Experimental and Analytical Study on Behaviour of Checkered Steel-encased Concrete Composite Beams

Amalu Prem[1], Tennu Syriac[2]

[1] M.Tech Student, Dept. of civil engineering, SCMS School of engineering and technology, Kerala, India
[2] Asst.Professor, Dept. of civil engineering, SCMS School of engineering and technology, Kerala, India for

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Abstract-*A beam is a structural element that can resist loads applied laterally to beam's axis. Its mode of deflection is by bending. The checkered steel-encased concrete composite (CSCC) beam generally consists of a rolled U-shaped or C-shaped steel beam. To strengthen bonding effect and enhance slipping resistance, a CSCC beam is introduced. To investigate the real bending of the new-type of composite beam, static load tests on simply-supported CSCC beams were conducted. Trapezoidal CSCC beam can carry more load than rectangular CSCC beam according to geometry. Yield strength of CFRP (carbon fibre reinforced polymer) is much higher than checkered steel, so CFRP encased concrete composite beam can carry more load than CSCC beam. All numerical simulations were performed using the finite element software Ansys 16.1. The load-deformation responses were analyzed using Universal testing machine (UTM).*

***Key Words*: CSCC beam, Trapezoidal, CFRP, bonding effect, static load, UTM**

1. INTRODUCTION

Checkered steel-encased concrete composite beam utilizes a convex checkered pattern in the steel beam to improve the bonding effect between steel and concrete and their cooperative performance. In theory, the checkered pattern arrangement can effectively reduce the number of bolts and enhance the slipping-resistance property of the composite beam. Thus, the new pattern improves the mechanical behavior of the composite beam.

With a certain degree of slip resistance, good corrosion resistance, beautiful appearance and economic cost, galvanized steel checker plate is widely used in elevator decorative plate, shops decoration, engineering, exterior design of the building, etc.

2. EXPERIMENTAL STUDY

2.1 Preliminary Test Results on Materials

Specific gravity test was conducted on cement, fine and coarse aggregate. Water absorption test was conducted on fine and coarse aggregate. The test results are shown in table 1.

Table-1: Preliminary Test Results

Sl. No	Materials	Property details	
1	Cement	Grade	OPC 53
		Specific gravity	3.125
2	Fine aggregate	Specific gravity	2.85
		Water absorption	2%
3	Coarse aggregate	Specific gravity	3.2
		Water absorption	3.71

2.2 Tension test of checkered steel

Tension test was conducted in Universal testing machine (UTM) as shown in fig 6. Dimensions are taken in accordance with IS 1608:2005. Dimensions of specimen is shown in fig 1.

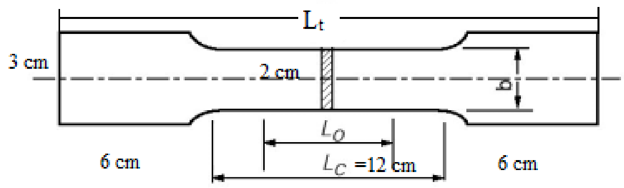

Fig-1: Checkered steel specimen for tension test

Where, Lt = total length
Lo = Original guage length
Lc = parallel length
From stress-strain curve, Young's modulus (E) is calculated.

$$E = \frac{Stress}{Strain} = 250 \text{ GPa}$$

2.3 Compressive strength test on concrete

The test was conducted in compression testing machine. Values of compressive strength at 28th day for reference specimen are given in table 2.

Table-2: Compression Test Results

	Compressive strength (N/mm2) at 28 days	Average compressive strength (N/mm^2)
M25 mix	44.8	44.4
	44.4	
	44	

2.4 Test setup and results

Flexural test is done to determine the strength of composite beams. In this test rectangular composite beam of size 1000 x 122 x 100 mm and trapezoidal composite beam of size 1000 x 254 x 94 x 80 mm were tested. After 28 days of curing period flexural strength is measured in Universal testing machine (UTM). Both specimens fails at different load. Trapezoidal beam carries more load than rectangular beam. Fig 2 and 3 shows Universal testing machine with rectangular and trapezoidal composite beams.

Fig-2: Rectangular CSCC beam

Fig-3: Trapezoidal CSCC beam

The values obtained from UTM is shown in table 3.

Table-3: Test Results

Specimen	Load (kN)	Deflection (mm)
Rectangle	61.2	7.9
	63.3	7.2
Trapezoid	69.5	8.9
	71.15	9.4

The failure of specimen is shown in fig 4 to fig 7.

