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Finite Element Analysis of Hollow Beams Strengthed With Frp Wrapping

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Abstract: ***In recent years, the structural applications of hollow core beams became widespread because of its advantages such as high strength, large energy absorption capacity, light weight, adequate ductility and concrete saving. The main objective of this study is to analyse the performance of reinforced hollow core beams strengthened with CFRP (Carbon Fibre Reinforced Polymer) wrapping. Experimental results revealed that the confinement of CFRP wrapping significantly enhanced the load carrying capacity, stiffness of hollow core beams. Numerical models were developed with the help of ANSYS software to validate the behaviour of hollow beams with CFRP wrapping.***

Index Terms: ***Carbon Fibre Reinforced Polymer, deformation, failure modes, Hollow beams***

I. INTRODUCTION

Nowadays the usage of concrete materials is vastly increasing due to the rapid growth in construction sector [1]. Stake holders are urged to practice many alternate ways which reduced the usage of concrete. Hollow beams are one of the techniques in which the usage of concrete is reduced in some extent. In RC beams concrete strength is not fully used at neutral axis [2]. So, this un-utilized concrete is removed to optimize the usage of concrete. Hollow beams are used at the place of the structural application in which the dead loads are not necessary. Strengthening the concrete structures is necessary to avoid damages due to deterioration and aging [3]. Strength of the concrete beams are increased by the introduction of reinforcement by the use of steel rods [4]. Further increase in strength is achieved by means of FRP (Fibre Reinforced Polymer) wrapping. Deterioration and aging are the main reasons for strengthening the RC structures. An ideal strengthening should not increase the dead loads and minimize disruption to the structure and its usage. FRP wrapping is a strengthening method which meets the above-mentioned requirements. Normally FRP strengthening is provided in various structures such as bridges and buildings due to their superior properties like high energy absorption, high strength-to weight ratio and high corrosion resistance. FRP is a new class of composite material which is made up of fibres and resins [4]. Compared to steel and concrete FRP is 1.5 to 5 times lighter and also it provides nominal increase in stiffness which significantly increases the structural strength of the concrete [5]. Durability against steel corrosion can be achieved in RC structures by FRP wrapping [6]. External confinement with the FRP is achieved by usage of resins. This paper attempts to study the behaviour of hollow beams strengthened with CFRP wrapping in addition to that the determination of the hollow area which provide optimized results also have been studied with the help of analytical models. ANSYS software is used to validate the analytical results.

II. SIGNIFICANCE OF THE WORK

The main target of this study is to determine the effectiveness of hollow section location and the effectiveness of CFRP wrapping with the help of load vs deflection measurement. The various cases assigned for this investigation are Hollow along neutral axis, Hollow below neutral axis, Hollow at neutral axis and hollow at centre of the beam. While steel fibre reinforcement the loading capacity is slightly increased in hollow beams further the addition of CFRP wrapping significantly increases the loading capacity of hollow beams. Hollow along neutral axis provides better performance compared with other cases.

III. SPECIMEN DETAILS

Test specimens were casted in the dimensions of 150x 200x 1500 mm and the mix proportions were 1:1.14:2.49 with the water to cement ratio of 0.40. M45 grade of concrete is selected for casting the specimens. Steel rods of 12 mm bar diameter was chosen for the reinforcement of the hollow beams. Beams are wrapped with Carbon fibre reinforced polymer using epoxy resins. The mechanical properties of CFRP is given in the TABLE I. The test specimens were modelled based on 5 cases in each case four types of beams were modelled. Control specimen is specified as CS, CS with Steel fibre is specified SF, Control specimen with FRP is specified as FRP.

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Table I
Mechanical Properties of CFRP

Sl. No	Property	Value
1	Density	1.75 g/cc
2	Tensile Strength	2550 MPa
3	Modulus of elasticity	120 GPa

Beam is extruded along the neutral axis named as HNA; Hollow space created above the neutral axis is named as HANA. Hollow space created below the neutral axis is named as HBNA. Hollow created at the centre of the beam is named as CB.

IV. FINITE ELEMENT ANALYSIS USING ANSYS

This paper adopts ANSYS software to study the behaviour of hollow beams wrapped with CFRP. ANSYS comprises two phases first one is pre-processing module which includes geometry creation and meshing, the second one is post processing module in this module static structure and solutions are generated depends on the loads applied over the beams [7]. FEA in ANSYS has two modes they are: batch and interactive [8]. Interactive mode visualizes the graphical mode of the structure built by the graphical user. Batch mode associate with the commands which is written by the programmer [9]. In this investigation both batch and interactive modes were used for the modelling of a solid beam with FRP wrapping [10]. RC beam is modelled by the graphical input commands and the FRP wrapping is done with the help of command mode [11]. Hollow beams are constructed in three phases. The first one is Geometry followed by modelling and solutions. Geometry involves 4 steps to construct a hollow beam.

