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"Structural Analysis of Reinforced Concrete beams Laminated With and Without Fiber Reinforced Polymer"

Milan Motta[1], Rahul Pachori[2], Yashesh Ahirwar[3]

Sr. Asst. Prof., Mechanical Engineering Department, Indur Inst. of Engg & Tech, Siddipet, India [1, 2, 3]

Abstract: As Hundreds of new materials appear on the market each month, each of these materials has its characteristics, applications, advantages, limitations and cost. Thus, the task of knowing the properties and behavior of all types numerous studies has been carried out. Life cycle assessment has become an important tool for determining the overall performance of component. So, nonlinear Finite Element Analysis (FEA) has been carried out in this paper to simulate the behavior of failure modes of reinforced concrete (RC) beams strengthened in flexure by fiber reinforced polymer (FRP) laminates. Two beams were modeled in fem software using ANSYS. In those two beams, one beam is control beam without FRP and other beam is Glass Fiber Reinforced Polymer (GFRP) strengthened beams. From the analyses the load deflection relationships, maximum deformation, factor of safety, von-misses stresses, crack pattern, first crack load and ultimate load was obtained and compared with the experimental results available in literature. The load deflection plots obtained from numerical studies show good agreement with the experimental plots. There was a difference in behavior between the RC beams strengthened with and without GFRP layers.

Key Words: Fiber Reinforced Polymer, FEA, Structural Analysis, Reinforced Concrete.

I. INTRODUCTION

Composites are multifunctional material systems that provide characteristics not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form. Specificity or the laws which give it and which distinguishes it from other very banal, meaningless mixtures. The application of fiber reinforced polymers as external reinforcement has received much attention from structural engineering. FRP laminates have gained popularity as external reinforcement for the strengthening or rehabilitation of reinforced concrete structures. Externally bonded FRP laminates and fabrics can be used to increase the flexural strength of reinforced concrete beams. Flexural strengthening of beams, however, is likely to be more problematic when they are cast monolithically with slabs. FRP composites applied to the reinforced concrete members provide efficiency, reliability and cost effectiveness in rehabilitation. Experimental based testing has been widely used as a means to analyze individual elements and the effects of concrete strength under loading. While this is a method that produces real life response, it is extremely time consuming and the use of materials can be quite costly. The use of finite element analysis to study these components has also been used. Amer Ibrahim [1] performed Numerical analysis on RC beams by ANSYS finite element program and results show that the general behavior of the finite element models represented by the load-deflection curves at mid span show good agreement with the test data. They also conclude that the load carrying capacity of the Flexure strengthening beam predicted by the finite element analysis is higher than that of the control beam. Saifullah [2] performed destructive test on simply supported beam in laboratory and load-deflection data of that under RC beam. They compared both the computer modeling and experimental data and found that computer based modeling is can be an excellent alternative of destructive laboratory test with an acceptable variation of results. Jayajothi [3] carried out the nonlinear Finite Element Analysis of Reinforced Concrete (RC) beams strengthened in flexure and shear by Fibre Reinforced Polymer (FRP) laminates and they found that the ultimate load carrying capacity of all the strengthened beams is higher when compared to the control beams and general behaviors of the FE models show good agreement with observations and data from the experimental tests. Patil [4] described analysis of deep beams subjected to two points loading with different span to depth ratios using Non-linear FEM. They found that the smaller the span/depth ratio, the more pronounced was the deviation of strain pattern at mid section of the beam. As the depth of the beam increases the variation in strength, flexural steel and deflection were found to be more experimentally than the non-linear finite element analysis.

II. MATERIAL CHARACTERIZATION

From the available literature survey the Cement (Ultratech Cement) properties are shown below:

The physical properties of cement such as Initial and Final setting time are 170 and 270 minutes. Amount of Fly ash content in the cement is 28%. Fine Aggregates: Locally available river sand was used as fine aggregate as per IS 383: 1970 and their properties are given below.

TABLE I PROPERTIES OF RIVER SAND

Properties	Results of Natural Sand
Bulk Density (kg/m^3)	1.23
Specific Gravity	2.56
Fineness Modulus	3.20
Water Absorption (%)	1.4

Coarse Aggregate**:** Crushed angular aggregate with maximum grain size of 20 mm and used as coarse aggregate as per IS 383: 1970. Their properties are bulk density 1.34 kg/m3, specific gravity and fineness modulus was found to be 2.74 and 4.5, respectively.

