



BEHAVIOUR OF PRE-FABRICATED STEEL TRUSS AS REINFORCEMENT IN RC BEAMS

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Abstract

Various methods were developed to increase flexural strength of the reinforced concrete (RC) beams by changing geometry or by incorporating different additional aids in flexural zone or by varying the shear reinforcement; these innovative arrangements enhance the load carrying capacity of the beam. In this experimental work the main objective was to study the behavior of conventional steel reinforced concrete (RC) beam replaced by pre-fabricated steel truss as reinforcement and also to study model behavior analytically by using ANSYS Software for comparison. A series of beam specimens were casted and tested to study the effect of conventional reinforced concrete beams replaced by prefabricated lattice and warren type steel truss reinforcement.

Keywords: Conventional RC beam, Lattice and Warren type steel truss reinforcement, Load carrying capacity, Flexural strength, Shear strength, Deflection, Finite elements: ANSYS.

1 Introduction

The Reinforced concrete has been extensively used in India for construction of buildings, roads, bridges and dams because of its various advantages as construction material(8). The natural behaviour of the concrete which is strong in compression and steel which is strong in tension are suitably combined to construct structural members, this combination of steel and concrete permits the almost unlimited uses arranged within the concrete core. M20 grade concrete was used to cast the specimens with a W/C ratio of 0.50 and tested for flexure using loading frame after curing at the age of 28 days. Results show that truss reinforcement influences the flexural behavior of RC beams more effectively compared to conventional beams and ANSYS analytical model results were also compared with the tested results. It has been concluded that the test results of failure loads, deflections and crack pattern shows good agreement with the analytical results.

2 LITERATURE REVIEW

Sooryaprabha M Saju and Usha.S [12] have conducted an experimental investigation on flexural strength of truss reinforced concrete beams, based on the obtained experimental results they concluded that the beam with steel truss reinforcement arrangement shown increase in ultimate load, strength and stiffness and the deflection of steel truss reinforcement beams found less. Neelima Khare and Shingade. V.S [9] has conducted investigation on structural behaviour and properties of composite steel and concrete beams. They tested three types of beams one with normal conventional reinforcement other two with composite beam using rolled steel angle and rolled steel channel section and tested, based on the obtained results they concluded that the rolled steel angles as main reinforcement found to be more effective in enhancing the load carrying capacity of the beam section and reduction in weight of structure and increased ductility. Parthiban.B et al.[10] have studied the flexural behaviour of hybrid fibre reinforced concrete beams strengthened with FRP laminates, based on the obtained results, finally they concluded that the hybrid arrangement of fibres in the beam showed increased stiffness and reduction of cracks. All the experimental re-

sults were compared and in agreement with analytical results given by the ANSYS software. Muneeb Ullah Khan et al. [8] have studied the effect of using swimmer bars at an angle of 45° as shear reinforcement in reinforced concrete beams and observed that ultimate load carrying capacity of the beam with swimmer bars found to be more when compared with normal RC beam, also enhanced shear capacity of the beam. Rudy Djamaluddin et al. [11], in their research work on effect of the truss system to the flexural behaviour of the external reinforced concrete beams, concluded that the truss reinforced beam without concrete in tension zone developed same load carrying capacity to that of normal concrete beam, increased stiffness and also slower development of cracks. Jadhav. H. S and Koli. M. D [7] carried out investigation of flexural behaviour of hybrid fibre reinforced concrete beam by using hybrid fibres and they concluded that maximum deflection of hybrid beams more compared to normal beam thus increased ductility of the member and also increased load carrying capacity with increase in percentage of volume of fibre.

In this experimental work, the main objective was to study the behaviour of conventional steel reinforced concrete (RC) beam replaced by pre-fabricated lattice and warren type steel truss as reinforcement and to study its effect on enhancement of flexural strength, shear strength, deflection and load carrying capacity. Also an analytical model was studied using ANSYS Software for comparison.

3 MATERIALS AND METHODOLOGY

a. Cement

Cement used in this work was an Ordinary Portland Cement (OPC) - 53 Grade. The cement was purchased directly from the open market and tested. Which satisfies the requirement of IS: 12269-2013 code specification. Physical properties of tested cement are given in Table 1.

b. Manufactured Sand

Manufacture sand was purchased from the supplier, used as fine aggregate. The sand used was having fineness modulus of 3.9 and confirmed to grading zone-II as per IS: 383-1970 specification, phys-

ical properties of tested manufacture sand are given in Table 2.

