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Analytical Study on the Behavior of Hybrid Steel Trussed Concrete Deep Beam

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Abstract

The Hybrid Steel Trussed Concrete Beam (HSTCB) is an innovative form of beam appeared recently in the construction industry. It forms a steel truss embedded in the concrete core. The steel truss typically composed by, a steel plate or a precast concrete plank working as bottom chord, a system of ribbed or smooth steel rebar welded to form the diagonals of the truss and a coupled rebar used to form the upper chord of the truss. The scope of this study is to introduce a new structural element that can be a substitution for the conventional reinforcements in deep beams, by utilizing the advantages of diagonal web bars in Hybrid Steel Trussed Concrete beams. This paper aims to compare the strength of hybrid steel trussed concrete deep beam with conventional concrete deep beam by varying the truss configuration by using ANSYS 17 (workbench) software.

Keywords: *Hybrid Steel Trussed Concrete Deep Beam (HSTCB), Conventional concrete Deep Beam, Steel Plate, Diagonal Steel Bar, Comparison.*

1. Introduction

When concrete and steel combined they form composite member. The composite construction has gained importance due to its ability to combine the advantage of steel and concrete. Reinforced concrete beams are used to transfer the imposed loads from slabs to walls and then to columns. A beam must have an adequate safety margin against bending stress and shear stresses so that it will perform effectively during its service life. Reinforced concrete structures being the most commonly used structures need proper design and utmost care in the joint construction. In reinforced concrete beams of usual proportions, when subjected to relatively high flexural stresses and low shear stresses the maximum principal tensile stress is given by the flexural stress in the outer fibre at the peak moment locations and results flexural cracks. On the other hand, in short span beams which are relatively deep subjected to high shear stresses and low flexural stresses results shear cracks or diagonal tension cracks. Due to this problem of conventional shear reinforcement, the use of independent inclined and horizontal bars in the high shear region are recommended.

In this paper, the effect of orientation and position of the different shear reinforcements in deep beams are verified. Beams with inclined stirrups were found to show more ultimate strength and less deflection than vertical and horizontal bar systems.

2. Hybrid Steel Trussed Concrete Deep Beam

The hybrid steel trussed concrete beam (HSTCB) represent a new structural solution for beams often utilized in light industrial building and seismic framed structures. In particular, hybrid steel trussed concrete beam is a typical Italian structural typology that is very wide spread because it represents an effective tool for light industrialization. In the hybrid steel trussed concrete deep beam (HSTCDB), the truss usually composed by a steel plate or a precast concrete plank working as bottom chord, a system of ribbed or smooth steel rebars welded to form the diagonals of the truss and coupled rebars used to form the upper chord. It could leads to a significant reduction in construction time and at the same time minimizes the risk of injury because no formwork or intermediate supports due to the presence of the bottom steel plate and the intermediate supports devices, as shown in Fig.1. Moreover, the construction details can be controlled well without the need of the in situ welding or tying. Finally, HSTCBs are able to cover large span.

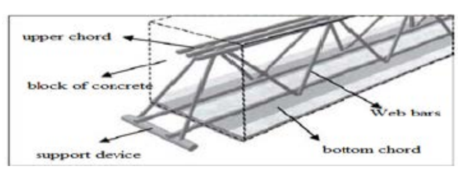

Fig. 1 beam topology.

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3. Objectives and Methodology

The main objective of the present study is to compare the strength of hybrid steel trussed concrete deep with conventional concrete deep beam in ANSYS 17.0. The Main objectives of the study are;

1. To study the effect of hybrid materials on strength of deep beams

The numerical analysis investigations were to be performed with commercial software ANSYS. This software is a suite of powerful engineering simulation programs, based on finite element method, which can solve problems ranging from relatively simpler linear analyses to the most challenging non-linear simulations. The analysis of a structure with ANSYS is performed in three stages.

