Bonded Concrete Beam with CFRP and GFRP Layers: Evaluation of Strength and Weight

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Abstract

Simulation of the CFRP and GFRP layers to study their effect on the strength of the structural beam has been studied in the present paper. CFRP (carbon fiber reinforced polymer) and GFRP (glass fiber reinforced polymer) as an added layer over the structural beam has been studied in detail. Four sets of simulation have been conducted, one is simple concrete beam, second having one layer of FRP, third having two layer of FRP and fourth having one FRP layer plus reinforcement over the structural beam respectively. FRP materials have low weight and high resistance skills which makes them suitable for strengthening applications. ANSYS has been used to simulate the FRP layers with structural beam to study the effect of it on the beam strength and weight. To study the effect of the FRP layers, total deformation and weight under a loading condition have been compared. Results reveal that the FRP layers strengthen the structural beam. From the results it has also concluded that the same dimensions structural beam having FRP layers are lighter in weight compared to same dimensions conventional structural beam. FRP (CFRP & GFRP) materials in place of the concrete decreases the total deformation occurs in the beam under a loading condition. CFRP shows less deformation and are also lighter in compared to GFRP. Reinforcement inside the concrete beam with one layer of FRP decreases the total deformation occurs in the beam.

Keywords: FRP, Concrete, CFRP, GFRP, Strength

I. INTRODUCTION

In the recent years FRP materials have dominate over other materials to resolve the corrosion problem in concrete structures. They are new class of composite materials and are made of fibres, resin or polymers, additives and surface veil. The fibre materials like glass and carbon provide stiffness and strength to FRP while resins or polymers like epoxy and polyester bind the fibres together. Additives can be pigments and fire retardants etc., surface veil are those which increase the resistance to corrosion or to UV-rays. FRP has been using in different applications mainly construction, automation, aerospace and marine. Two different types of FRP materials have been considered in this study CFRPand GFRP. They have high strength and high stress compared to ordinary steel.

A. CFRP:

Carbon fibre reinforced polymers containfibres 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.

B. GFRP:

Glass fibre reinforced polymers 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.

CFRP

GFRP

Fig. 1: Different Reinforced Polymer

Al-Rousan etal[1] in 2013 and Haddad et al[2] in 2013 studied the effect of FRP on the concrete strength. Haddad developed an analytical model for total bonded area, effective FRP bonded area and bond strength. Mohamed et al[3] in 2015 reviewed the super-hydrophobic surface corrosion behaviour. Zhou et al[4] 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 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. E_f, t_f and ρ are the elastic modulus, thickness and stiffness ratio of FRP layer to concrete respectively. While α and β are the constants.

Zhou et al[5] in 2015 conducted experimental and modelling study of bond degradation for FRP-concrete under sulphate attack. Parandaman and Jayaram[6] in 2014 studied the Finite element analysis of reinforced concrete beam retrofitted with different fibre composites. hen et al[7] in 2015, Hassan et al[8] in 2015, Baji etal[9] in 2015, Godat et al[10] in 2013, Chen et al[11] in 2012 and Wong and Vecchio[12] in 2003, conducted FEM analysis of FRP for strengthening the RC beams. Zhang and Teng[13] in 2014 performed FEA of end cover separation for RC beams with FRP. Vecchioet al[14] 2015, Baggio et al[15] in 2014, Domenico et al[16] in 2014 and Si-Larbi et al[17] in 2012 conducted study of strengthening RC beam with FRP. Tettaet al[18] in 2015 studied FRP and TRM (Textile Reinforced Mortar) comparison for RC beam strengthening. Sweedan et al in[19] 2013 studied the mechanical behaviour of interfacial layers of FRP for strengthening steel beams.

Tenget al[20] in 2015 conducted nonlinear FEA of two new composites for strengthening the concrete by FRP. Burke et al[21] in 2013 studied the effect of high temperature on FRP near surfaces. Spadeaet al[22] in 2015 studied the FRP structural effectiveness for strengthening the RC beams. Sharma et al[23] in 2015 studied corrosion monitoring of FRP utilizing ultrasonic waves. Naik et al[24] in 2006 studied the sulphate attack monitoring by micro-tomography (micro-CT) and Energy Dispersive X-Ray diffraction (EDXRD) for different cements, water-cement ratio and aggregates.

II. MATERIAL PROPERTIES

Concrete as a base material of the beam, CFRP and GFRP as added layer while structural steel as reinforcement material has been considered. Table 1 shows the properties of the all the material considered in the study.