Step 1: Set location of the axis.
Step 2: Sketch the beam structure with dimensions.
Step 3: Hollow space is introduced in the beam by extruding the appropriate location
Step 4: Finally, for loading tests, a plate is placed over the beam.
Step 5: Connections should be defined in this step to avoid separation of surfaces of the constructed beam.
Step 6: Meshing the beam structure to prepare for the loading process.
Step 7: Apply the forces and measure the deflections and tabulate them.
The forces are applied over the support and the deflections were recorded in the TABLE II.

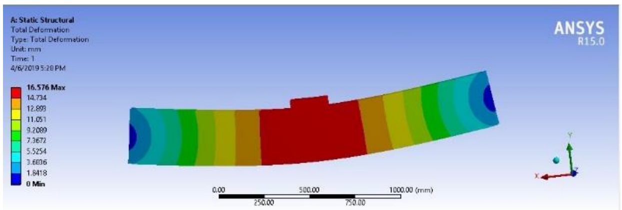


Fig. 1. Solid beam under load

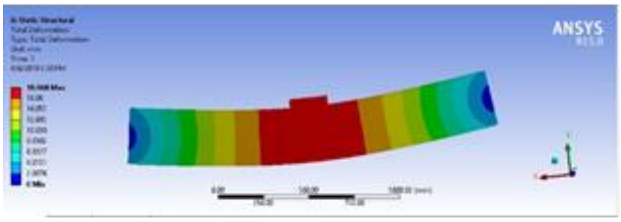


Fig. 2. Beam with SF subjected to load

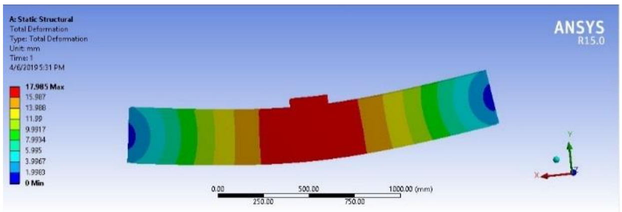


Fig. 3. Beam with FRP subjected to load

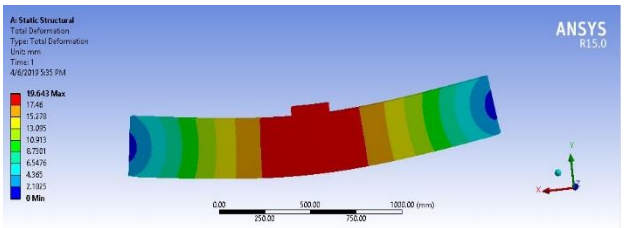


Fig. 4. Beam with SF & FRP subjected to load

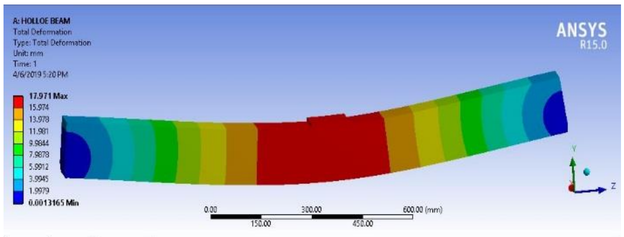


Fig.5. Hollow Beam subjected to load

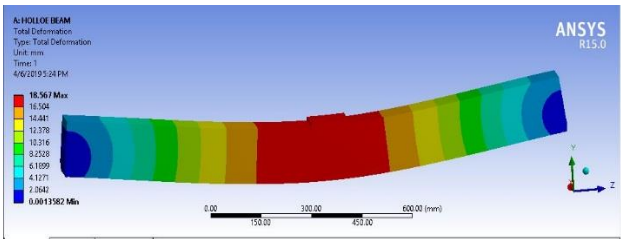


Fig.6. Hollow Beam with SF subjected to load

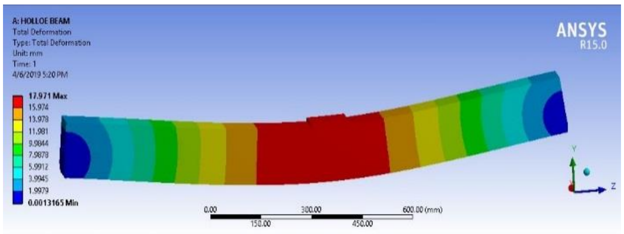


Fig.7. Hollow Beam with FRP subjected to load

Table II
ANSYS results for Loading Tests

Sl.No	Specimen Designation	First Crack Load (kN)	Ultimate Load (kN)	Deflection at first Crack (mm)	Ultimate Deflection (mm))
1	CS	28.56	64.21	1.87	16.57
2	SF	33. 34	65.15	1.40	18.06
3	FRP	29.68	63.80	1.56	17.98
4	SF&FRP	38.5	67.56	1.45	19.64
5	HNA	28.90	63.72	1.78	17.97
6	HNSF	32.34	64.12	1.67	18.56
7	HNFRP	28.98	61.66	1.75	17.98
8	HNSF&FRP	39.14	68.77	1.63	18.73
9	HANA	28.57	59.63	1.97	19.978
10	HASF	31.11	62.54	1.85	18.14
11	HAFRP	27.14	63.01	1.88	19.66
12	HASF&FRP	38.01	65.23	1.65	17.91
13	HBNA	27.94	60.63	1.96	20.26
14	HBSF	30.15	62.54	1.78	19.46
15	HBFRP	27.19	60.01	1.85	19.54
16	HBSF&FRP	37.99	67.23	1.75	18.86
17	HCB	28.14	61.36	1.9	20.10
18	HCBSF	31.78	62.57	1.78	19.60
19	HCBFRP	28.01	61.27	1.85	19.77
20	HCBSF&FRP	37.15	65.23	1.75	19.26

