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Comparative Study of GFRP Rebar and Steel Rebar used in Concrete Sections

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Abstract

The main problem encountered in steel reinforced concrete structures is the corrosion of the steel bars which eventually results in the failure and disintegration of the structure. Fiber-reinforced polymer (FRP) rebar has been considered as an alternative for this since corrosion is a material problem. The purpose of this research was to investigate flexural behaviour of GFRP and steel reinforced beams. The beam sections used in this research is of size 150 x 200 mm and of 1600 mm length. Flexural strength was determined and crack pattern studies were carried out.
Keywords- GFRP, RC, Steel Rebar, Flexural Behaviour

I. INTRODUCTION

The development of FRP reinforcement can be traced to the expanded use of composites after World War II. The aerospace industry had long recognized the advantages of the high strength and light weight of composite materials, and during the Cold War, the advancements in the aerospace and defense industry increased the use of composites. Furthermore, the rapidly expanding economy of the U.S. demanded inexpensive materials to meet consumer demands. Pultrusion offered a fast and economical method of forming constant profile parts, and pultruded composites were being used to make golf clubs and fishing poles. It was not until the 1960s, however, that these materials were seriously considered for use as reinforcement in concrete. The expansion of the national highway systems in the 1950s increased the need to provide year-round maintenance. It became common to apply deicing salts on highway bridges. As a result, reinforcing steel in these structures and those subject to marine salt experienced extensive corrosion, and thus became a major concern. Various solutions were investigated, including galvanized coatings, electro-static-spray fusion-bonded (powder resin) coatings, polymer-impregnated concrete, epoxy coatings, and glass FRP (GFRP) reinforcing bars (ACI 440R). Of these options, epoxy-coated steel reinforcement appeared to be the best solution, and was implemented in aggressive corrosion environments. The FRP reinforcing bar was not considered a viable solution and was not commercially available until the late 1970s. In 1983, the first project funded by the U.S. Department of Transportation (USDOT) was on “Transfer of Composite Technology to Design and Construction of Bridges” (Plecnik and Ahmad 1988).

II. OBJECTIVE

To compare the behavior of steel bars and GFRP bars in flexural members and comparison of crack pattern in steel and GFRP Reinforced beams.

III. SCOPE

The study is to be carried out by incorporating GFRP rebar and steel reinforcement in concrete. The concrete section to be used for the study are of dimension 150x200x1600mm in beams The experiment is to be done with M30 concrete only and the beam design is done for the same moment in both GFRP and steel reinforced beams.

IV. MATERIALS USED

The cement used for this project work is Ordinary Portland Cement of 53 grade. The fine aggregate to be used in the study is manufactured sand. Steel rebar and GFRP rebar. The recommended super plasticizer is MasterGlenium SKY 8233.

Table 1: Material Property Comparison of GFRP Rebar and Steel Rebar

MATERIAL CHARACTERISTICS	*GFRP REBAR*	*STEEL REBAR*
Density	*1850 kg/m^3*	*7850kg/m^3*
Coefficient of thermal expansion	*10.8 × 10–6/°C*	*12 × 10–6/°C*
Tensile strength	*750 MPa*	*415MPa*
Elastic modulus	*50GPa*	*200GPa*
Poisson ratio	*0.25*	*0.30*

V. BEAM DESIGN DETAILS

Table 2: Beam Design Details

Diameter of bars	*GFRP used beam(150x200) No of specimens*	*steel used beam(150x200) No of specimens*
10mm Ø bar,2nos Stirrup provided @150mm c/c	*3*	*NA*
12mm Ø bar,2nos and 10mm Ø bar,1no Stirrup @150 mm c/c	*NA*	*3*