Table – 1
Properties of the material considered

Material	*Concrete*	*Structural steel*	*CFRP*	*GFRP*
Density (kg/m^3)	*2300*	*7850*	*1800*	*1850*
Elastic modulus (Pa)	*3×10^{10}*	*2×10^{11}*	*2.4×10^{11}*	*0.89×10^{11}*
Poisson's ratio	*0.18*	*0.3*	*0.32*	*0.1*

III. MODELLING OF BEAM

Four different sets of geometry have been modelled in the present work. First set is a simple concrete beam, second set having one FRP layer over the beam. Third set having two FRP layers over the structural beam and fourth set having one FRP layer plus reinforcement inside the structural beam. Figure 2 (a-d) represents all the four sets respectively. The inner part represents concrete while the outer parts are made of FRP material. Table 2 represents the dimensions of the four sets. In the table, length represented the extruded dimension of the beams. A basic dimension of the beam is 280×280 mm^2 with 3600 mm length. While FRP are the layers added over the basic dimensions of structural beam.

Table – 2
Dimensions of the beam with FRP and reinforcement

Set no.	*Concrete (Height × Width)*	*First FRP layer (Thickness)*	*Second FRP layer (Thickness)*	*Reinforcement (Radius)*	*Length (mm)*
1	*280×280 mm²*	-	-	-	*3600*
2	*280×280 mm²*	*20 mm*	-	-	*3600*
3	*280×280 mm²*	*20 mm*	*20 mm*	-	*3600*
4	*280×280 mm²*	*20 mm*	-	*5 mm*	*3600*

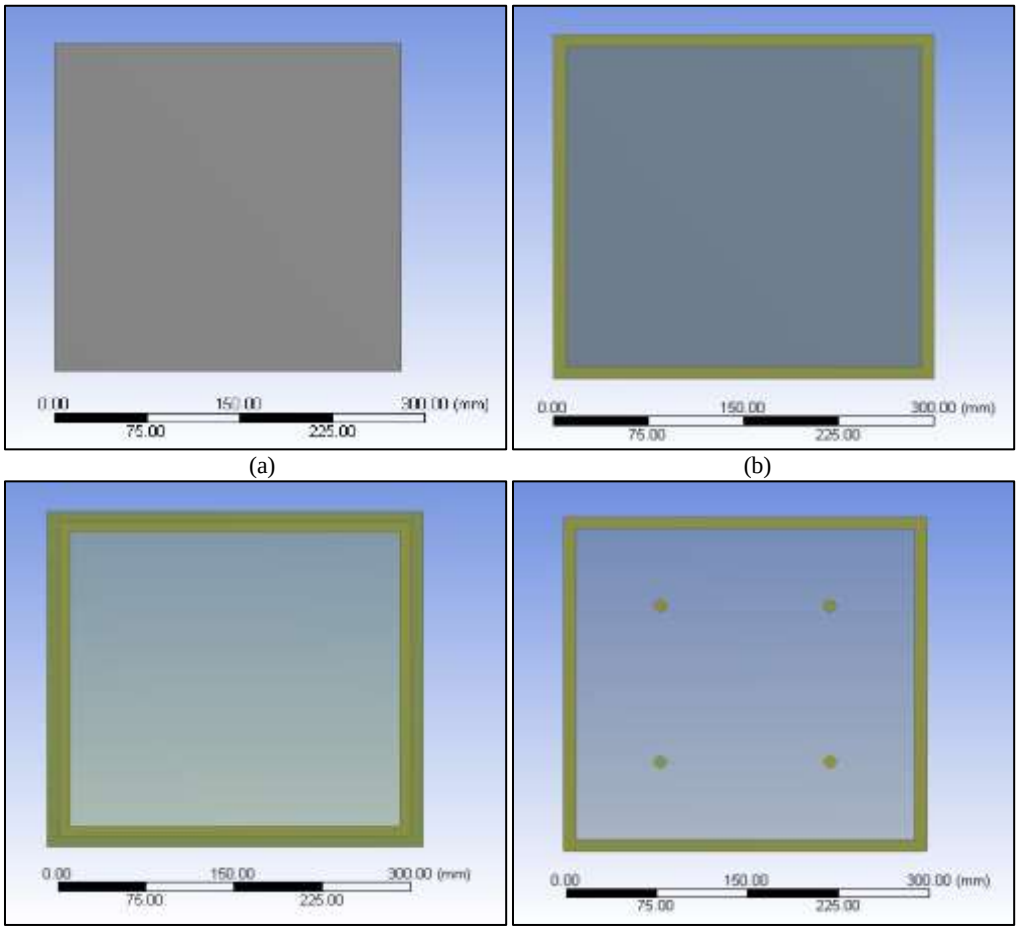

Fig. 2: (a) Basic structural beam (b) Beam with one FRP layer (c) Beam with two FRP layer (d) Beam with one FRP layer and reinforcement

