EXPERIMENTAL AND ANALYTICAL INVESTIGAION ON PLAIN AND RC BEAMS WITH CFRP USING ANSYS

Sushit S. Babaji[1], Prof. Kiran M. Malipatil[2]

[1]*M. Tech Scholar KLE's Dr. MSSCET, Belagavi, Karnataka, India*
[2]*Asst. Professor, Dept. Of Civil Engineering, KLE's Dr. MSSCET, Belagavi, Karnataka, India*

---***---

Abstract - *Concrete is the most common material all over the world which is used in construction of structural and nonstructural elements. But it has less tensile strength and less ductility. It has compressive strength of 10 to 15 percentage. Engineers and researchers have been trying to overcome these drawbacks of concrete from many years by using composite materials like FRC and RCC. Fiber Reinforced Concrete is the recent method to successfully increase the tensile strength of concrete, cracking characteristics, fatigue, impact resistance, toughness, ductility. The FRC can be achieved by either by mixing the fiber in the concrete or by wrapping the FRP sheets on the concrete elements. In the present study an attempt has been made to compare performance of the plain and reinforced concrete beam with the concrete beams wrapped with layers of carbon fibers. The laboratory tests are conducted on beams subjected to flexural loading and the analytical study is carried out using the FEA software package ANSYS 15.0.*

Key Words: Fiber Reinforced Concrete, Finite Element Analysis.

1. INTRODUCTION

All affable building structures are at first composed relying upon certain configuration criteria, for example, plane loads, admissible anxieties and so forth. Be that as it may, harm because of an amazing occasion is constantly conceivable in a structure amid its configuration life. Some of the time, undetected and un-repaired harm may prompt auxiliary failure requesting excessive repair and a tremendous loss of lives. The benefits of FRP composites over the customary materials for retrofitting of basic and nonstructural components are astounding consumption resistance, weariness resistance, high quality to weight proportion, high solidness to weight proportion, nearby adaptability to utilize and least changes in the part estimate subsequent to retrofitting. FRP composites are electrically and attractively dormant and alluring for fortifying structures where the sign impedances have to be stayed away from.

1.1 CARBON FIBRE REINFORCED POLYMER(CFRP)

FRP composites have discovered broad applications in the ground of Structural Engineering because of their favourable properties, for example, high quality to weight proportion and great erosion resistance. An expansive number of strengthened cement (RC) segments worked in the previous are deficient toward meeting present seismic configuration prerequisites as far as both quality and ductility. From some years, engineers have been investigating alternates to steel confinement to lessening more costs of maintenance and repair of damaged or insufficient structures. The composite materials that are shaped by mix of 2 or more unmistakable materials in tiny scale has increased boundless use in retrofit for auxiliary frameworks. FRP materials are generally new class of composite material produced by strands and saps, which were initially used in mechanical and aeronautical building created in the mid of 1940's for various kind of utilizations. The mix of high quality and more firmness basic filaments with less weight naturally safe polymers produces composite materials with preferable mechanical properties and solidness over both of the constituents alone.

FRP plates and/or sheets can be clung to the outside of solid structures with high quality glues to give ductile or restricting support as a supplement gave by inner strengthening steel. The advantages are twofold: (1) decreasing the effect of other debasement forms because of forceful natural conditions, and (2) upgrading the quality of cement because of the imprisonment of FRP.

1.2 CFRP AS STRUCTURAL MATERIAL

The approach of the FRP composites in the field of development and basic applications was in the mid 1940's. The most punctual FRP materials utilized glass strands which were inserted in polymeric pitches. The mix of high quality, high solidness basic filaments with ease, light weight and environment safe polymers have brought about composites which have preferable mechanical properties over any of their constituents. FRP being exceedingly costly has beforehand limited their application to aviation and resistance purposes alone.

2. EXPERIMENTAL INVESTIGATION

Present study investigates to comparing the performance of the beams where carbon fibres have been wrapped in different configurations, with the plain beams. Following sections give the details of the present investigation.

Two different types of specimens have been tested. The details of the test specimen are as shown in the following pictures, all dimensions shown are in mm. OPC, coarse aggregate [10 mm down size], N sand passing through a 4.75 mm sieve were used for the mix. The beam specimens were casted using a 1:1.77:2.93 and W/c ratio of 0.5. The specimens were demoulded after 24 hr and kept for curing in a curing tank for 28 days. The beams were then kept for 24 hour under room temperature.