Table 1: Physical Properties Ordinary Portland Cement (OPC)-53 Grade

Properties	Results	Permissible limit as per IS: 12269-2013
Fineness	20.3 m ² /N	Should not be more than 22.5 m ² /N
Normal consistency	33%	---
Specific gravity	3.09	---
Setting Time a. Initial b. Final	40 Min. 190 Min.	Should not be less than 30 Min Should not be more than 600 Min

Table 2: Physical Properties of Manufacture Sand

Properties	Results	Permissible limit as per IS: 2386-1963
Organic impurities	Gray Colour	Colour less /Straw Colour/Dark Colour
Silt content	Nil	Should not be more than 6-10%
Specific gravity	2.53	Should be between the limit 2.6-2.7
Bulking of sand	22.5%	Should not be more than 40%
Moisture content	Nil	---
Sand particles	88.73	---
Silt and Clay particles	11.27	---
Water absorption (%)	5.2	---

c. Coarse Aggregates

The crushed stone aggregate by local quarry purchased from the supplier. The coarse aggregates used in the experimentation were 20mm down size aggregate and tested as per IS: 383-1970 and 2386-1963 (I,II and III) specifications. The aggregates used were having fineness modulus of 1.96. Physical and Mechanical properties of tested coarse aggregates are given in Table 3

Table.3: Physical and Mechanical Properties of Coarse Aggregate

Properties	<u>Resu</u> <u>Its</u>	Permissible limit as per IS: 2386-1963 and IS:383-1970
Impact value	5 %	Should not be more than 30% used for concrete
Crushing value	22.5 0%	Should not be more than 30% for surface course and 45% other than wearing course
Specific gravity	-	In between range 2.6-2.8
Moisture content	0.2%	---
Water absorption (%)	0.35	---

d. Water

Ordinary potable water ($\text{pH} = 7.60$) free from organic content, turbidity and salts was used, for mixing and for curing throughout the work.

e. Steel

Fe-500 Steel was used as a conventional reinforcement which satisfies the requirement of IS: 1786-2008 code specification.

f. Mild Steel Pipe

M S pipe of nominal bore 15mm, outer diameter of 21.3mm and 2mm thickness was used for fabricating truss, which satisfies the requirement IS:1161:1998 code specification.

h. Reinforcement Details

Con-ventional RC beam (CB-1andCB-2) provided with 212 mm dia bars as longitudinal reinforcement at the bottom and 210mm dia bars as anchor bars provided at the top and 8mm dia bar stirrups spaced @ an interval of 150 mm c/c was considered as shear reinforcement as per the design of singly reinforced beam as shown in Figure 1. Beam Lattice type (HBL-3, HBL-4) and Warren type (HBW-5, HBW-6) pre-fabricated trusses were prepared using mild steel tube of 15 mm bore to replace regular reinforcement. Details of reinforcement shown in Figure 2, Figure 3 and Figure 4

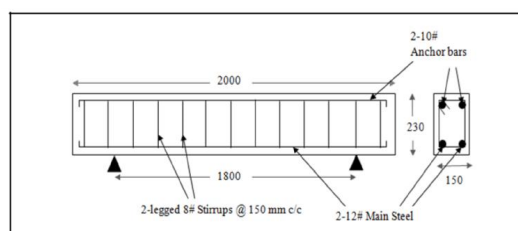


Figure 1: Reinforcement Details of Conventional RC beam

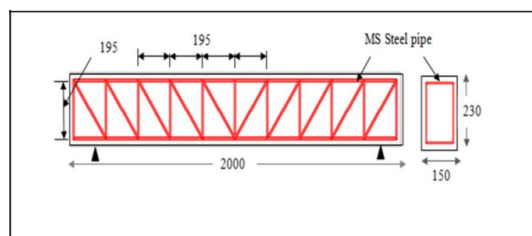


Figure 2: Details of Lattice Steel truss RC beam

g. Mix proportion

A mix of M20 Grade Concrete was used. Concrete was produced by hand mixing and volume batching, by adopting the nominal mix ratio of 1:1.5:3 with a water to cement ratio of 0.50.

i. Specimens

Totally six beam specimens of 2000 mm length with a cross section of 150 mm x 230 mm were casted using M20 grade of concrete for the proportion 1:1.5:3 with a W/C ratio of 0.50 and moist cured

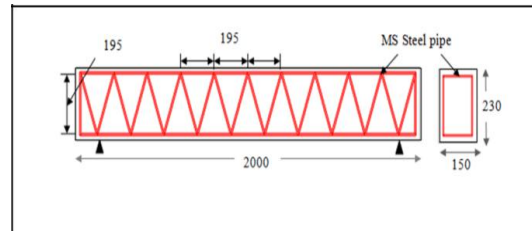


Figure 3: Details of Lattice Steel truss RC beam



Figure 4: Pre-Fabricated Conventional, Lattice and Warren steel truss reinforcement

for 28 days using gunny bags. Also standard concrete cubes of size 150 x 150 x 150 mm were casted and tested for compressive strength after water curing for 28 days as per IS: 516-1959 specification. The test results are shown in Table 4.

