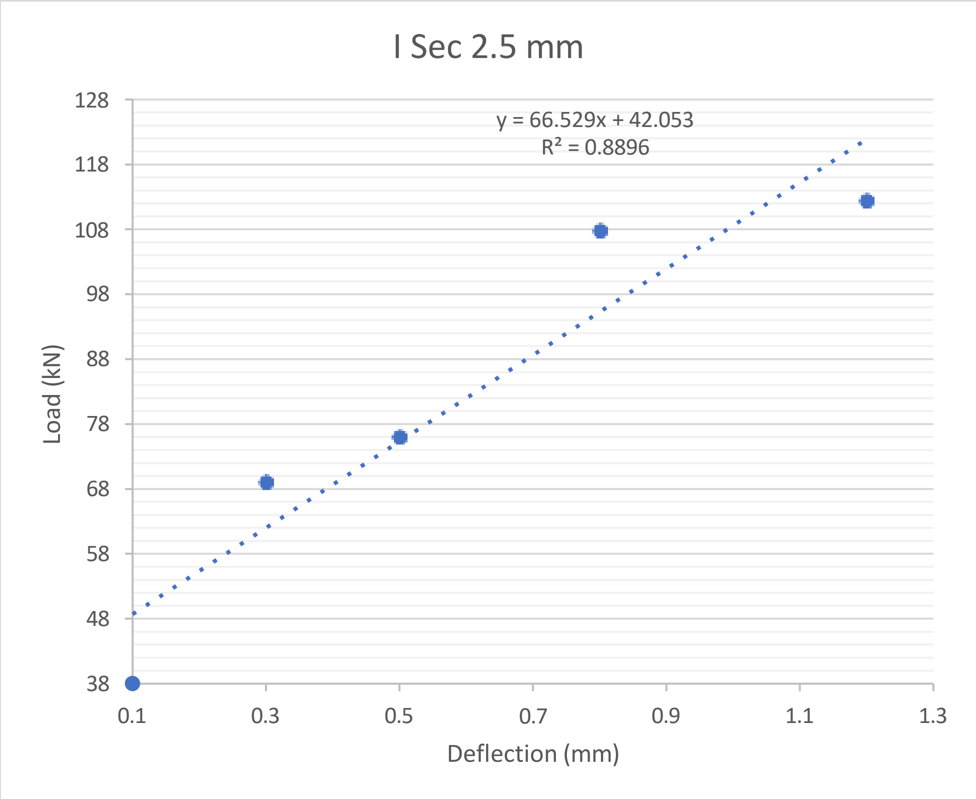

Fig 11 Regression analysis for I sec(2.5mm) beam

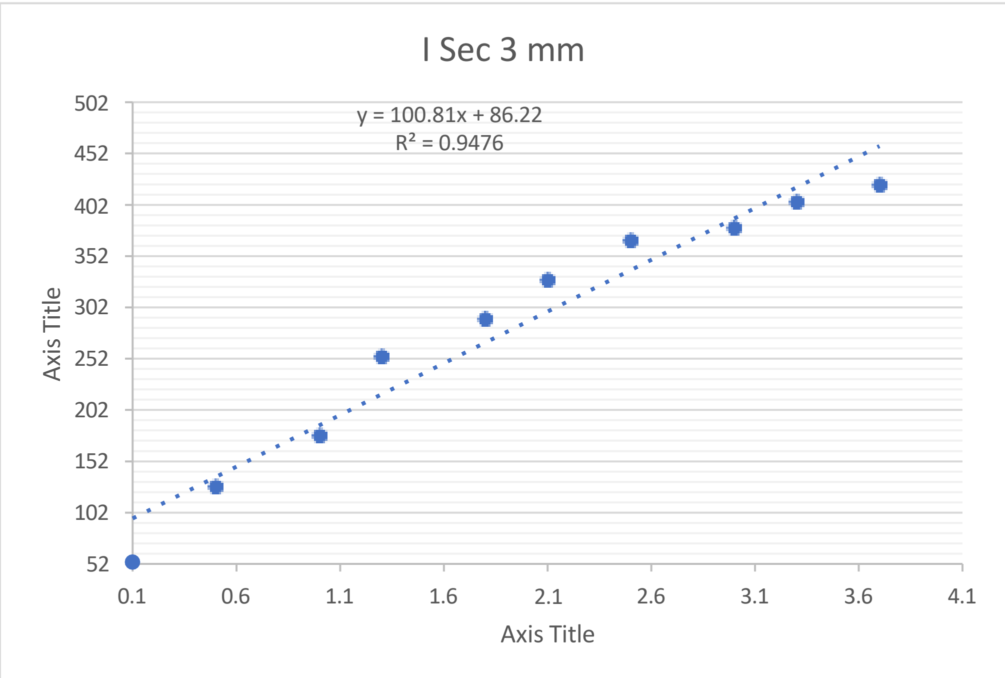

Fig 12 Regression analysis for I sec (3 mm) beam

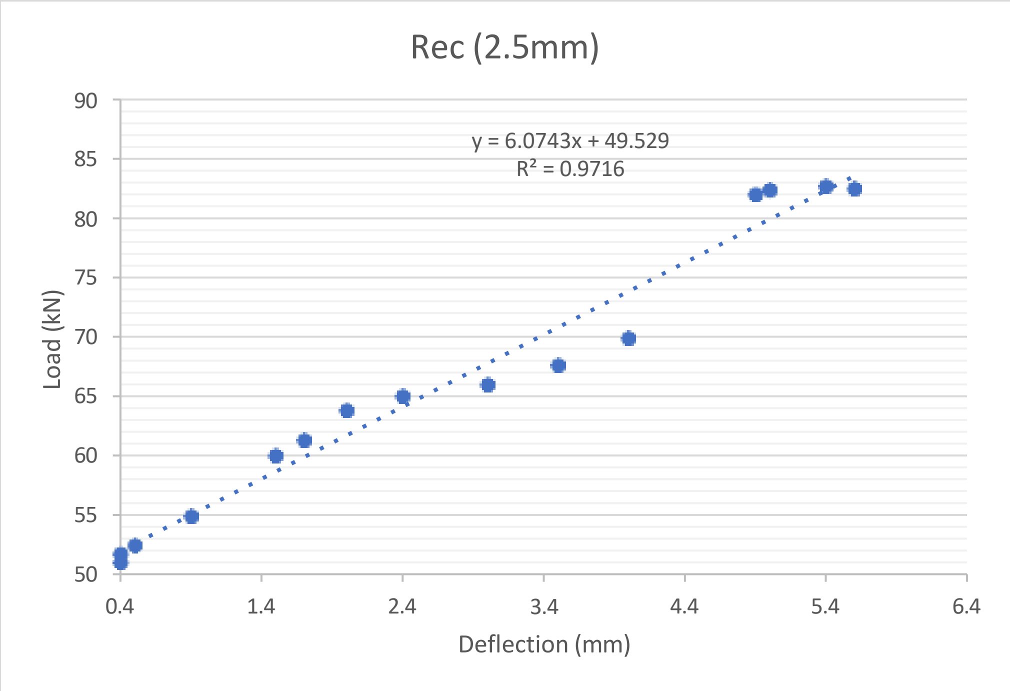

Fig 13 Regression analysis for Rec(2.5mm) beam

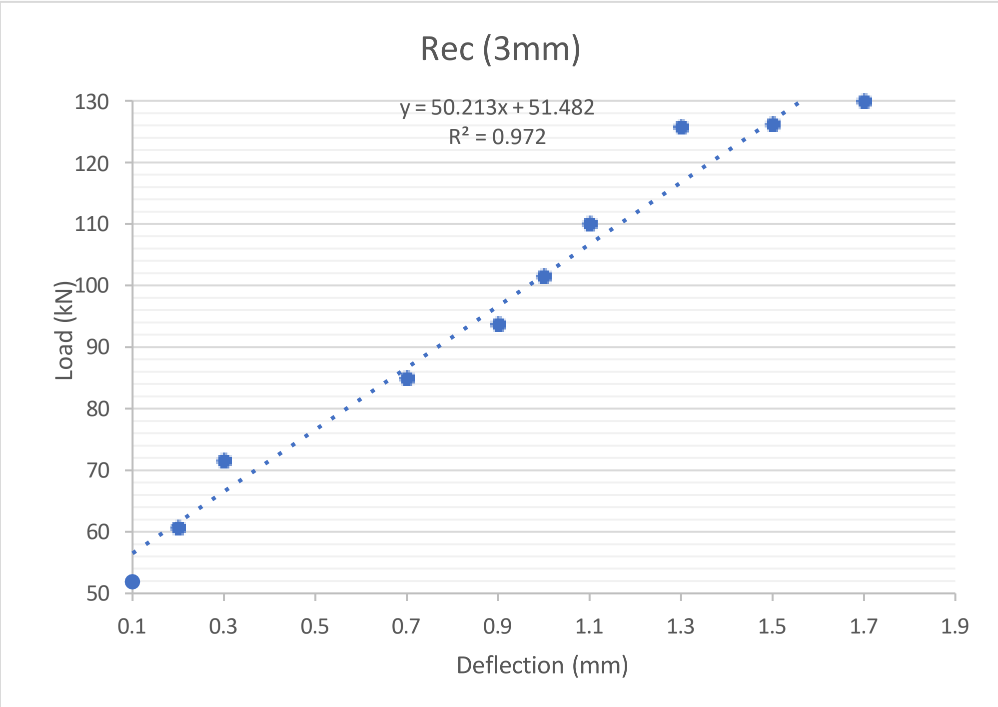

Fig 14 Regression analysis for Rec s(3mm) beam

Following tables give the ductility test results of hybrid fiber reinforced concrete produced by using fiber of different aspect ratios. Variations of ductility characteristics are depicted in the form of graph as shown in figure