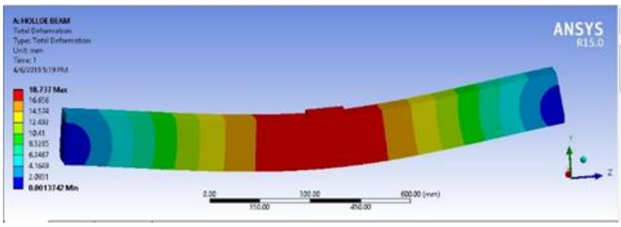


Fig.8. Hollow Beam with SF & FRP subjected to load

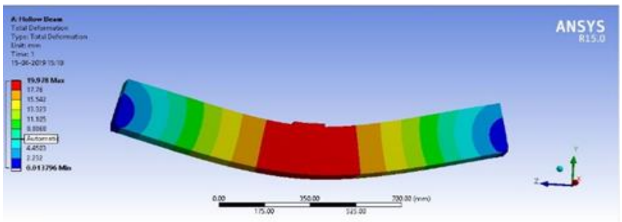


Fig.9. Hollow beam above neutral axis subjected to load

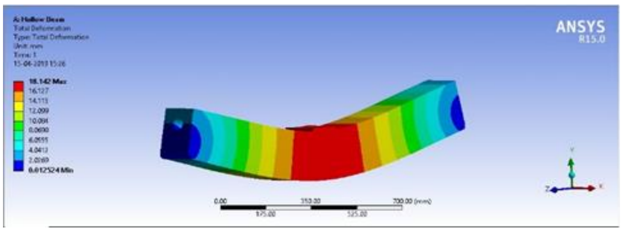


Fig.10. Hollow Beam Above Neutral Axis With SF Subjected To Load

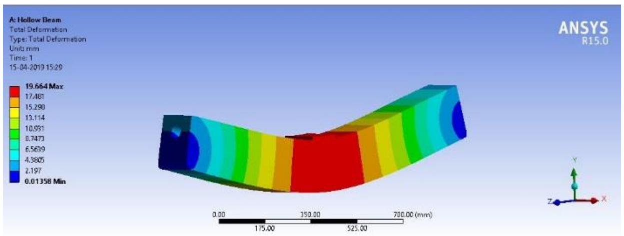


Fig.11. Hollow Beam Above Neutral Axis With FRP Subjected To Load

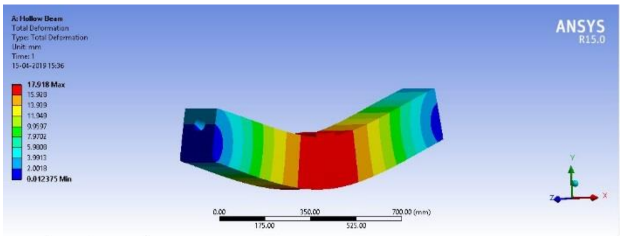


Fig.12. Hollow Beam Above Neutral Axis With SF&FRP Subjected To Load

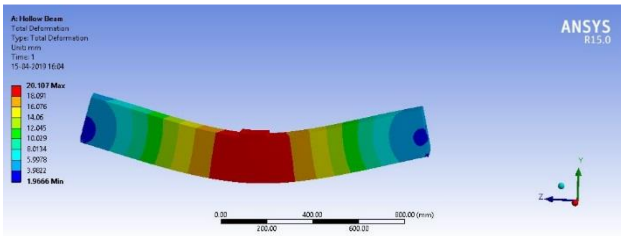


Fig.13. Hollow Beam Below Neutral Axis Subjected To Load

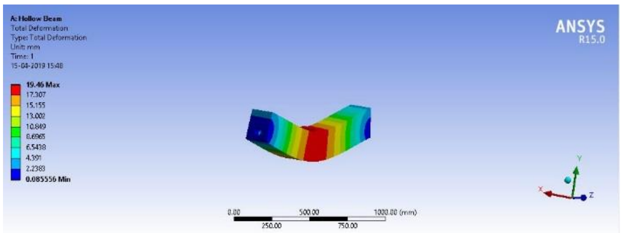


Fig.14. Hollow Beam Below Neutral Axis With SF Subjected To Load

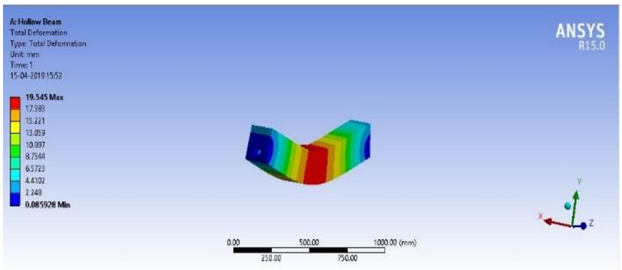


Fig .15. Hollow Beam Below Neutral Axis With FRP Subjected To Load

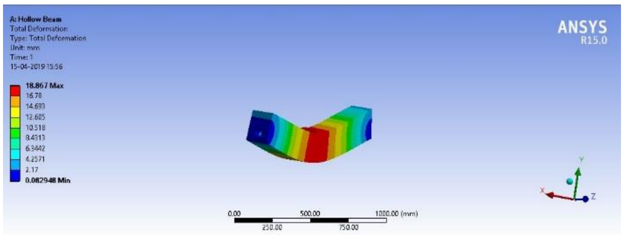


Fig.16. Hollow Beam Below Neutral Axis With SF&FRP Subjected To Load

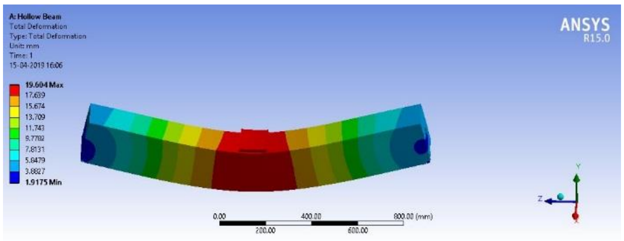
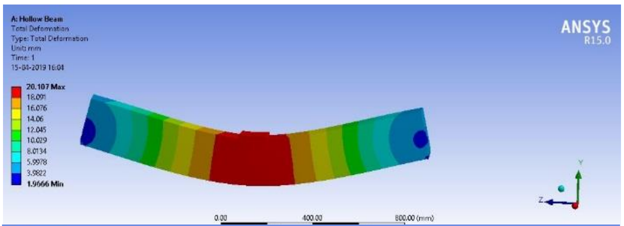