IV. RESULTS AND DISCUSSION

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4	*280×280 mm²*	*20 mm*	-	*5 mm*	*3600*

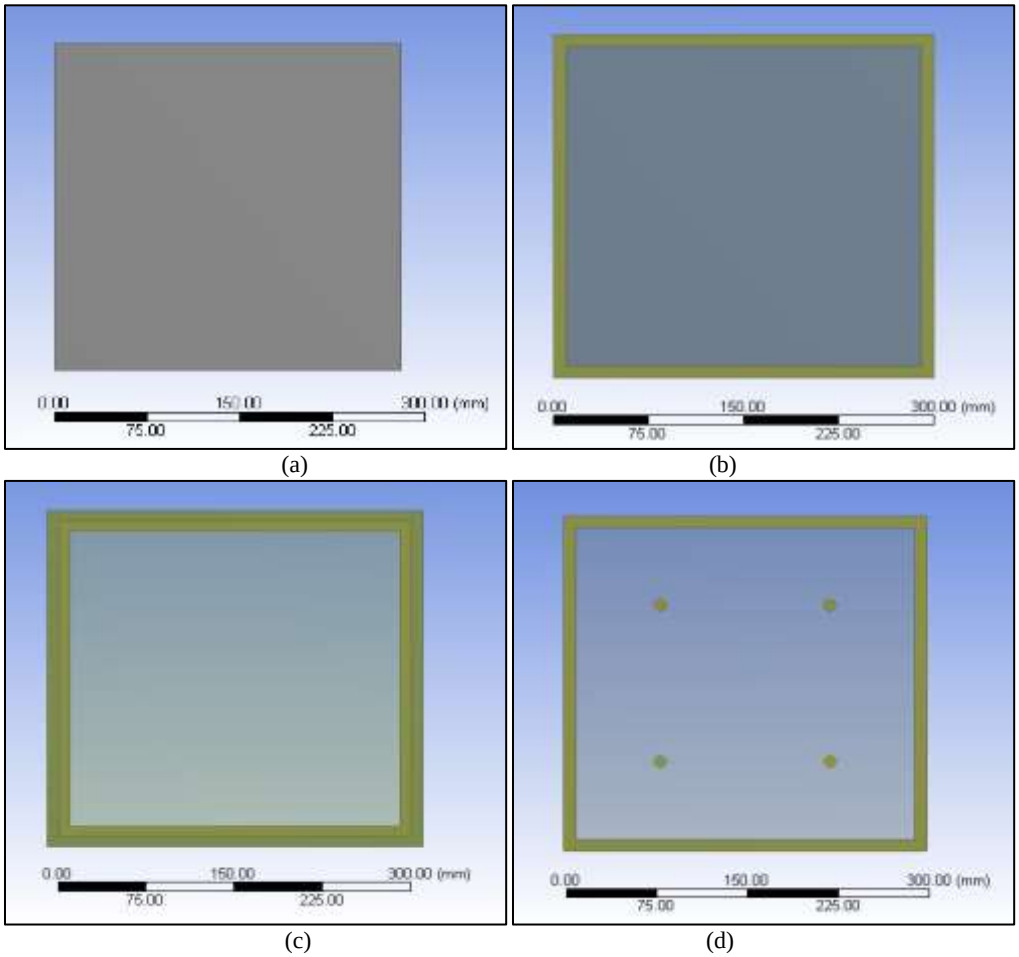

Figure 2 (a) Basic structural beam (b) Beam with one FRP layer (c) Beam with two FRP layer (d) Beam with one FRP layer and reinforcement

V. CONCLUSION

- FRP (CFRP & GFRP) materials in place of the concrete decreases the total deformation occurs in the beam under a loading Condition.
- It can also be easily observed that the beams with FRP material are lighter in weight compared to the beam made of concrete only.
- It can also be observed that the beam with CFRP as an added layer shows less deformation compare to beam having GFRP as an added layer.
- Adding the reinforcement inside the concrete beam with one layer of FRP decreases the total deformation and weight occurs in the beam when compared to the beam without reinforcement.

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