Fig-4: Failure of rectangular CSCC beam (top view)

Fig-5: Failure of rectangular CSCC beam (side view)

Fig-6: Failure of trapezoidal CSCC beam

Fig-7: Failure of trapezoidal CSCC beam (side view)

The load-deflection graph of rectangular and trapezoidal composite beam is shown in fig 8 and fig 9.

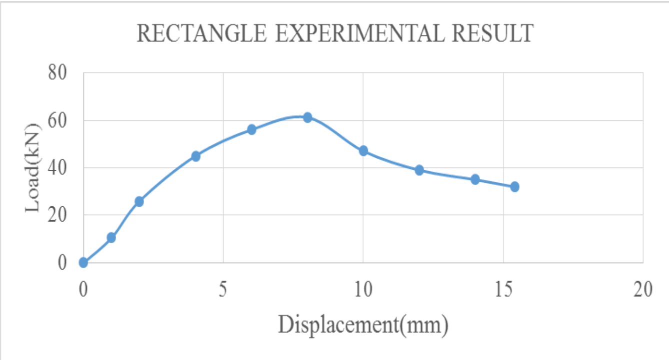

Fig-8: Load-deflection graph of rectangular CSCC beam

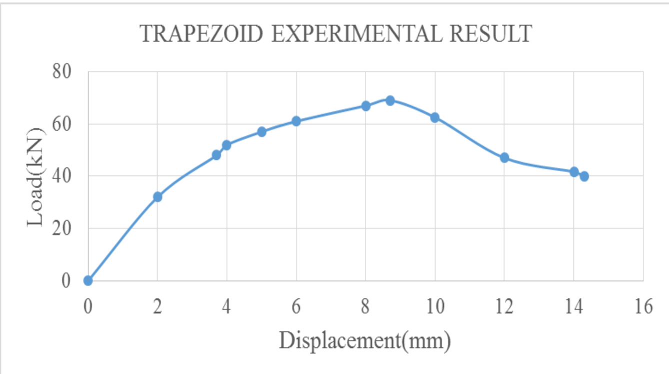

Fig-9: Load-deflection graph of trapezoidal CSCC beam

3. ANALYTICAL STUDY

For easier and repeated computation FE analysis can be adopted. Here ANSYS 16.1 workbench is used for the analysis.

3.1 Analytical Modelling of Rectangular and Trapezoidal Checkered Steel Encased Concrete Composite Beam

The dimensions for analytical model are as follows:
Rectangular beam: Dimension = l×b×h
= 1000 × 122 × 100 mm

Where l = length, b = breadth, h = height

Trapezoidal beam: Dimension = l × a × b ×h
= 1000 ×254 × 94 × 80 mm

Where l = length, a = top width, b = bottom width, h = height

Rectangular and trapezoidal checkered steel encased concrete composite beam of steel thickness 5mm is analyzed using ANSYS.

Properties of steel

Density	= 7850 kg/m^3
Poissons ratio	= 0.3
Youngs modulus, E	= 250GPa
Yield strength	= 250MPa
Tensile strength	= 410MPa

Properties of concrete

Density for M_{25}	= 2400kg/m^3
Poissons ratio	= 0.18
Youngs modulus, E	= 25000N/mm^2
Tensile strength	= 3.5 N/mm^2

Modelling, meshing and analysis of rectangular composite beam is shown in fig 10 to fig 12.