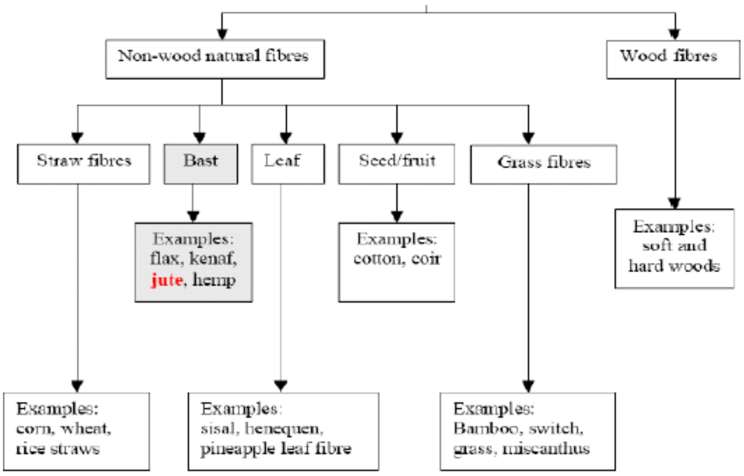

Fig. 1: Classification of Natural Fibers can be used as reinforcement cement

TABLE II MIX DESIGN PROPERTIES

Volume of Concrete	Cement	Water	Fine Aggregate	Course Aggregate
By weight (kg/m3)	394.32	197.16	669.53	1121.8
By volume	1.00	0.50	1.70	2.85

III. LITERATURE SURVEY

Harish et al. [2] developed coir composite and mechanical properties were evaluated. Scanning electron micrographs obtained from fracture surfaces were used for a qualitative evaluation of the interfacial properties of coir /epoxy and compared with glass fibers. Wang and Huang [1] had taken a coir fiber stack; characters of the fibers were analyzed. Length of the fibers was in the range between 8 and 337 mm. The fibers amount with the length range of 15~145 mm was 81.95% of all measured fibers. Weight of fibers with the length range of 35~225 mm accounted for 88.34% of all measurement. The average fineness of the coir fibers was 27.94 tex. Longer fibers usually had higher diameters. Composite boards were fabricated by using a heat press machine with the coir fiber as the reinforcement and the rubber as matrix. Tensile strength of the composites was investigated. Nilza et al. [3] use three Jamaican natural cellulosic fibers for the design and manufacture of composite material. They took bagasse from sugar cane, banana trunk from banana plant and coconut coir from the coconut husk. Samples were subjected to standardized tests such as ash and carbon content, water absorption, moisture content, tensile strength, elemental analysis and chemical analysis.
Bilba et al. [4] examined Four fibers from banana-trees (leaf, trunk) and coconut-tree (husk, fabric) before their incorporation in cementitious matrices, in order to prepare insulating material for construction.
Conrad [5] investigates the connection between the distribution of lignin and pectin and the loading of Pb and Zn on coir. The coir consisted mainly of xylem and a fiber sheath. The lignin was evenly distributed in the cell walls of the

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fiber sheath, but in the xylem, there was no detectable content in the compound middle lamella, and a smaller content of lignin in the secondary walls than in the walls of the fiber sheath. The only detectable content of pectin in the fiber sheath walls was in the middle lamella, cell corners and extracellular matrix, while in the xylem, the pectin was almost evenly distributed in the wall, with a higher concentration in the middle lamella and cell corners.

IV. GEOMETRY CONSTRAINTS

The beams were modeled as volumes by using Catia V5-R20 Version. The model is 2000 mm long, with a cross-section of 230mm x 300mm. The reinforcement at the bottom of beam is 2-12 mm diameter and the reinforcement at top of beam is 2-10 mm dia.

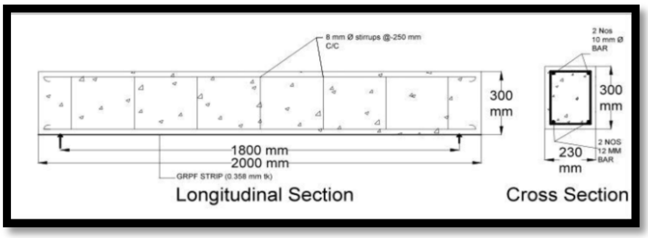

Fig. 2 (a): Typical details of test beam

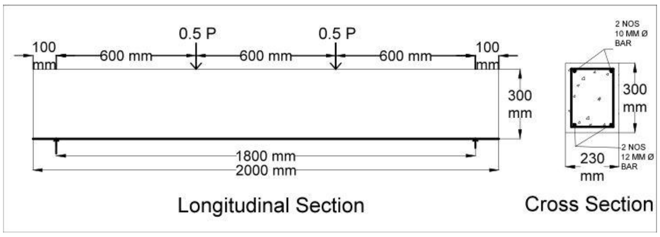

Fig. 2 (b): Details of Loading and Support Condition

V. METHODOLOGY

Firstly the solid model is prepared in Catia Environment and then imported into ANSYS V-12 in IGES format. The ultimate goal of this work is to identify the loop points for both the beam and then performed the comparative study. The iterations will be continue till the solution is now comes in the safer zone.