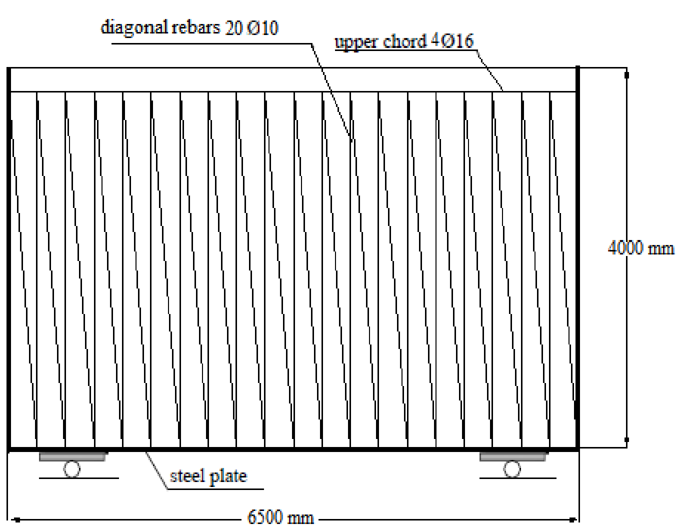
a) Pre-processing – defining the finite element model and environmental factors to be applied to it.

b) Analysis solver – solution of finite element model.

c) Post-processing of results like deformations contours for displacement, etc., using visualization tools.

4. Structural model and Material Property

ANSYS Workbench 17 was used to develop 3-dimensional finite element model. The hybrid steel trussed concrete deep beam and the conventional deep beam were designed for 4000 mm overall depth. It is composed of a metallic steel plate placed at the supports to protect the concrete. A three-point loading is provided with a simply supported boundary condition. Length of the beam L= 6500 mm and the width W= 400 mm.



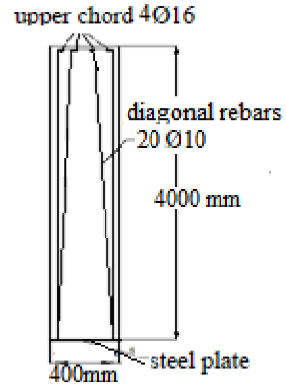


Fig. 2 Sectional drawing of steel trussed deep beam

The conventional deep beam is provided with 16 numbers of 16-mm diameter bars as positive reinforcement placed at the bottom layer of the tension zone at a zone depth of 700mm, 10-mm diameter at 325 mm as vertical reinforcement and 12-mm diameter as side face reinforcement. The steel trussed deep beam was provided with 4 numbers of 16- mm diameter bars at the top layer, an inner steel plate of 5mm thickness and 10-mm diameter rebars along the diagonal direction. Material properties are demonstrated in Table 1 and sectional drawing is shown in Fig. 2.

Table 1: Material properties

Material	Fe 415 steel	concrete	GFRP	CFRP
Modulus of elasticity (Pa)	2 E+11	3 E+10	3.1E+11	5.5E+11
Poisson's ratio	0.3	0.18	0.3	0.3
Density(kg/m^3)	7850	2300	2500	1700

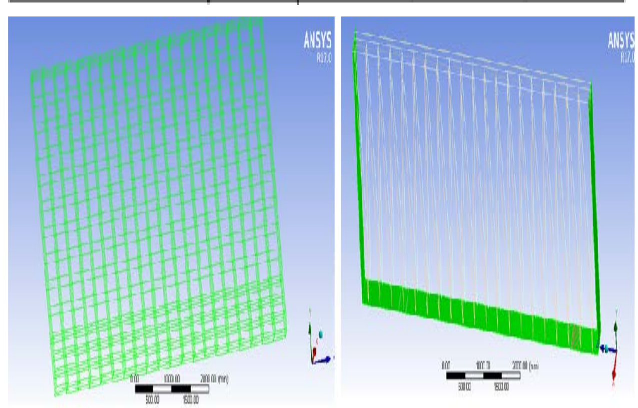


Fig. 3 Geometrical model of conventional deep beam and hybrid steel trussed concrete deep beam

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Fig.3. shows the geometrical model of hybrid steel trussed concrete deep beam and the conventional deep beam in ANSYS.

5. Finite Element Analysis

Depending on the type of physics involved (static structural, modal structural, harmonic, random vibration, response spectrum) provides several means to control the solution of the physics simulation. Deformation and stress is measured at mid-span of the beam from load-deformation diagrams by analytical results. Static Structural analysis determines the displacements and stresses of different hybrid materials. The hybrid steel trussed concrete deep beam and the conventional deep beam were modeled with different reinforcement pattern to investigate their strength. The basic details like cross sectional dimensions, number of rebars used are kept constant for all models. Each model are created and analyzed in ANSYS 17.0 software