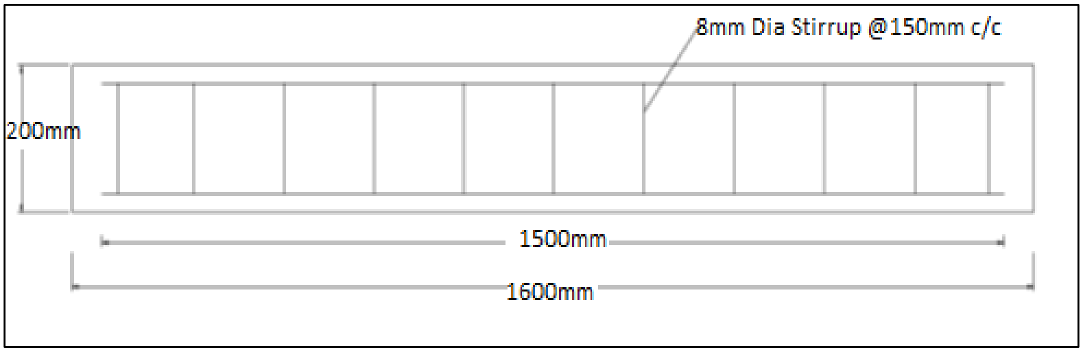

Fig. 1: Longitudinal Section of Beam

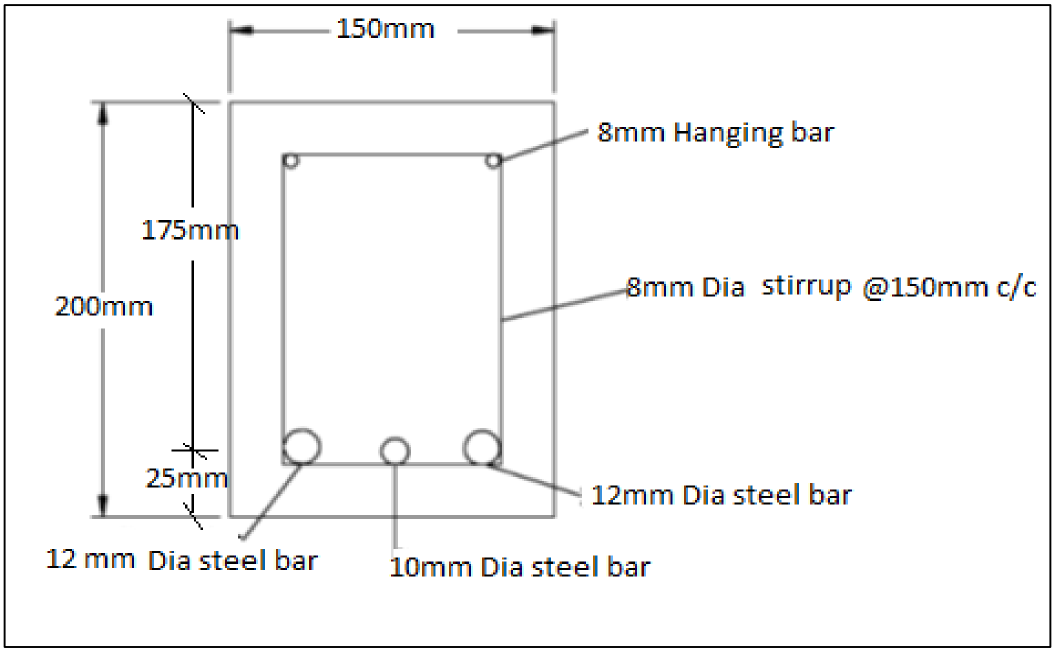

Fig. 2: Steel Reinforced Beam

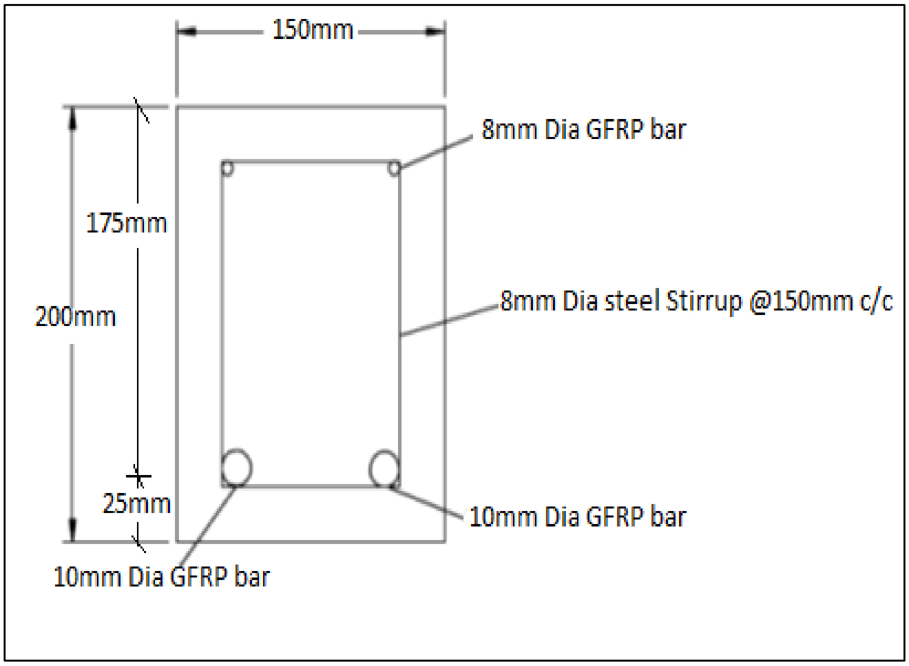

Fig. 3: GFRP Reinforced Beam

VI. TESTING OF SPECIMENS

A. Beams

The specimens casted were tested for their failure load using loading frame of capacity 50tonnes after 28 days.

1) Loading frame

The apparatus used for testing the specimen is a loading frame of capacity 50tonnes.the loading frame consisted of steel frames to transfer the load to foundation and pumps and jack to apply the load to specimen. There were three types of jack available 10tonnes, 50tonnes, 100tonnes.for testing of beams 50 ton jack were used.

2) Failure load

The specimen casted were tested for their failure load .the specimens were placed on the loading frame with two end simply supported. The load was applied at constant rate without shock and increased continuously.

For testing of beams, hydraulic jack of 50T capacity was used .and I section was placed below the jack and beams was placed below the I section with roller support at a distance 500mm from both ends, beam was placed over the roller support, spacing between the rollers is 1500mm.load is applied corresponding deflections are measured till the beam fails. Load applied was measured using a dial gauge with 0.1T accuracy.