3.ANALYTICAL STUDY

ANSYS is a general Finite element program; it has a vast variety of components. Each component is distinguished by its name, most extreme of 8 characters, for example, Solid65 alludes a gathering mark Solid and an exceptional recognizing number 65. In the accompanying segments, components that are utilized in the demonstrating of the issue under thought have been talked about.

In ANSYS phrasing, model era as a rule tackles the smaller significance of creating the nodes and elements that speak to the spatial volume and network of the genuine framework. In this way, demonstrate era in this discourse implies the procedure of characterizing the geometric arrangement of the model's nodes and elements. For strong demonstrating the model can be made inside the ANSYS or it can be foreign from PC supported configuration (CAD) framework. In the present study the section model was implicit the ANSYS 10.0 utilizing the instruments accessible as a part of PREPROCESSOR. The created model was meshed utilizing mapped mesh command which helps as a part of controlling the quantity of elements. Modification of mesh expands precision of recreation likewise expanding the investigation time. The size of the mesh fluctuate with model measurement. Component credits was doled out the particular elements. FRP segment were meshed with SOLID46.

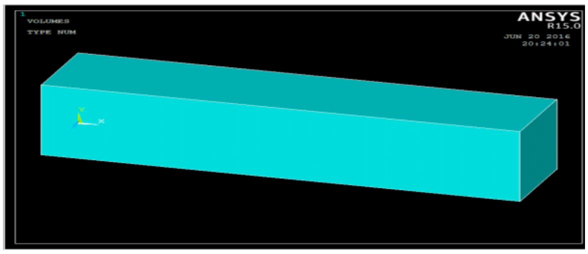

Fig-1 ANSYS Model of the beam.

In the model, the Y-axis of the coordinate system coincides with the longitudinal axis of the beam. The boundary conditions are: 1) Bottom end of the beam is fixed i.e. all the 6 DOF on that surface are constrained. 2) An unchanging displacement is applied at the top surface nodes in the axial direction. The load is applied on the beam at two points according to meshing. Then the applied loads are increased till the beam fails flexurally.

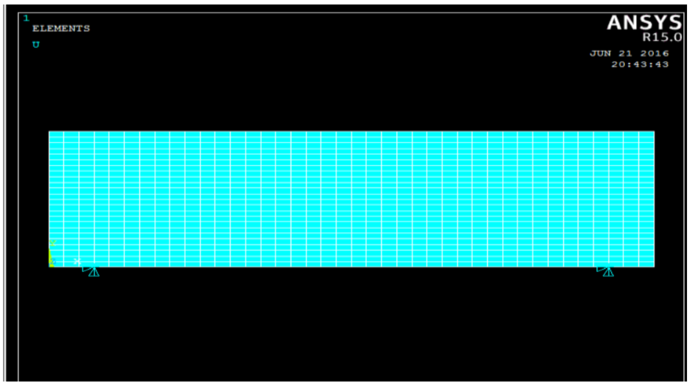

Fig-2 Applying supports to the model

After applying the load the model is solved by solve command and results are obtained from the postprocessor command. When the load applied is solved the displacement of the beam is shown as in below fig.

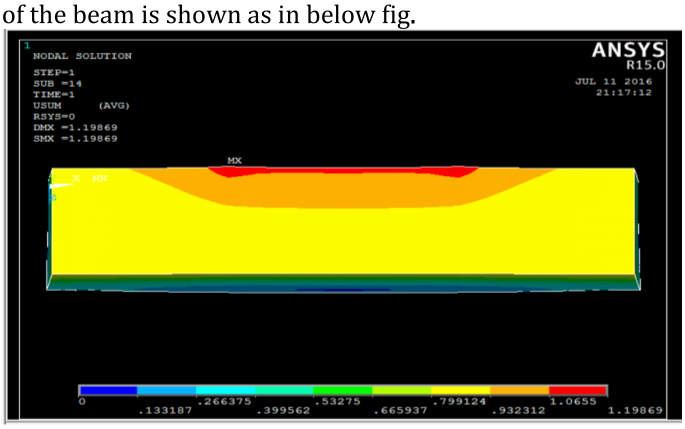

Fig-3 stress distribution in concrete

4 RESULTS

4.1 Load and Deformation

The deformation of concrete beams increases with increase in flexural load during the test and it was compared with analytical study. Charts below shows the results of the tests for different specimen.