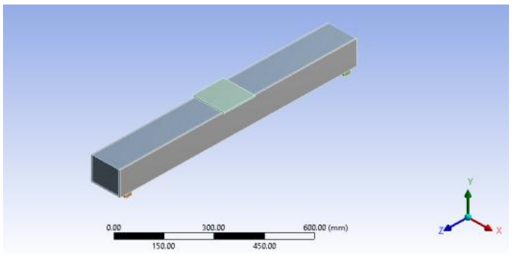

Fig-10: Model of Rectangular CSCC beam

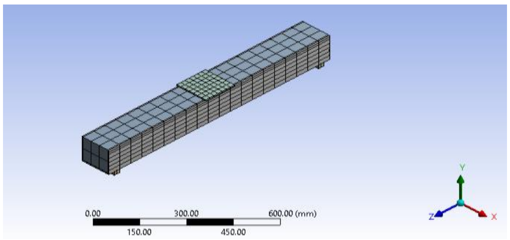

Fig-11: Meshed Rectangular CSCC beam

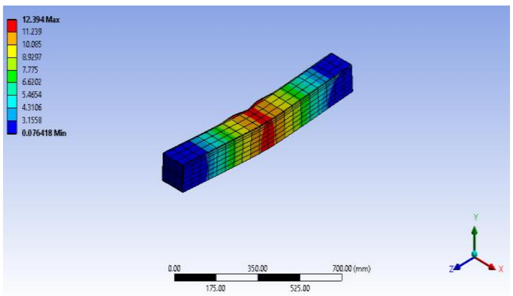

Fig-12: Deflection of Rectangular CSCC beam

Modelling, meshing and analysis of trapezoidal composite beam is shown in fig 13 to fig 15.

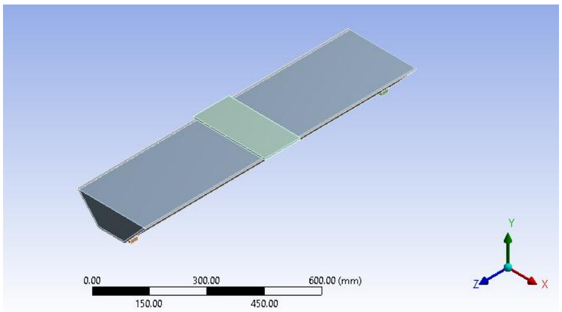

Fig-13: Model of Trapezoidal CSCC beam

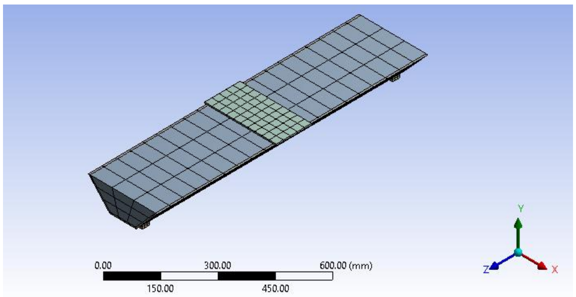

Fig-14: Meshed Trapezoidal CSCC beam

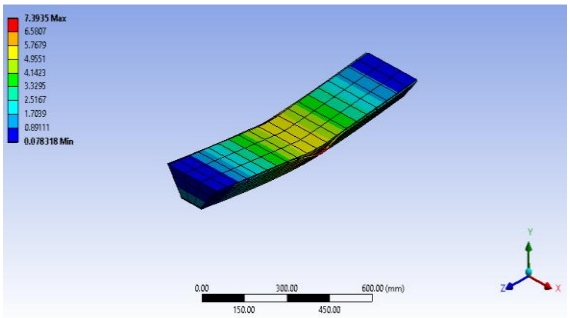

Fig-15: Deflection of trapezoidal CSCC beam

The values obtained after analysis is shown in table 4.

Table-4: Analytical Values of Beams

Rectangular composite beam		Trapezoidal composite beam		% variation
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	
64.769	7.12	74.276	10.6	14.67

The graph showing load deflection of Rectangular and trapezoidal composite beam is shown in fig 16 and fig 17.