Table 4: Test results of compressive strength of concrete

Particulars of cubes	28 days Strength(MPa)
Sample 1	25.4
Sample 2	26.1
Sample 3	26.3

4 TOOLS USED AND MODEL PREPARATION

a. ANSYS Software

ANSYS is basic nonlinear finite element software offering a vast range of engineering applications like in Structural analysis and Thermal analysis of structures etc...

b. Analytical modelling of beams using ANSYS

Analysis and Simulation of Beams was done using ANSYS v15.0. A typical ANSYS analysis has three stages as mentioned below :

c. Building the model

The concrete beam for present study was modeled from the ANSYS element library by selecting element type SOLID 65. The SOLID 65 element has eight nodes with three degrees of freedom at each node, translations in the nodal x, y, and z directions. SOLID65 element is capable of cracking in tension and crushing in compression. The SOLID65 element assigned with linear isotropic and multi linear isotropic material properties to model concrete as shown in Table 5. The reinforced concrete beam of size 150 230 2000mm and reinforcement as the link element for the model was selected.

Table 5: Material Property assigned to Concrete model

Material Property	ANSYS Label	M20 Concrete
Young's Modulus (E) N/mm ²	EX	22360
Poisson's ratio (ν)	PRXY	0.2
Open Shear transfer Coefficient		0.2
Closed Shear transfer Coefficient		0.9
Uniaxial Cracking Stress		3.13
Uniaxial Crushing Stress		20

d. Model 1- Conventional RC beam using conventional reinforcement

By selecting element type SOLID 65 Concrete element, BEAM 188 element and using link element, the steel reinforcement of concrete beam was modeled by input of linear isotropic material properties as shown in Table 6.

Table 6: Material Property assigned to steel reinforcement

Material property	ANSYS Label	Steel
Young's Modulus (E) N/mm ²	EX	200000
Poisson's ratio (ν)	PRXY	0.3
Density kg/m ³	DENS	7850

e. Model 2- Modeling of Beam with Lattice type steel truss reinforcement

The beam was modeled using SOLID 65 Concrete element, BEAM 188 element and PIPE 288 element for steel truss reinforcement. The properties of structural steel tube used for fabrication of truss were as per IS 1161:1998 code specification.

f. Model 3-Modelling of Beam with Warren type steel truss reinforcement

The beam was modeled similarly using SOLID 65 Concrete element, BEAM 188 element and PIPE 288 element for steel truss reinforcement.

The details of models developed using ANSYS are as shown in Figure 5, Figure 6 and Figure 7.

Model Analyses Using Ansys Software

To simulate the model and to get a unique solution, displacement boundary conditions were applied as per actual supports and loading conditions as applied in experiment. The loading was applied on the nodes at one-third point i.e., application of two points loading on to the beam element with simply supported conditions as shown in Figure 8 and Figure 9. The range of load applied for flexure was in between 10kN to 90kN for prepared models. In this nonlinear static analysis, the total load applied to a finite element

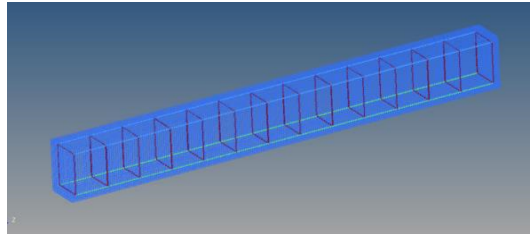


Figure 5: Model-1: Conventional RC beam modeling using ANSYS

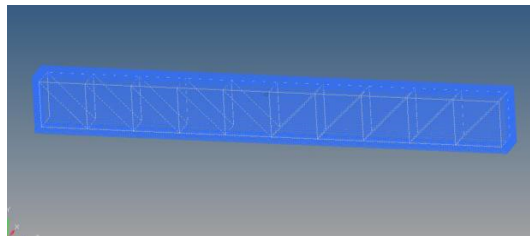


Figure 6: Model-2: Beam with Lattice type steel truss reinforcement using ANSYS

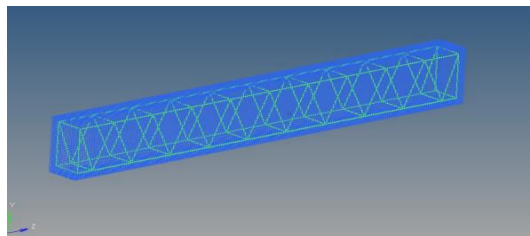


Figure 7: Model-2: Beam with Warren type steel truss reinforcement using ANSYS

model was divided into a series of load increments called load steps, automatic time stepping in the ANSYS program predicts and controls load step sizes. ANSYS takes all the data such as loading information and boundary conditions from database of the model and calculates and generate the results. The details of analysis results are represented pictorially for the three beam models as shown in Figure 10 to Figure 12.