Table-1 Load - Deformation Values of Unconfined Beam

Sl.No.	Experimental		Analytical	
	Load (KN)	Deformation (mm)	Load (KN)	Deformation (mm)
1	0.00	0.00	0.00	0.00
2	10	0.80	10	1.19
3	20	1.15	20	2.34
4	30	1.4	30	2.74
5	40	1.73	40	2.99
6	50	2.35	50	3.18
7	58	3.30	58	4.57

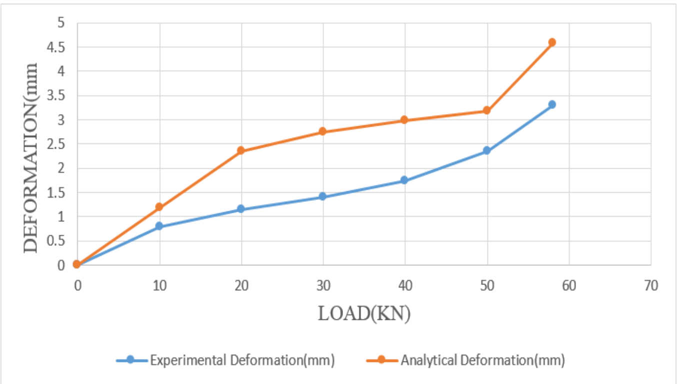

Chart-1 Load v/s Deformation Curves for Unconfined Beam.

Table-2 Load - Deformation Values of FRP Beam

Sl.No.	Experimental		Analytical	
	Load (KN)	Deformation (mm)	Load (KN)	Deformation (mm)
1	0.00	0.00	0	0
2	10	0.50	10	0.63
3	20	1.27	20	1.32
4	30	1.85	30	1.96
5	40	2.45	40	2.57
6	50	2.85	50	3.12
7	60	3.10	60	4.2
8	70	3.51	70	5.41

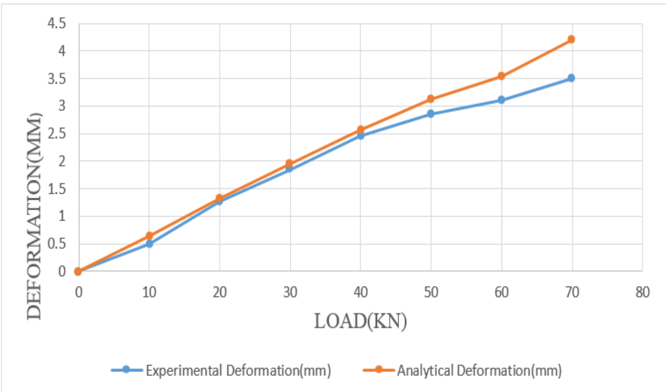

Chart-2 Load v/s Deformation Curves for Single Layered CFRP Beam

Table-3 Load - Deformation Values of Reinforced Concrete Beam

Sl.No.	Experimental		Analytical	
	Load (KN)	Deformation (mm)	Load (KN)	Deformation (mm)
1	0	0	0	0
2	10	1.1	10	0.478
3	20	1.4	20	0.84
4	30	1.8	30	1.16
5	40	2	40	1.83
6	50	2.2	50	2.46
7	60	2.55	60	2.711
8	70	2.8	70	3.23
9	80	3.2	80	3.32
10	90	3.8	90	4.35

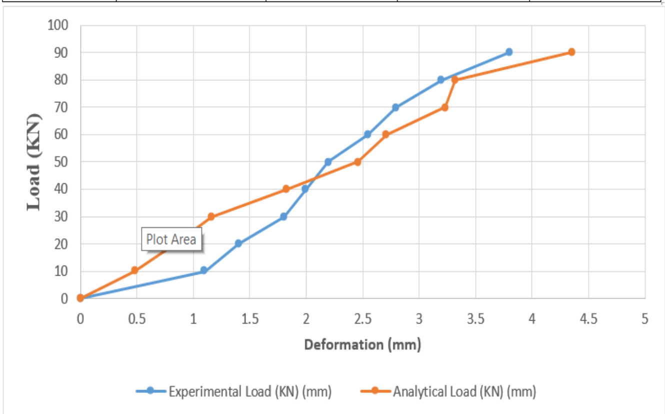

Chart-3 Load v/s Deformation Curves for Reinforced Concrete Beam

Experimental results for both RCC and FRP beam as given in chart 2 and chart 3. Along with experimental results the RCC model is validated with Load required for first crack to appear. When the depths of the CFRP confined beams are decreased in order 300mm to 250mm and 200mm the deformation of the beams increases with respect to the depths decreased. As the depth of the beam is increased the load carrying capacity of the beams also increases.