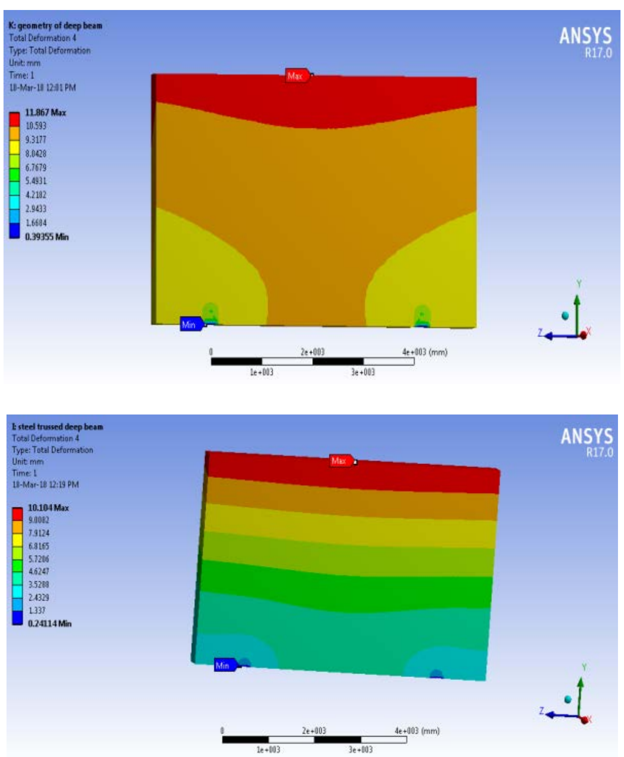

Fig. 4 Total deformation of conventional deep beam and hybrid steel trussed concrete deep beam

On comparing the results of total deformation on Fig.4, the conventional deep beam and the hybrid steel trussed deep beam shows 11.867 mm and 10.106 mm deformation.

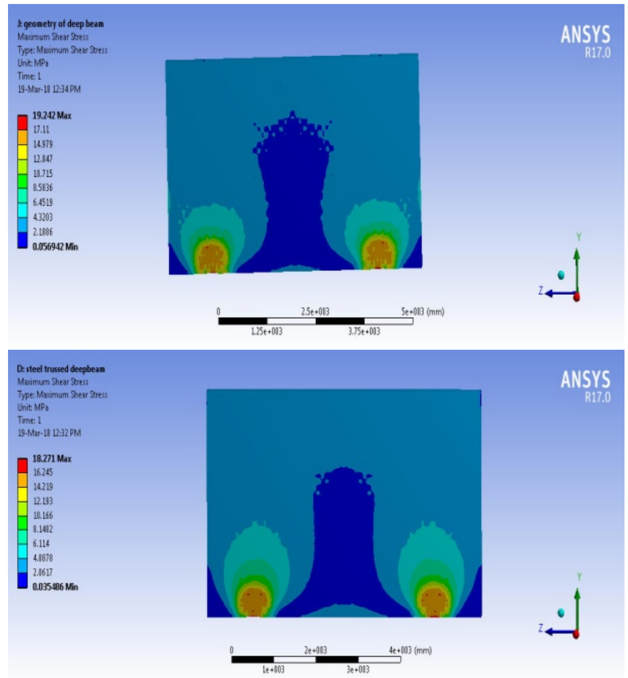

Fig. 5 Shear stress of conventional deep beam and hybrid steel trussed concrete deep beam

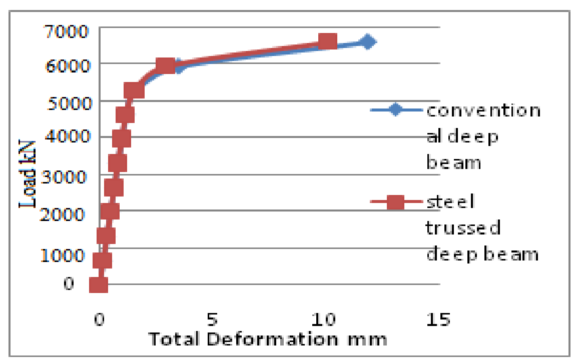

Fig. 6 comparing load- deflection graph

On comparing the results of shear stress on Fig.5, the conventional deep beam and the hybrid steel trussed deep beam shows 19.242 Mpa and 18.271 Mpa stress. From the Fig.6.the hybrid steel trussed deep beam shows higher strength than that of conventional deep beam.

6. Effect of Hybrid materials

Two models of hybrid steel trussed deep beam are created by varying steel plate with different FRP materials of 5mm thickness and analyzed in ANSYS 17.0 software. The FRP's are Carbon fiber (CFRP) and Glass fiber (GFRP).