Testing of Beams Using Loading Frame



Figure 8: Arrangement of Beam Specimen on loading frame for testing

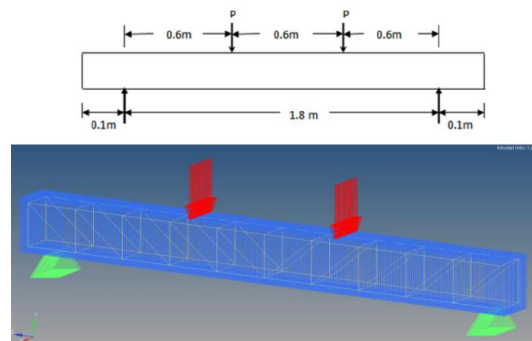


Figure 9: Loading set up for beams

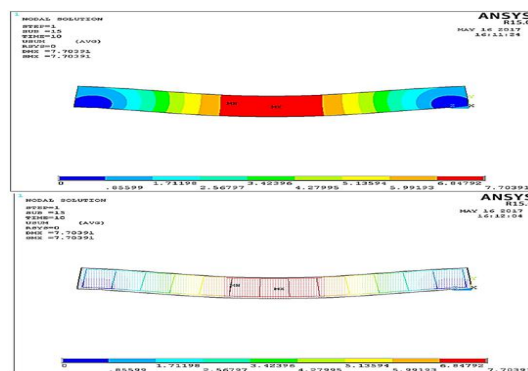


Figure 10: Model-1: Displacements contours of the conventional beam

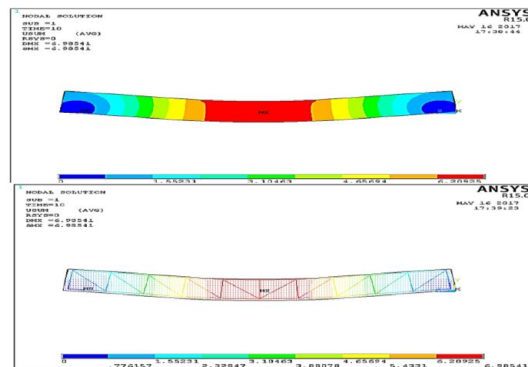


Figure 11: Model-2: Deflections of the Lattice steel truss reinforced beam

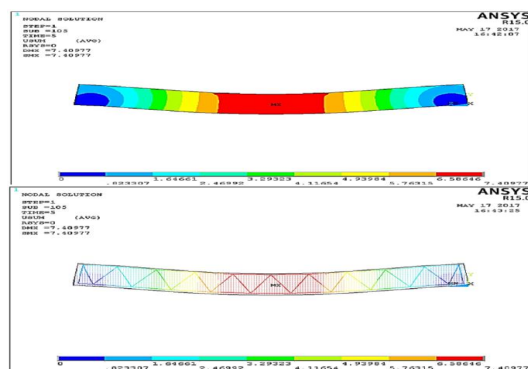


Figure 12: Model-2: Deflections of the Warren steel truss reinforced beam

The testing arrangement is shown in the Figure 8. After completion of 28 days curing, the reinforced beam specimens were arranged in a two point loading manner with an equal interval of 600mm each on loading frame as specified in Figure 9. Loading cell of 1000kN capacity was used to apply the uniform loading at the rate of 2kN/Sec. LVDT was fixed at the centre of the beam to note down the deflection. The load was applied gradually using hydraulic jack in increments till failure of the beam specimens. The performance of the beams was observed throughout the loading period until the specimen failed. Load-Deflection curves for

each beam was obtained from the software. Also the appearance of Bending, Propagation of cracks and failure of the beam were observed and recorded.

Experimental results-The following Table give the details of the experimental results.

Flexural Strength and Shear Strength Test Results- The following Table No 7 gives the flexural strength and shear strength test results of conventional RC Beams and Steel Trussed RC Beams.