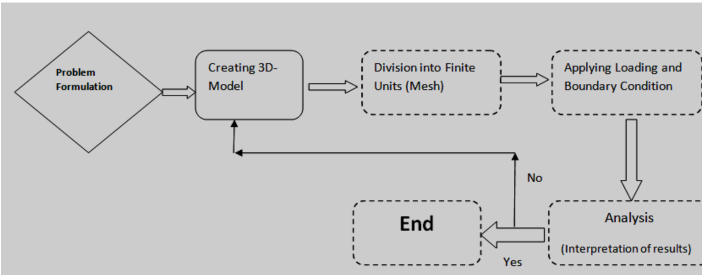

Fig. 3: Flow chart of process used

VI. ANALYSIS METHODOLOGY

In our work, two beams were modeled and analyzed using ANSYS software. In two beams, one beam was control beam and one beam was FRP Strengthened beam in bottom single strip.

TABLE II ELEMENT TYPE FOR BEAM

Element Type	ANSYS Element
Concrete	Solid 65
FRP Composites	Solid 46
Steel Reinforcement	Link 8

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Material Model Number	Element Type	Material Properties		
1	Solid 65	Linear Isotropic		
		EX	25000	N/mm2
		PRXY	0.2	
		Multilinear Isotropics		
		Point	Strain (mm/mm)	Stress (N/mm2)
		1	0.0003	7.5
		2	0.00054	12.68
		3	0.00124	22.39
		4	0.00184	24.91
		5	0.00237	25
		Concrete		
		Open Shear Coeff.		0.3
		Closed Shear Coeff.		1
		Uniaxial Cracking Stress		3.58
		Uniaxial Crushing Stress		-1
2	Solid 46	Linear Isotropic		
		EX	76000	N/mm2
		PRXY	0.28	

The control beam (CB) and Bottom Single Strip beam (BSS) is of size 2000 x 230 x 300 mm. Element was used for analysis purpose which is shown in table. Design variable are defined using these shapes. Two responses namely mass and stress are defined. The design constraints is design in the form of stress and the upper limit of stress is set to identify, In order to have required factor of safety on yield strength as per Soderberg theory.

VII. CREATION OF 3D MODEL

The first step is that we have to generate the computer graphical model of the given component which will represent the original component, same consideration have been considered during the modeling of the component for example same material properties, loading and boundary condition etc. Based on real dimensions following model is generated by using the CATIA V5-R20 version modeling software

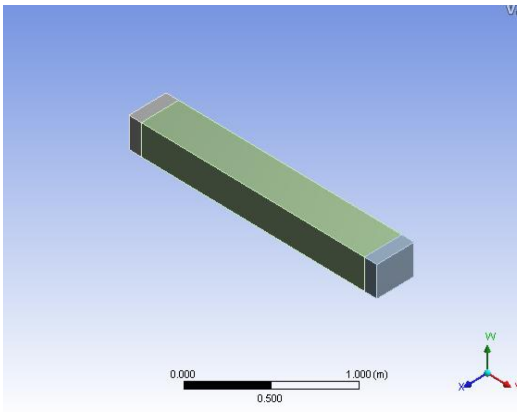

Fig. 4: Solid model of Beam

A. Meshing

A Finite Element Analysis requires meshing of the model. In other words, the model is divided into a number of small elements. The bond strength between the concrete and steel reinforcement should be considered. To provide the perfect

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bond, the link element for the steel reinforcing was connected between nodes of each adjacent concrete solid element, so the two materials shared the same nodes.