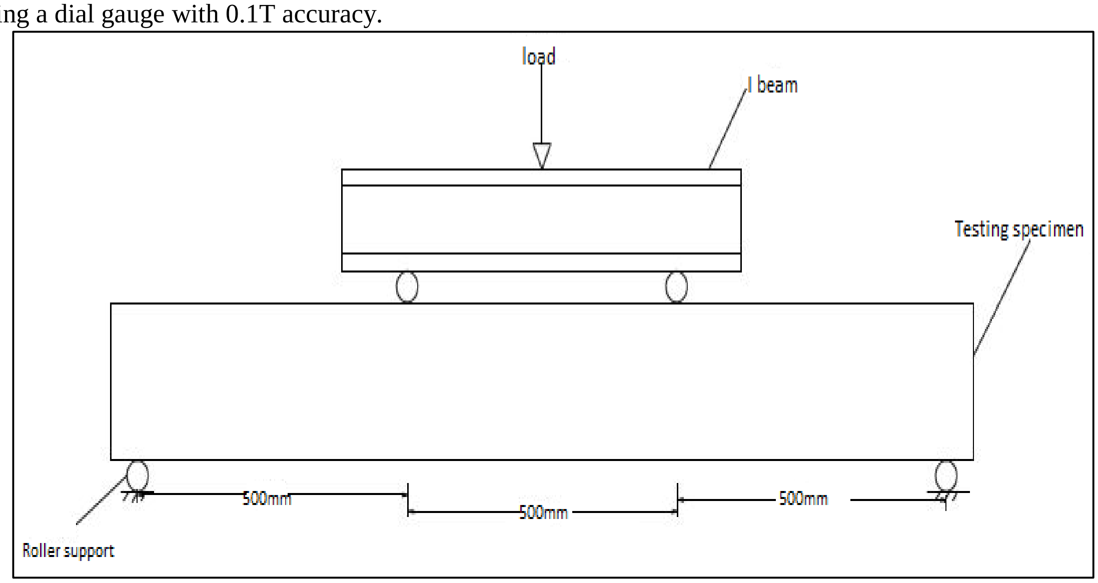

Fig. 4: Loading Arrangement

Fig. 5: Failure Pattern of Steel Reinforced Beam

Fig. 6: Failure Pattern of GFRP Reinforced Beam

VII. TEST RESULT AND DISCUSSION

Table 3: Ultimate load and deflection comparison

	Ultimate Load(KN)		Ultimate Deflection(mm)	
	STEEL	FRP	STEEL	FRP
Sample 1	92.0	72.0	14.70	16.82
Sample 2	88.0	74.0	13.30	16.80
Sample 3	91.0	71.0	14.20	16.10
Average	90.3	72.3	14.06	16.57