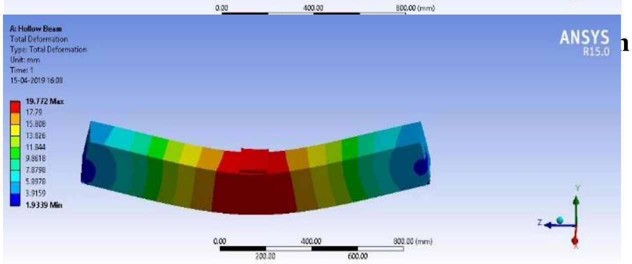


Fig.17. Hollow Along The Centre Of The Beam Subjected To Load





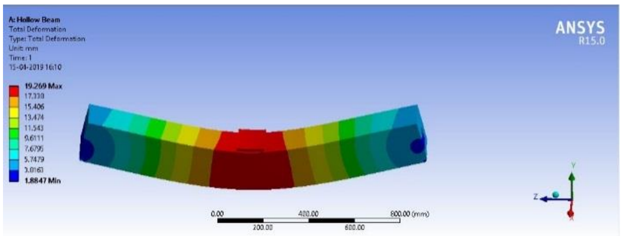


Fig.20 Hollow Along The Centre Of The Beam With SF & FRP Subjected To Load

V. RESULTS

The performance of the CFRP wrapping over the RC beam was analysed from the ANSYS results. From the simulation results and analysis, it is evident that the usage of CFRP in RC hollow beams significantly enhanced the shear capacity of the hollow beams. Normally steel fibres provide better strength properties this is further increased by providing FRP wrapping over the external surface of the RC hollow beams. The location of the hollow space also plays a major role in this investigation. From the analysis the hollow space at the neutral axis case provides higher strength compared to other cases. CFRP wrapping gives additional strength to the RC hollow beam this results the change in failure mode of beam.

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