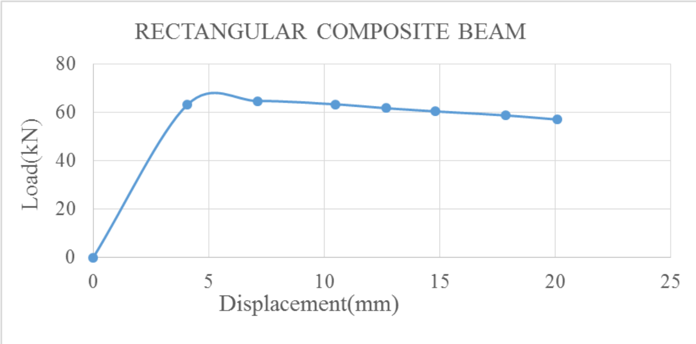

Fig-16: Load-deflection graph of rectangular CSCC beam

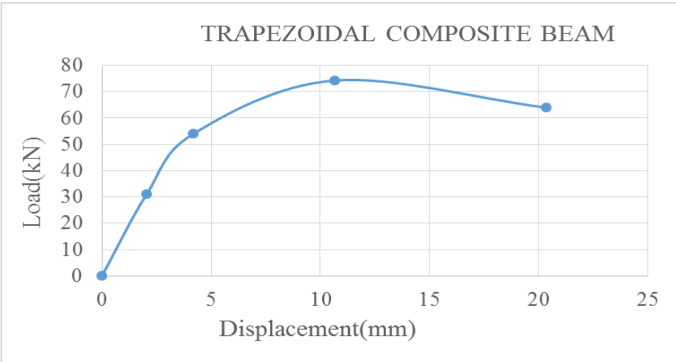

Fig-17: Load-deflection graph of trapezoidal CSCC beam

3.2 Analytical Modelling of Rectangular and Trapezoidal CFRP Encased Concrete Composite Beam

The dimensions of model are same as given above. Rectangular and trapezoidal CFRP (carbon fibre reinforced polymer) encased concrete composite beam of CFRP thickness 1.2mm is analyzed using ANSYS. Modelling, meshing and analysis of beams is shown in fig 18 to fig 23.

Properties of CFRP [11]

Density = 1750 kg/m^3
Poissons ratio = 0.26
Youngs modulus, E = 165 GPa
Yield strength = 3100 MPa

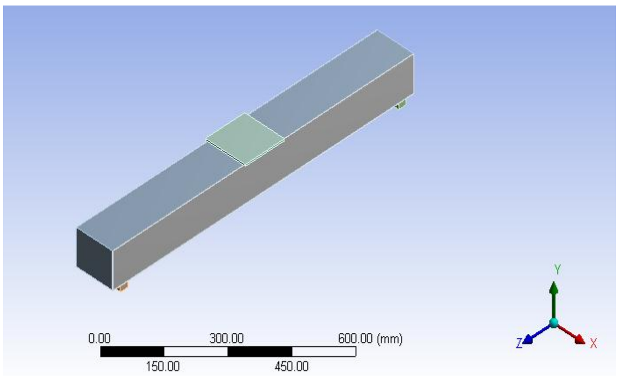

Fig 18: Model of Rectangular composite beam (CFRP)

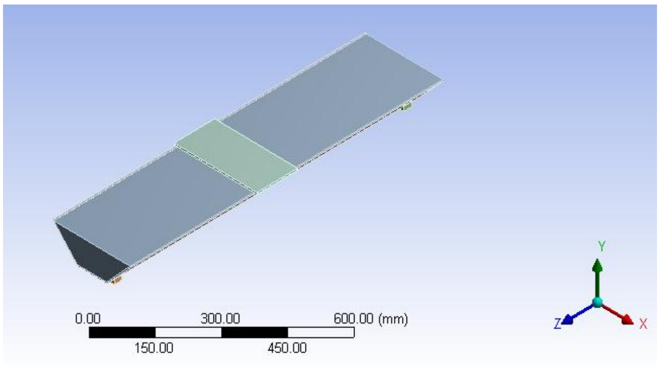

Fig-19: Model of Trapezoidal composite beam (CFRP)

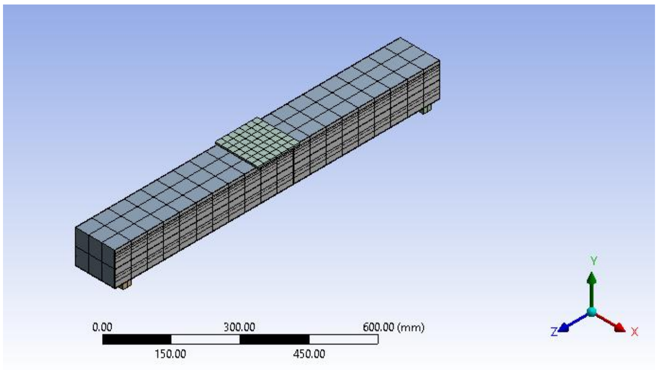

Fig-20: Meshed Rectangular composite beam (CFRP)

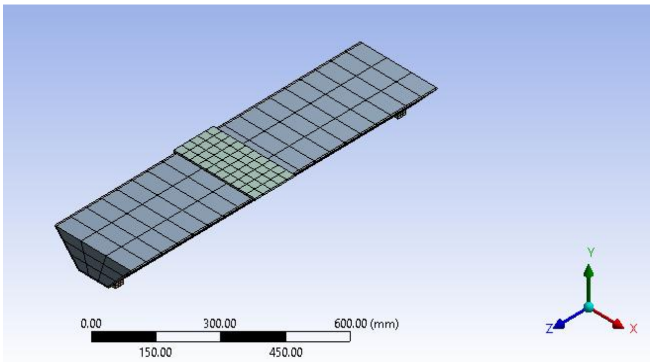

Fig-21: Meshed Trapezoidal composite beam (CFRP)