Table 7 Beam Ductility Factor Results

Beam Type	**Thickness (mm)**	**Ductility factor**
RCC Beam	12Ø main bar & 8Ø stirrups	0.94
I-Section Beam	2.5	1.47

I-Section Beam	3	2.37
Hollow Rectangular Beam	2.5	1.29
Hollow Rectangular Beam	3	1.81

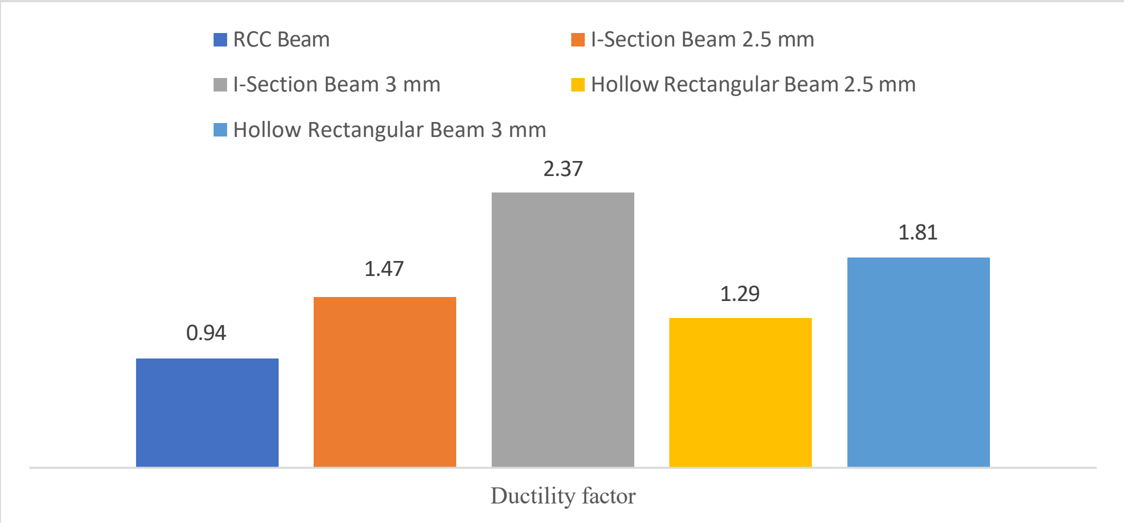

Fig 15 Ductility factor

Key Observations:
I-Section with 3mm thickness had the highest load-bearing capacity (421.28 kN) and ductility factor (2.37) making it the strongest and most efficient among all tested beams. Hollow rectangular beams with 2.5mm and 3mm thickness showed lower load capacity and ductility factor compared to I-sections but demonstrated better torsional resistance due to their closed profile. RCC beams, although stable, had a significantly lower strength-to-weight ratio compared to composite encased beams. I-Section with 2.5mm thickness had the lowest deflection (1.2 mm), indicating high rigidity and minimal bending. I-Section with 3mm thickness showed deflection (3.7 mm) due to its greater flexibility and higher load-carrying capacity. Hollow rectangular beams with 2.5 mm thickness showed higher deflection (5.7 mm). RCC beams exhibited moderate deflection (1.2 mm) but lacked the efficiency of composite beams. Hollow rectangular beams had a balanced deflection performance, offering better stability than RCC beams but slightly more flexibility than I-section beams. the results of the regression analysis indicated that the R squared value ranging from 0.8883 to 0.972. these figures will clearly indicate that the mathematical models developed are clearly demonstrating the relation between the input variables and the performance parameters under the study. The regression models developed in the study can be used to predict the results for the incorporation of any other steel section without conducting the experimental investigation.

CONCLUSIONS
While RCC beams provided stability, composite encased steel beams showcased superior load distribution and higher strength-to-weight ratio. I-section beams outperformed RCC beams in terms of load capacity and stiffness, making them more suitable for applications requiring high strength and minimal deflection. Increasing the steel gauge thickness from 2.5mm to 3mm significantly improved load carrying capacity but resulted in higher deflection due to increased flexibility. Thinner sections (2.5mm) had lower strength but provided better rigidity, making them more suitable for applications where deflection control is a priority. The use of composite encased steel beams optimizes material utilization, reducing overall weight and construction costs. These beams improve the efficiency of structural designs, making buildings safer, more economical, and durable.

Conflict of Interest: The authors declare that we do not have competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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