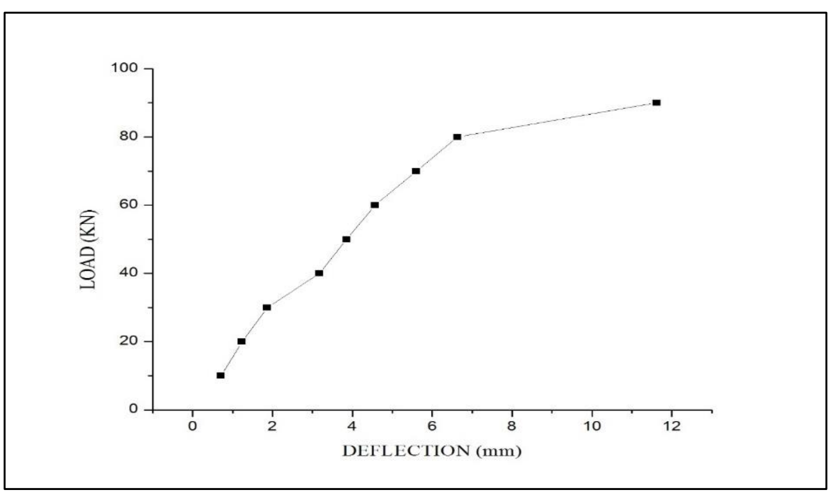

Fig. 7: Load Vs Deflection Diagram of Steel Reinforced Beam

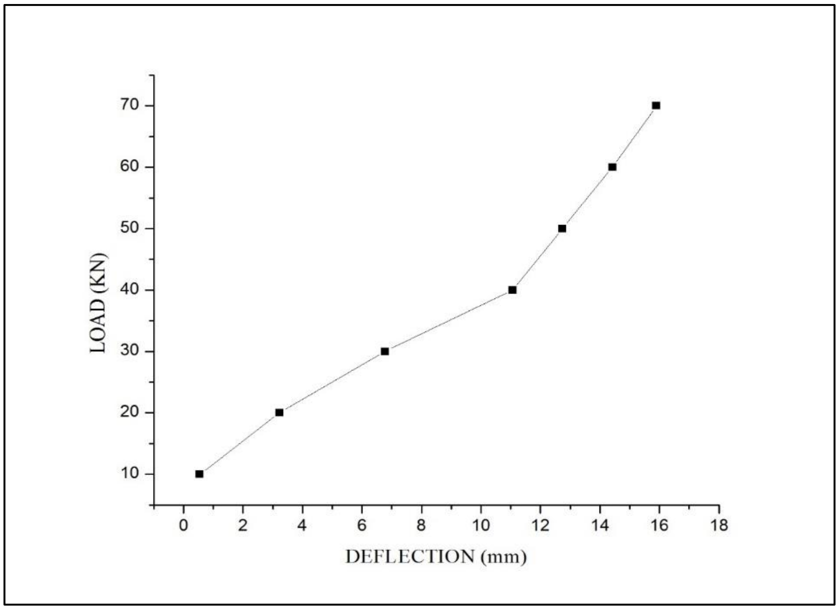

Fig. 8: Load Vs Deflection Diagram of GFRP Reinforced Beam

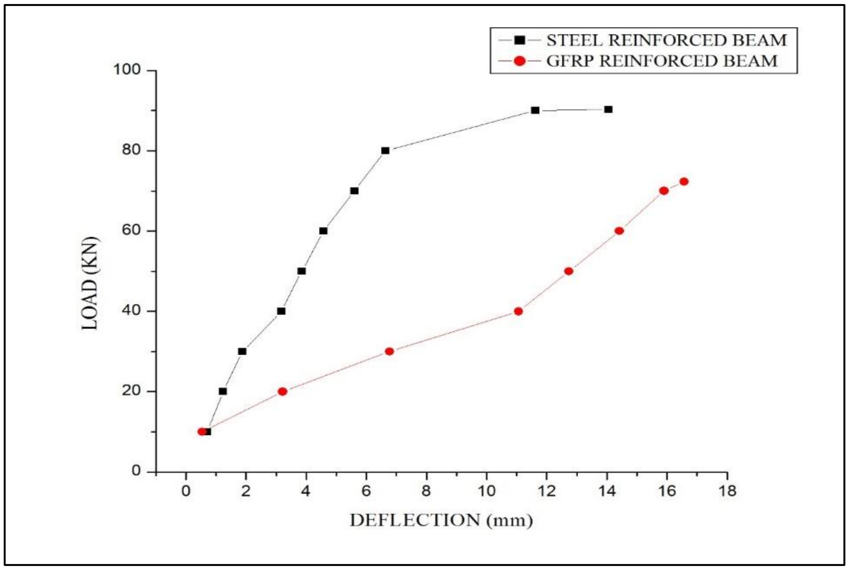

Fig. 9: Combined Load Vs Deflection Diagram

B. *Crack Pattern Study*

1) *Steel Reinforced Beam*

In the initial stages of loading, for all the beams, cracks first appeared in the constant moment zone. As the load increased, additional cracks developed in the mid span and new vertical cracks formed in the shear span. Crack pattern observed in steel reinforced beam is tensile crack, in middle of the beam more tensile crack observed. Crushing of concrete take place at the top of the beam and at bottom layer of beam, yielding of steel rebar occurred .All the beams reinforced with the steel rebar failed in flexure at an ultimate load. The crack pattern of steel reinforced beam showed that the initial crack originated at the outermost fiber of the tension zone at mid span and propagated towards the center of the beam. First crack obtained at a load of 38.6KN.

2) *GFRP Reinforced Beam*

In the case of GFRP reinforced concrete beams, one of the vertical cracks in the shear span became critical and extended towards the loading point at the ultimate stage. The failure was observed to be mainly due to the slip of the rebar from the surrounding concrete. The slipping of rebar in GFRP reinforced beams was indicated by splitting of concrete at the level parallel to the reinforcements. Crack pattern mainly due to shear failure of beam, comparatively less number of middle crack was observed. Failure of GFRP reinforced beam mainly due to shear. The initial crack originated near the supports and propagated towards the loading points. First crack obtained at a load of 26.7KN.