Table 7: Test results of Flexural Strength and Shear Strength of RC Beams

Beam Type	Ultimate Load (kN)	Flexural strength(kN-m)		Shear Strength (kN)	
CB-1	55.9	16.77	16.8	27.95	28
CB-2	56.1	16.83		28.05	
HBL-3	63.6	19.08	19.01	31.8	31.68
HBL-4	63.1	18.93		31.55	
HBW-5	60.9	18.27	18.3	30.45	30.5
HBW-6	61.1	18.33		30.55	

The above results can be depicted in the form of Graph as shown Figure 13.

Analytical results in ANSYS-The details of analysis results given by ANSYS are represented pictorially for the three beam models as shown in Figure 14

5 OBSERAVATION DISCUSSION AND CONCLUSION

It has been observed that the crack patterns of all the beams were almost similar. Load Vs deflection curves were plotted for each beam and the results were compared as shown in Figure 15 and

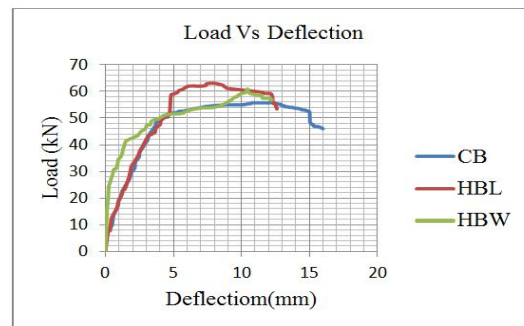


Figure 13: Load Deflection results of RC Beams

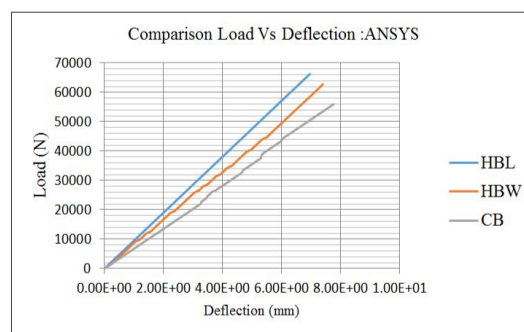


Figure 14: ANSYS-Load Deflection results of RC Beams

Figure 16. Load-Deflection of all beams showed almost linear pattern up to yield value and after that it shows a nonlinear pattern with gentle slope. Considering the load-deflection diagram of the beams, it is clear that, the specimen with truss reinforcement was found to take more load than regular RC beam specimen.

It has been observed that increase in ultimate failure load by 14% and 9% with Lattice type truss reinforcement and Warren type truss reinforcement respectively, when compared to regular steel reinforcement beam.

It has been observed that beams with truss reinforcements were less deflected during the service stage (before yielding) and hence, they have more stiffness and strength than the beams with conventional reinforcement

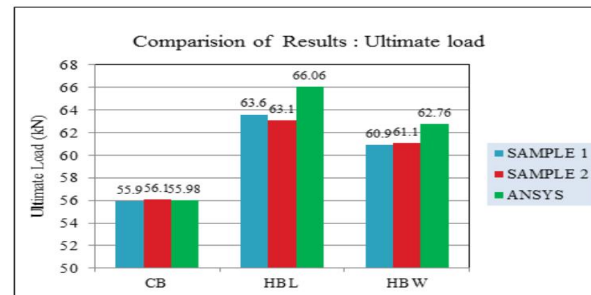


Figure 15: Comparison results of ultimate Load of RC Beams

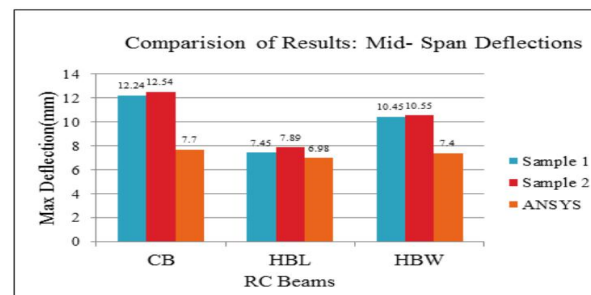


Figure 16: Comparison results of deflections of RC Beams

It has been observed that the pattern and type of the truss reinforcement does have effect on the ultimate failure load and failure mode of the beams, though the crack pattern of both beams were similar.

It has been observed that the strut effect of diagonal members in the truss reinforcement, contributed towards increased flexural capacity of the truss reinforced concrete beams. Lattice type truss has shown more capacity than Warren type truss.

6 CONCLUSION

Based on the experimental and ANSYS analytical results the following conclusions were drawn. It can be concluded that, modification in conventional reinforcement by steel truss reinforcement increases the flexural strength and shear strength of RC beam can

be concluded that, analytical results generated by ANSYS for the beams were closely in agreement with experimental results.

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