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Strengthening the Structural Beam by FRP Layers using ANSYS: Review Paper

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Abstract: Preservation of concrete or structural beams from the corrosion attack utilizing FRP (Fibre Reinforced Polymer) materials has been reviewed in the present paper. FRP materials have low weight and high resistance skills which makes them suitable for strengthening applications. The FRP as an external reinforcement is used extensively related to flexure and shear in structural systems. Advantages and disadvantages have been discussed. Different types of FRP like CFRP (Carbon-FRP), GFRP (G- FRP) and ARFP (Aramid- FRP) have been discussed with their chemical composition, fibres they made-off and different applications. Review of the published works has been done in the present paper which reveals that FRP materials can be used for reducing the corrosion and raising the strength of structural beams. CFRP and GFRP have applications in structural industries while AFRP is mostly used in military applications. A FEM tool like ANSYS will be used to simulate the FRP laminates structural beams to study the effect of it. A simple concrete structural beam has been modelled then the FRP material will be laminated over it. Effect of tension and various loading condition will be studied in the present paper.
***Keywords*: FEM, CFRP, GFRP, ANSYS, Strength.**

I. INTRODUCTION

Upgrading of solid structures may be required for a wide range of reasons. The solid structures may have turned out to be fundamentally in sufficient for instance, because of material deterioration, poor configuration or development, maintenance absence, redesigning of outline burdens, for example, natural causes like earthquakes. But GFRP and solid epoxy paste can strengthen the structures. Fundamentally the method includes giving extra layers of GFRP to concrete surfaces. These plates act compositely with the solid and increase the load carrying capacity. The utilization of GFRP to steel and solid structures has turned out to be progressively alluring because of the understood great mechanical properties of these materials. These properties are good strength to density proportion, good corrosion resistance, less cost of maintenance and less installation time with routine materials.
There are different advantages and disadvantages of FRP materials shown in table 1, which should be considered while opting for a FRP material. Different types of FRP materials have been explained in the later text.

S. N.	FRP Advantages	FRP Disadvantages
1	Corrosion resistance	No yielding before brittle break
2	Light weight	Low transverse strength
3	Low thermal conductivity	Low durability of glass in moist environment
4	High heat temperature distortion	Low durability of glass & aramid in alkaline environment
5	High fatigue endurance	Damage due to UV rays
6	High impact absorber	Low modulus of rigidity
7	Fast and Easy installation	Tensile strength
8	Durable	Cost
9	Environment friendly	Lack of codes
10	Low electrical conductivity	Lack of design standard

Table 1: FRP material advantages and disadvantages

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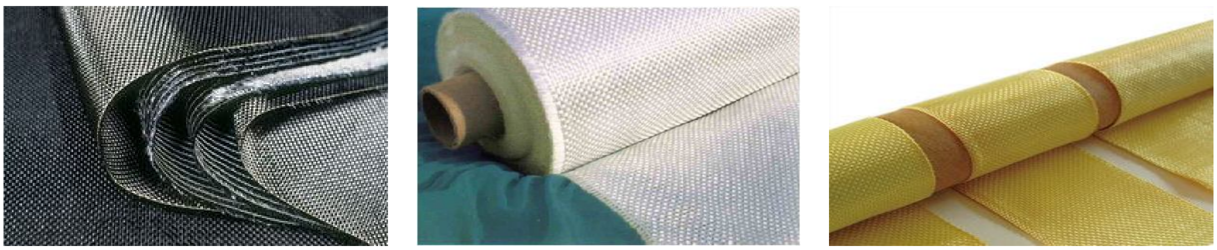
II. TYPES OF FRP

Different types of FRP materials are there in the market base on the content used to make them. These are CFRP (Carbon Fibre Reinforced Polymer), GFRP (Glass Fibre Reinforced Polymer) and AFRP (Aramid Fibre Reinforced Polymer). They have high strength and high stress compared to ordinary steel.

A. CFRP (Carbon Fibre Reinforced Polymer)

They contain fibres of carbon as en external agent and their crystal structure is microscopic which makes its very strong reinforcing material. Fibres used to make them are very less in diameter 0.005 to 0.01mm. Figure 1 represents the CFRP. They can be further classified into different categories base on the elastic modulus, stress and elongation. CFRP have been used in different industries like automotive, aerospace and building structures. They also been using in other applications because of their low weight and stiffness.