VIII. CONCLUSION

- Steel reinforced beam has more ultimate load than the GFRP reinforced beam with same design capacity. The GFRP reinforced beam has ultimate load of 72.3KN whereas for steel reinforced beam, the ultimate load obtained was 90.3KN. It can be inferred that the steel reinforced beam has ultimate load 25% more than the GFRP reinforced beam.
- Ultimate deflection obtained in the GFRP beam is more than that of steel reinforced beam. The ultimate deflection obtained for GFRP reinforced beam is 16.57 mm and for steel reinforced beam is 14.06 mm. The ultimate deflection obtained for GFRP reinforced beam is 17.85% higher than that of steel reinforced beam.
- In the case of steel reinforced beam flexural failures occurs, that is crushing of concrete take place at the top of the beam and at bottom layer of beam, yielding of steel rebar occured. In the case of GFRP reinforced beam shear failure occurred.
- The crack pattern of steel reinforced beam showed that the initial crack originated at the outermost fiber of the tension zone at midspan and propagated towards the center of the beam. For GFRP reinforced beam, the initial crack originated near the supports and propagated towards the loading points.
- First crack obtained in the GFRP beam is 26.7 KN and steel beam is 38.6KN.
- Area of reinforcement required for steel reinforced beam is 1.94 times GFRP reinforced beam with same moment capacity.

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