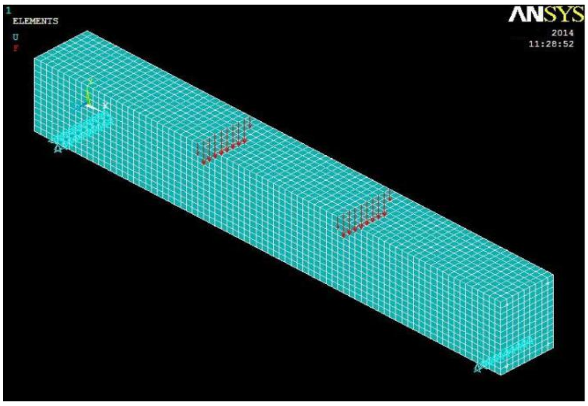

Fig. 5: Meshed Geometry

Analyses were carried out at room temperature. The testing arrangement was shown in figure. Two point loads were applied on Control Beam (CB) and Bottom Single Strip Beam (BSS) of span 2m through hydraulic jack of capacity 1000 KN.

VIII. RESULT AND DISCUSSION

Based on the analytical results and observations, it could be concluded that the ultimate load carrying capacity of the strengthened beam (With FRP) is higher when compared to the control beam (Without FRP). As per our design, beam has failed in flexure region under the application of two point load in Control Beam.

A. Deformation Pattern

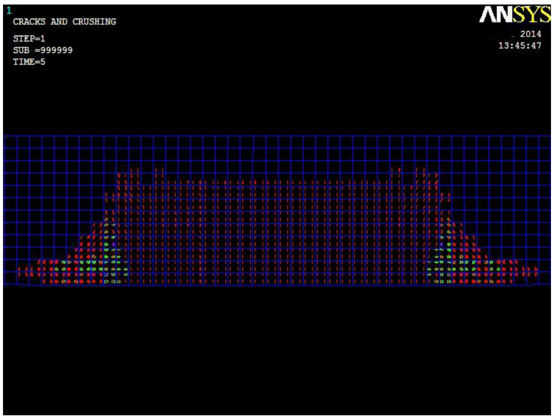

Fig. 4 (b): Deformation pattern in strengthened beam

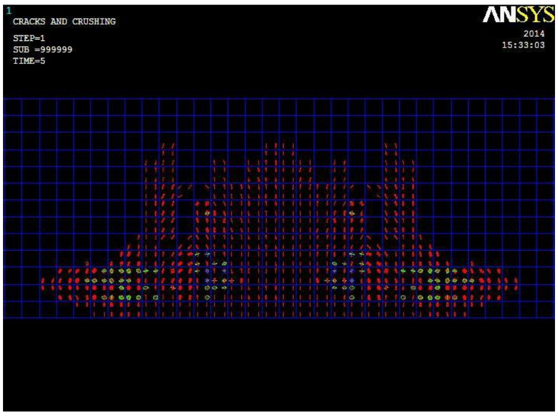

Fig. 4 (a): Deformation pattern in control beam

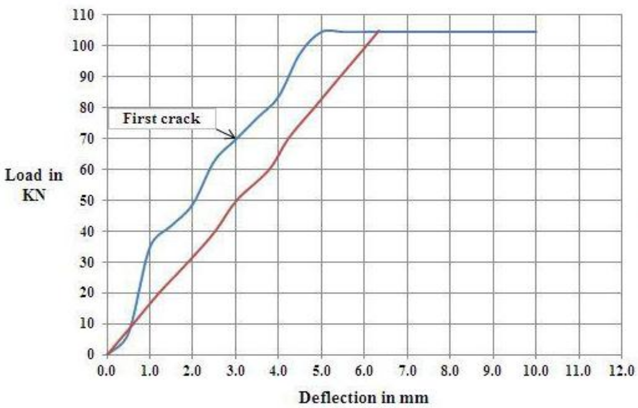

Fig. 5.1: Deformation pattern in control beam

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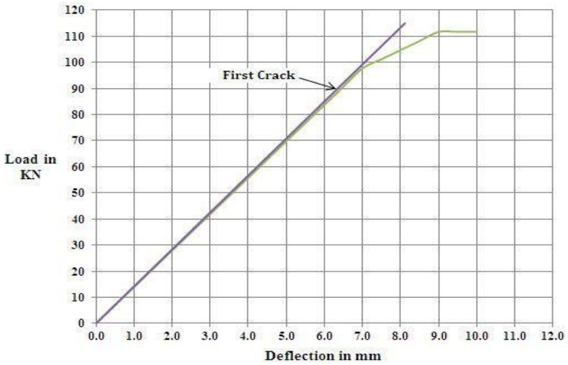