CFRP GFRP AFRP

Figure 1: Different Reinforced Polymer

B. GFRP (Glass Fibre Reinforced Polymer)

They have been used in the industries because of their light weight. They can be made of polyester, epoxy and phenolic. They possess high impact strength, environmental resistance and damage tolerance. A GFRP has been shown in figure 1. While table 2 shows the GFRP shows different types of GFRP and their chemical compositions.

Type	SiO_2	Al_2O_3	K_2O	Na_2O	MgO	CaO	B_2O_3	TiO_2	Fe_2O_3
A-Glass	67.5	3.5	3.0	13.5	4.5	6.5	1.5	-	-
C-Glass	64.6	4.1	0.5	9.6	3.3	13.4	5.0	-	-
D-Glass	74.0	-	2.0	1.5	-	-	22.5	-	-
E-Glass	55.0	14.0	0.3	0.5	1.0	22.0	7.0	0.2	-
EGR-Glass	61.0	13.0	0.5	-	3.0	22.0	-	-	-
R-Glass	60.0	24.0	0.1	0.5	6.0	9.0	-	-	-
S-Glass	65.0	25.0	-	-	10.0	-	-	-	-
Basalt	52.0	17.2	1.0	5.0	5.2	8.6	-	1.0	5.0

Table 2: Chemical Compositions of different GFRP

C. AFRP (Aramid Fibre Reinforced Polymer)

Aramid is a synonym of “aromatic polyamide”. They are quality heat resistant material and have been utilizing in military and aerospace industries. Molecules of these fibres are joined with strong hydrogen bonds shown in figure 1 that help in mechanical heat transfer. They are thinner than human hair and are sensitive to temperature and UV rays which makes them unsuitable in structure applications.

D. Failure Criteria for FRP Laminate

1) Hashin Criteria for 2D developed in 1980
2) Criteria for matrix failure under transverse compression

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3) Criteria for fibre failure under tension
4) Criteria for fibre failure under compression
5) Criterion for matrix damage in biaxial compression

III. LITERATURE REVIEW

All Banu D. et al [1] studied the numerical modelling of two-way reinforced concrete slabs strengthen with carbon fibres reinforced polymer strips. They applied FRP as an external layer to the RC (Reinforced Concrete) beams. They have used ANSYS software to analysis the effect of FRP material as an external layer to see the effect of it on load carrying capacity. They have used SOLI65 element to model the 3D concrete beams while SOLID45 has been used to design the thick shells. They have conducted their results for load-deflection and ultimate carrying capacity.

Scordelis A.C. et al[2] studies finite element study of reinforced concrete beams with diagonal tension cracks. The most punctual production on the use of the limited component system to the investigation of RC structures was exhibited. In their study, basic shafts were examined with a model in which concrete and fortifying steel were spoken to by consistent strain triangular components, and an extraordinary bond join component was used to associate the steel to the solid and portray the bond slip impact. A direct flexible investigation was performed on shafts with predefined split examples to decide essential hassles in solid, stresses in steel fortification and bon stresses.

Parandaman P. and Jayaram M.[3] studied the Finite element analysis of reinforced concrete beam retrofitted with different fibre composites.

They have use Pro-E software for modelling and ANSYS for analysis the modelled geometry.

The used carbon fibre reinforced polymer (CFRP) sheet for first layer of RC beam, glass fibre reinforced polymer (GFRP) sheet for second layer and Kevlar fibre reinforced polymer (KFRP) sheet for third layer.

SOLID65 element for concrete beam and SOLID45 element for FRP has been used by them.

They found that deflection has been minimized around 75% compared to the conventional RC beam when CFRP used.

Deflection minimized around 65% when GFRP used and 60% when KFRP used.

Load carrying capacity increases by using FRP laminates.

Strength increases after using FRP laminates.

TaranuN. and Bejan L. [4] studied Mechanical modelling of composite ARMIDE cu fibre. From the assortment of strands used to make FRP materials the carbon filaments have been observed to be more suitable in understanding the composite strips utilized for the basic restoration of strengthened solid twisted components. The carbon filaments have high quality toweight what's more, solidness to-weight proportions, low warm dilatation coefficient, high weakness resistance, substance inactivity, strength at high temperatures, high removal resistance, great warm conductivity, low thickness, and high strain quality. A few hindrances of this sort of fibre are low effect quality, high electric conductivity and high costs.