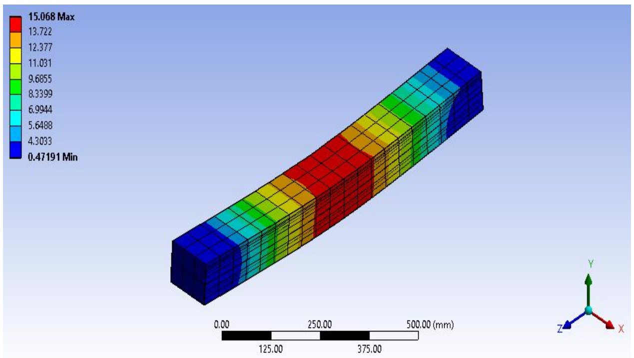

Fig-22: Deflection of rectangular composite beam (CFRP)

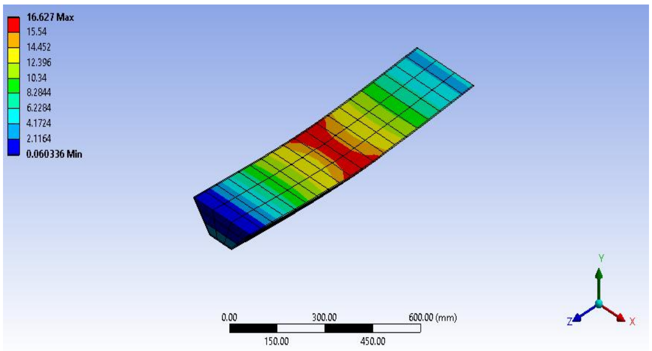

Fig-23: Deflection of trapezoidal composite beam (CFRP)

The graph showing load deflection of Rectangular and trapezoidal CFRP composite beam is shown in fig 24 and fig 25 and the values obtained is shown in table 5.

Table-5: Analytical Values of CFRP Beams

Rectangular composite beam		Trapezoidal composite beam		% variation
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	
149.89	41.99	170.37	21.798	13.66

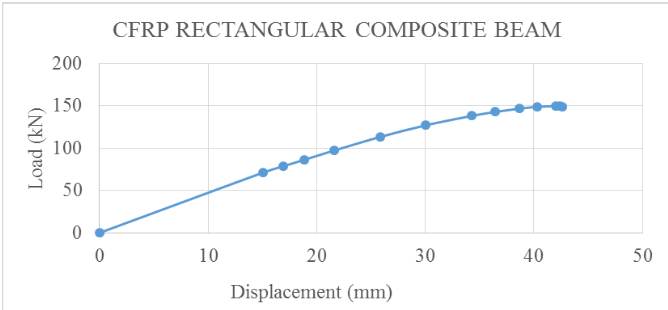

Fig-24: Load-deflection graph of rectangular composite beam

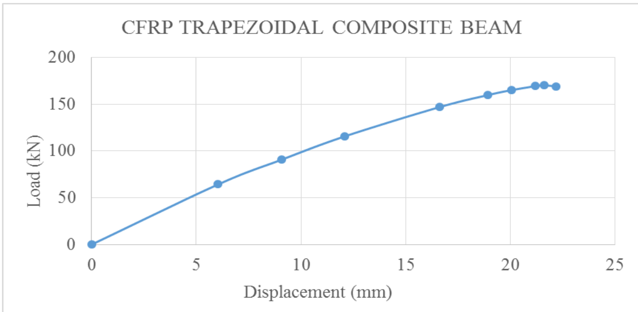

Fig-25: Load-deflection graph of trapezoidal composite beam

4. RESULTS AND DISCUSSION

The comparative graph of rectangular and trapezoidal checkered steel encased concrete composite beam (experimental and analytical) is shown in fig 26 and fig 27.