Fig. 5.2: Deformation pattern in strengthened beam

B. Total Deformation

Maximum deformation is highly induced in the beam without FRP as compare to beam with FRP coated. Higher stresses are built up in the Beam without FRP as compare to with FRP coated beam for the same loading condition. Beam without FRP is much strained as compare to beam with FRP coated

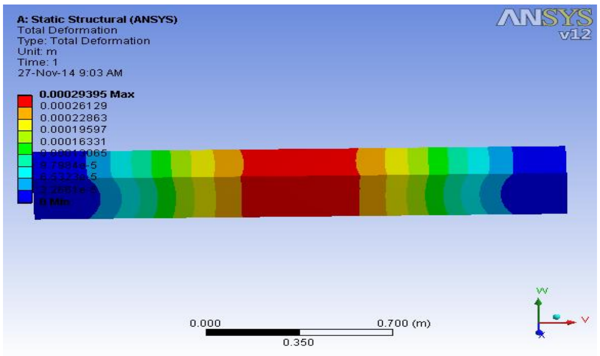

Fig. 6.1: Beam without FRP

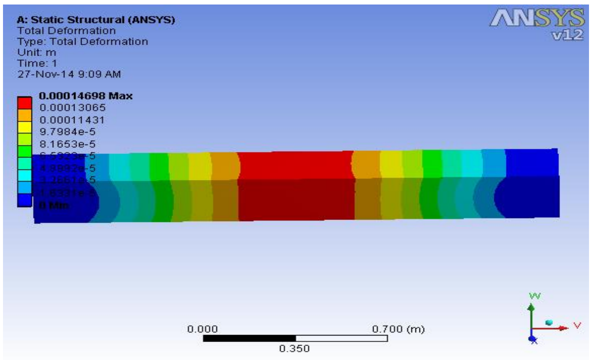

Fig. 6.2: Beam with FRP

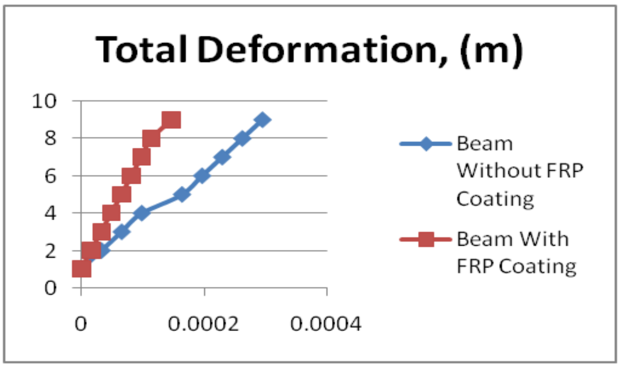

Fig. 6.3: Comparison of both the beam in terms of Total deformation

CONCLUSION

Based on the analytical results and observations, it could be concluded that the ultimate load carrying capacity of the strengthened beam is higher when compared to the control beam. As per our design, beam has failed in flexure region under the application of two point load in Control Beam. The failure load is 34% higher than the design load in case of Control beam and 13.42% in case of Bottom single strip beam. And also the type of failure changed from flexural failure to shear failure due to application of bottom single strip.

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BIOGRAPHIES

Milan Motta is an academician in a leading institute of one of southern Indian states in the region of Hyderabad Telangana. He has done in bachelor's degree in Mechanical engineering from Pt. R.S.U, Raipur (C.G.), Masters Degree in CAD/CAM Robotics from CSVTU, Bhilai and Masters of Business administration with specialization in Operations Management from IGNOU and pursuing his Doctorate program with specialization in Micro and Macro Structural Analysis of materials from University of Petroleum and Energy Studies, Dehradun He has participated in many national and international conferences and contributed various research papers published in proceedings and, some of which have been published in the renowned Journals.

Rahul Pachori is an academician in a leading institute of one of southern Indian states in the region of Hyderabad Telangana. He has done in bachelor's degree in Mechanical engineering from RGPV, Bhopal (M.P.), Masters Degree in Thermal Engineering from IIITDM, Jabalpur and pursuing his Doctorate program from Mewar University Rajasthan He has participated in many national and international conferences and contributed various research papers published in proceedings and, some of which have been published in the renowned Journals.

Yashesh Ahirwar is an academician in a leading institute of one of southern Indian states in the region of Hyderabad Telangana. He has done in bachelor's and Master's Degree in Mechanical engineering from GEC Jabalpur,(M.P.), with specialization in Heat Power Systems. He has participated in many national and international conferences and contributed various research papers published in proceedings and, some of which have been published in the renowned Journals.