Musmar M. A. et al [5] nonlinear finite element analysis of shallow reinforced concrete beams using solid65 element. They targeted their study towards the study of shallow reinforced concrete beam for transverse loading. SOLID65 eight node isotropic elements have been used to model the concrete beam. The analysis has been conducted using ANSYS. They concluded

Cracking initially occurs in the vertical flexural from in the model.

The cracking increases with increment in the load.

The relationship between the load and deflection has been found to be linear elastic up to cracking moment strength then it inclines in horizontal plane.

Santhakumar R. and Chandrasekaran E. [6] analysed retrofitted reinforced concrete shearbeams using carbon fibre composites. They have studied the effect of CFRP on the concrete beam with fibre orientation of 45° and 90°. A quarter part of the beam has been studied by them. They have compared their results with the experimental results available and found in good agreement. For un-cracked and pre-cracked beam at ultimate stage they found variation in the results but not large. They concluded that the numerical results help in tracking the formation and propagation of the crack which was not obtained by the experimental results because of the CFRP laminate sheets.

Ibrahim A. M. and Mahmood M. S. [7] finite element modelling of reinforced concrete beams strengthened with FRP laminates. They analysed the model for reinforced concrete beamsreinforced with fibre reinforced polymer (FRP) laminates using finite elementsmethod (FEM) adopted by ANSYS. The models have been established utilizing a smearedcracking method for concrete and 3D-layered elements for FRPcomposites. The results obtained have been matchedwith the experimental data for six beams with different conditions from researches. The results have been compared for load-deflectioncurves and failure load at mid length which are in good agreement. But the finite elements results found to be slightly stiffer than that from the experimental results. The maximum difference is 7.8% for all cases included in ultimate loads.

Robert R. S. and Prince A. G. [8] studied finite element modelling on behaviour of reinforced concrete beam-column joints retrofitted with carbon fibre reinforced polymer. The Finite element modelling (FEM) has turned to be recreating the physical conduct of complex building frameworks. The (FEA) programs have increased normal acknowledgment among architects in industry and analysts. The examination of retrofitted with carbon fibrereinforced polymer sheets (CFRP) utilizing ANSYS have been exhibited in this paper. Three different strengthened sheet of CPRF on solid shaft were displayed utilizing ANSYS. Both the ends of the beam in investigation have been kept pivoted. Static load was connected at the free end of the cantilever bar. The analyses have been conducted for the retrofitted beam and the outcomes have been exhibited.

More R.U. and KulkarniD. B. [9] studied flexural behavioural study on RC beam with externally bonded aramid fibre reinforced polymer. They represent the flexural manner of Aramid fibre reinforced polymer (AFRP) with RC beams of M_{25} grade cement. Results have been conducted for beam (simply supported) of cross-section 100mm×150mm×1200mm with laminated by aramid fibre polymer sheets. The impacts of reinforcing on burden conveying limit and impact of harm degree are talked about in subtle element. The outcomes demonstrate that the heap conveying limit of bars was essentially expanded as the quantity of layer expanded. The acceptance of the trial results was finished by utilizing ANSYS programming. To concentrate on the flexural conduct of the pillar, the examples were just subjected to two point stacking system just. The bars were wrapped with AFRP sheets in single layer and twofold layers along the length at the base face of the bar. The present work incorporates Effect of harm level of the pillar and impact of number of layers. In this manner it is an achievable technique for fortifying and retrofitting of RC pillars.

Jayajothi P. et al [10] studied finite element analysis of FRP strengthened RC beams using ANSYS. Remotely fortified FRP sheet can be utilized to increase flexural quality of strengthened solid pillars. Strengthened solid bars remotely fortified with fibre strengthened polymer sheets utilizing limited component strategy embraced by ANSYS. The precision of the limited component model is checked with help of correlation its outcomes with the trial results. The heap redirection bends acquired from the limited component investigation holds great with the trial results.

Al-Rousan et al[11] in 2013 and Haddad et al [12] in 2013 studied the effect of FRP on the concrete strength. Haddad developed analytical models for total bonded area, effective FRP bonded area and bond strength is as follows,

$$A_f = 2n_f w_f h_f = 2\left(\frac{h_f}{s_f}\right) w_f h_f = 2\frac{w_f h_f^{\,2}}{s_f} \quad (1)$$

$$A_{fe} = \beta A_f = 2\frac{\beta w_f h_f^{\,2}}{s_f} \quad (2)$$

$$\tau_{bond} = \gamma(0.765\beta_w \beta_t \beta_L) \quad (3)$$

Where A_f, A_{fe} and $\tau_{bond}$are the total bond area, effective FRP bond area and bond strength respectively. h_f, s_f, w_f and n_f are height, spacing, weight factors of FRP used and no. of FRP layers used respectively.