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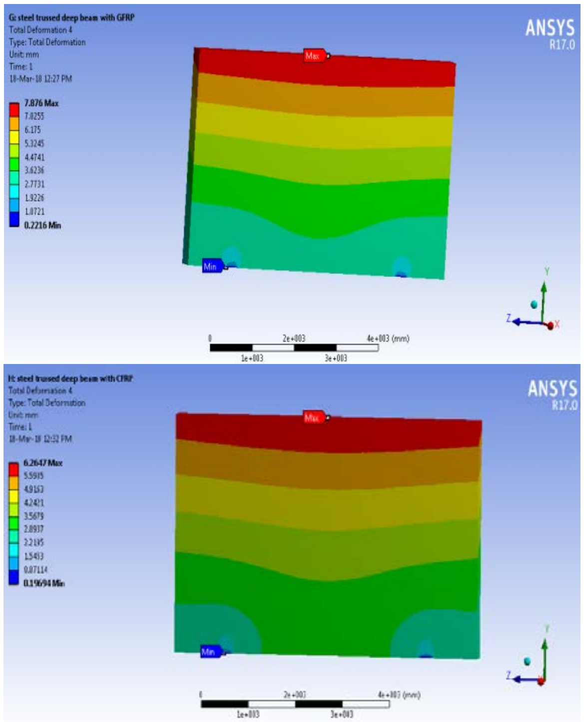

Fig. 7 Total deformation of hybrid steel trussed concrete deep beam with GFRP and CFRP

Fig.7. shows total deformation in which GFRP has 7.867mm and CFRP has 6.264mm compared with steel plate.

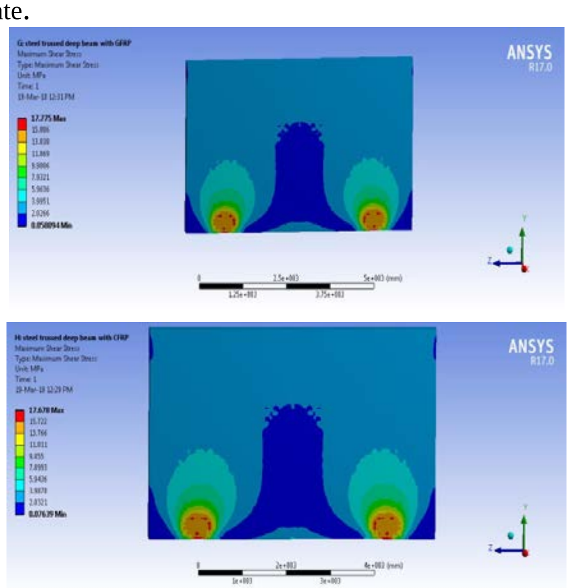

Fig 8 shear stress of hybrid steel trussed concrete deep beam with GFRP and CFRP

Fig.8. shows shear stress in which GFRP has 17.775 Mpa and CFRP has 17.678 Mpa.

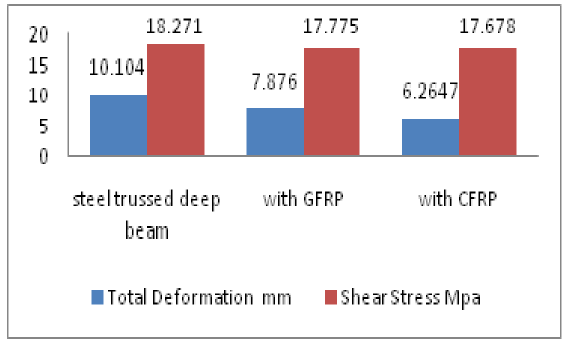

Fig.9. comparison of results of total deformation and shear

The CFRP fiber shows better results as compared with the GFRP in case of total deformation and shear stress, shown in Fig.9.

7. Conclusion

The finite element model was developed by using ANSYS 17 software. From the analysis, the result was obtained for both conventional deep beam and steel trussed deep beam. The hybrid steel trussed concrete deep beam has better Shear strength compared with conventional deep beam. The steel trussed deep beam gives 14.85% less deformation compared to conventional deep beam. The steel trussed deep beam gives 13.21% less shear stress compared to conventional deep beam. The steel trussed deep beam with CFRP plate gives less deformation and shear stress compared to steel trussed deep beam with GFRP and steel plate.

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