Table-4 Load - Deformation Values of Concrete Beams Confined with CFRP for different depths of beam

SL.	300 mm depth		250 mm depth		200 mm depth	
NO.	LOAD (KN)	DEFORMATION (mm)	LOAD (KN)	DEFORMATION (mm)	LOAD (KN)	DEFORMATION (mm)
1	0	0.00	0	0	0	0
2	10	1.50	10	0.77	10	0.45
3	20	1.90	20	1.43	20	1.88
4	30	2.25	30	2.48	30	2.44
5	40	2.45	40	2.62	40	3.77
6	50	2.85	50	3.42	50	4.94
7	60	3.10	60	4.58		
8	70	3.51				

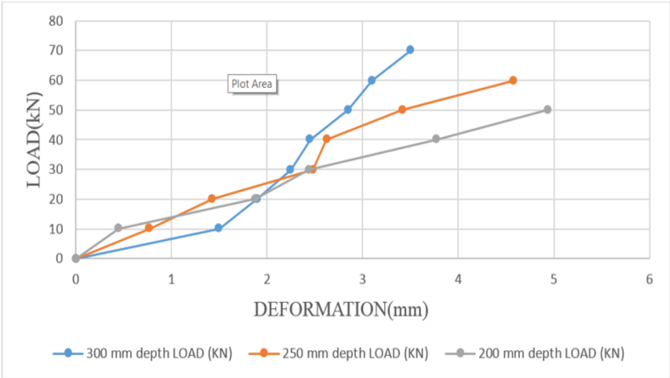

Chart-4 Load v/s Deformation Curves for Single Layered CFRP Beams with different depths.

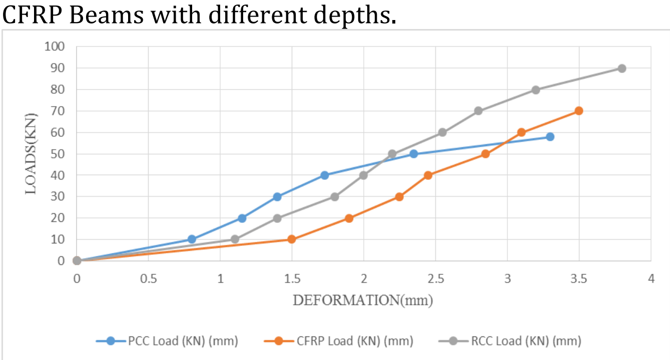

Chart-5 Load-Deformation Characteristics of various Specimens.

From above figures it can be seen that the carbon FRP sheets effectively increases the load carrying capacity of the concrete beams. From the fig. 6.3 and 6.4 it can be observed that the confinement not only increases the load carrying capacity of the specimens but the deformation of the beam is also controlled.

4.2 STRESS INTENSITY FACTOR (SIF)

In a structure there are three types of modes of crack propagation. They are Tensile, shear and axial. These are the forces which causes these crack and their propagation. The moment by the external load creates the Mode I crack in a RCC beam. The axial force along shearing force induced by steel bars create Mode II crack propagation. In this paper stress intensity factor related to Mode I cracks are been studied. Let us consider three point bending RCC beam. This beam creates moment M. The external moment M, induces Mode I cracks having stress intensity factor as follows:

$$K_I = M/d^{2/3}B \; Y_M(\xi)$$

Where

M= external moment in N mm,
d = depth in mm,

B = width of the beam in mm.

$Y_M(\xi)$ is given by the equation
$Y_M(\xi)= 6(1.99\xi2 - 2.47\xi2 + 12.97\,\xi2 - 23.17\,\xi2 + 24.80\xi^{9/2})$