Mohamed et al [13] in 2015 reviewed the super-hydrophobic surface corrosion behaviour. Zhou et al [14] in 2010 conducted analytical modelling of bon-slip relationship for adhesively-bonded joint at interface of EB-FRP (Externally Bonded- Fibre Reinforced Polymer) and concrete. The model they developed respond well for infinite bond length while it performs inappropriate for short bond length compared to effective bond length. They developed a bond-slip relationship within limited bond length for short joints. The bond-slip and strain-slip models developed by them are,

$$\tau(s) = \frac{E_f t_f \alpha}{(1+\rho)\beta^2} e^{-s/\alpha}(1 - e^{-s/\alpha}) \quad (4)$$

$$\varepsilon(s) = \frac{\alpha}{(1+\rho)\beta}(1 - e^{-s/\alpha}) \quad (5)$$

Where, τ and ε are the stress and strain respectively. E_f, t_f and ρ are the elastic modulus of FRP, thickness of FRP, and stiffness ratio of FRP layer to concrete respectively. While α and β are the constants. Where's' is the slip distribution.

IV. MODELLING OF BEAMS

Modelling of a simple structural beam and FRP laminates structural beam have been conducted as shown in the figure 1 below.

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Left-hand side of figure 1 shows the structural beam without FRP laminates while on right-hand side shows the structural beam with FRP laminates. Figure 2 shows the total deflection of the structural beam with and without FRP laminates.

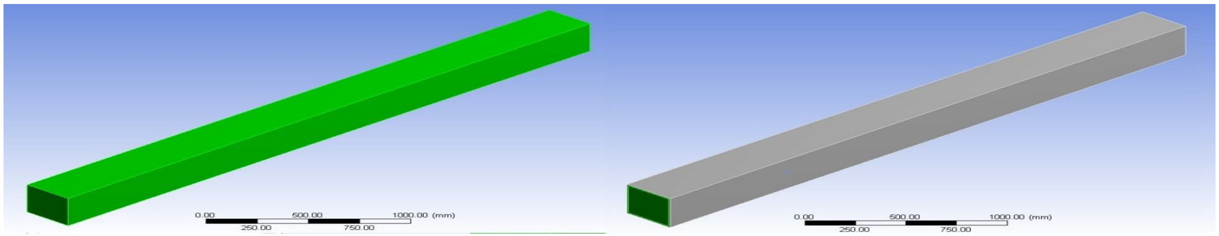

Figure 2 Geometry of the structural beam without and with FRP laminates

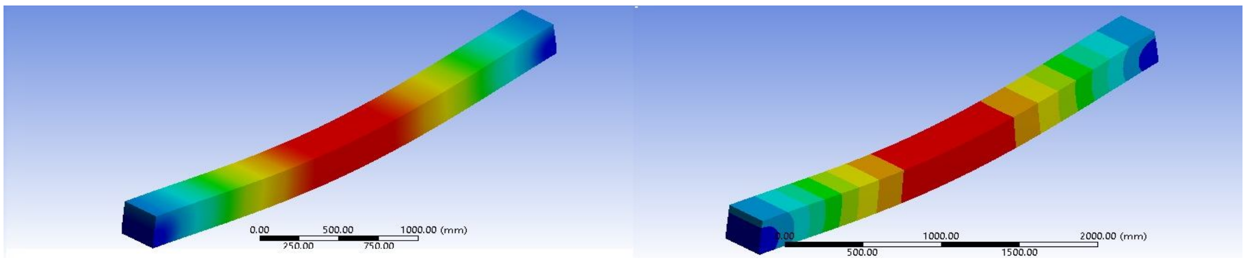

Figure 3Total deflection of the structural beam without and with FRP laminates

V. CONCLUSIONS

A. Review study of FRP (fibre reinforced polymer) materials (CFRP, GFRP and AFRP) have been studied in the present paper.
B. CFRP and GFRP have applications in structural industries while AFRP is mostly used in military applications.
C. Layers of FRP material gives high load carrying capacity and good corrosion resistance to a structural beam.
D. A FEM tool can be utilised to predict the behavior of a structural beam under the different loading condition.
E. Total deflection of the structural beam with FRP laminates decreases.

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