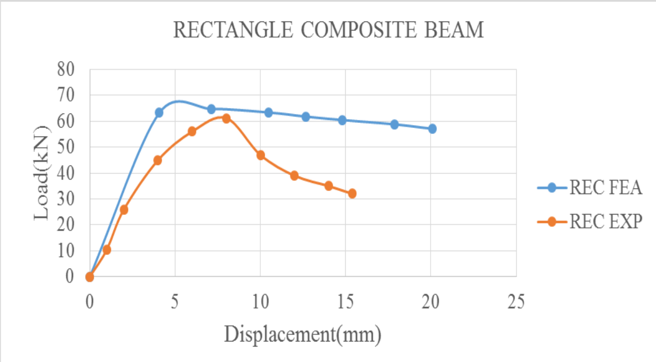

Fig-26: Comparative graph of rectangular CSCC beam

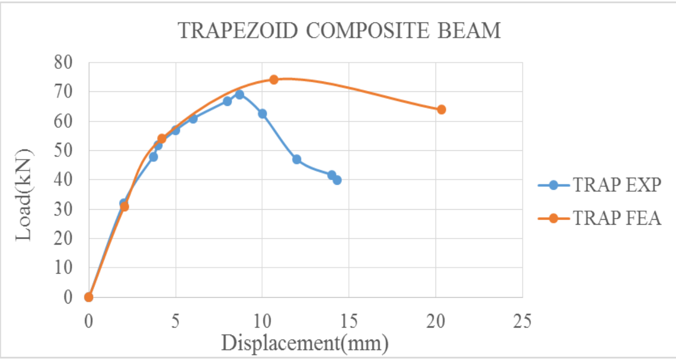

Fig-27: Comparative graph of trapezoidal CSCC beam

From experimental study, for rectangular checkered steel encased concrete composite beam the maximum load obtained is 63.3 kN and deflection obtained is 7.2 mm. From analytical study the load obtained is 64.769 kN and deflection obtained is 7.12 mm. The variation in result is 2.32% and the result is within the permissible limit.

From experimental study, for trapezoidal checkered steel encased concrete composite beam the maximum load obtained is 71.15 kN and deflection obtained is 9.4 mm. From analytical study the load obtained is 74.276 kN and deflection obtained is 10.6 mm. The variation in result is 4.39% and the result is within the permissible limit.

The comparative graph of rectangular and trapezoidal CFRP encased concrete composite beam is shown in fig 28.

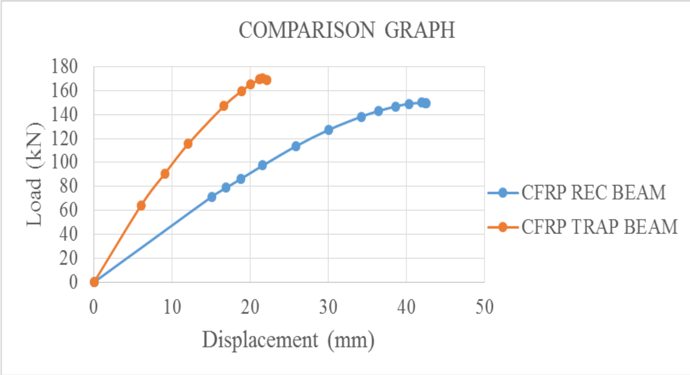

Fig-28: Comparative graph of rectangular and trapezoidal CFRP composite beam

From analytical study, for rectangular CFRP encased concrete composite beam the maximum load obtained is 149.89 kN and deflection obtained is 41.99 mm. For trapezoidal CFRP encased concrete composite beam the maximum load obtained is 170.37 kN and deflection obtained is 21.79 mm.

5. CONCLUSIONS

Preliminary tests were conducted on cement, sand and coarse aggregates. Compression strength test was done after 28 day curing. Tension test was done for checkered steel. Experimental specimens were casted, cured and load-deformation response was obtained from Universal testing machine. Modelling and validation of specimens was done using Ansys 16.1. The variation of experimental and analytical result for rectangular CSCC beam is 2.32 % and for trapezoidal CSCC beam is 4.39 %.

Trapezoidal CSCC beam caries 12.4% more load than rectangular CSCC beam. CFRP encased concrete composite trapezoidal beam carries 13.6% more load than CFRP encased concrete composite rectangular beam.

CFRP encased concrete composite beam carries more load than CSCC beam. Rectangular CFRP encased concrete composite beam carries 131.4% more load than rectangular CSCC beam. Trapezoidal CFRP encased concrete composite beam carries 129.3% more load trapezoidal CSCC beam.

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