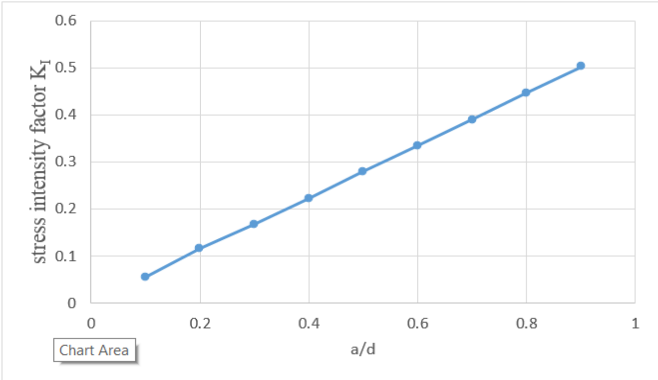

Chart-6 Stress intensity factor for beam with varying depth

5. CONCLUSIONS

- By laminating FRP sheets on the base of the plain concrete beam the deflections are increased as compared to the plain concrete beam when the flexural load is applied as shown in fig 6.7. The results vary by 8%.
- On comparing both FRP laminated plain concrete beam and reinforced concrete beam it can be seen that the deflections in FRP laminated concrete beams have less deflections as compared to RCC beam. But has good ductility as steel as shown in fig 6.7.
- With positive values of crack by depth ratio the stress intensity factor values increases for RC beam.
- Results indicate that the strength capacity of beams improved significantly as a result of the action of the transverse weaves of the composite fabric. Transverse elements enhanced the compressive capacity of the compression zone through confinement action.
- The one layer CFRP composite laminated at base of the beam increased the flexural strength of the plain concrete beam by 20%.

- It is also observed that as the plain concrete beam is laminated with one layer CFRP sheet at the base increases its stiffness and strength.

- In CFRP beams by decreasing depth the rate of deflection increases as shown in the fig 6.4. The deflections of beams having depth 300mm and 250mm varies by 24% and deflections of beams having depth 250mm and 200mm varies by 8%, deflections of beams having depth 300mm and 200mm varies by 28.5%.

REFERENCES

1. A Rama chandra murthy∗,G. S. Palani and Nagesh R Iyer, "State-of-the-art review on fracture analysis of concrete structural components", Vol. 34, Part 2, April 2009.
2. J.C. Walraven, "Fracture mechanics of concrete and its role in explaining structural behaviour", Delft University of Technology, The Netherlands.
3. Mangesh Dilip Ratolikar, M Chandra Sekhar Reddy, T Ravi Theja, Chintapatla Siddhartha, "Crack Detection for Various Loading Conditions in Beam Using Hilbert – Huang Transform", Volume 12, Issue 1 Ver. II (Jan- Feb. 2015).
4. M. Reza Esfahani, M. Reza Kianoush. Axial compressive strength of reinforced concrete columns wrapped with fiber reinforced polymers. IJE Transactions B: Applications 6 - Vol. 18, No.1, April 2005. pp1-11.
5. Mieczyslaw Kaminski, Tomasz Trapko. Experimental behaviour of reinforced concrete column models strengthened by CFRP materials. Journal of Civil Engineering and Management, 2006, Vol XII, No 2, pp109–115.
6. Pankaj Charan Jena , Dayal R. Parhi , G. Pohit Theoretical, "Numerical (FEM) and Experimental Analysis of composite cracked beams of different boundary conditions using vibration mode shape curvatures", vol 6, no 2, apr-may 2014.
7. Prof. J. M. Chandra Kishen Professor, "Quantification of Damage for Residual Life Assessment of Reinforced Concrete Infrastructures", Department of Civil Engineering, Indian Institute of Science, Bangalore, March 2012.
8. Reji John and Surendra P. Shah, "Mixed-mode fracture of concrete subjected to impact loading". Members, ASCE. 1990.
9. Saifullah, M. Nasir-uz-zaman, S.M.K. Uddin, M.A. Hossain and M.H. Rashid, "Experimental and Analytical Investigation of Flexural Behavior of Reinforced Concrete Beam" Vol: 11 No: 01 (Feb 2011).
10. Trisha Sain 1, J. M. Chandra Kishen, Associate Member, ASCE. "Damage and residual life assessment of structures using fracture mechanics", 16th ASCE Engineering Mechanics Conference July 16-18, 2003, University of Washington, Seattle
11. T. Sain & J.M. Chandra Kishen Dept. of Civil Engineering, "Probabilistic assessment of fatigue crack propagation in concrete", Indian Institute of Science, Bangalore 560 012, India.
12. Zdenek P. Bazant and William F. Schell, "Fatigue Fracture of High-Strength Concrete and Size Effect", October 1993.
13. IS.10262-2009, Concrete mix proportioning guidelines by Indian standard.