Indian J.Sci.Res. 17(2): 369 - 374, 2018
ISSN: 0976-2876 (Print)
ISSN: 2250-0138(Online)

STUDY ON THE EFFECT OF USING GLASS FIBER REINFORCED POLYMER BARS AS MAIN REINFORCEMENT IN BEAMS

[1] Shivapooja Vivek, [2] T.Dhilip, [3] B.Vijaya Prasad, [4] Dr. L. Sudheer Reddy
[1,2,3] Department of Civil Engineering, Methodist College of Engineering and Technology, Abids, Hyderabad, Telangana
[4]Department of Civil Engineering, Kakatiya Institute of Technology and Science, Warangal, Telangana

Abstract- Concrete is widely used construction material because of its good compressive strength. The disadvantage of concrete is that it has got a very low tensile strength. To enhance the tensile strength of the concrete it is reinforced with a material of high tensile strength. Steel is one such material. The main dis advantage of the steel is its corrosion and its high self-weight. To overcome this, fiber reinforced polymer bars are developed which are corrosion resistant and are inherited with good tensile strength. Extensive research has been done using different fibers to enhance the structural member's strength. It was found that behaviour of GFRP and steel reinforced concrete have similar shear behaviour [1]. The studies on bond strength, anchorage lengths, deflections [2], flexural cracks [3], the role of reinforcement detailing[4], the relation between tensile strength and bond strength[5], comparison of steel and GFRP stress-strain curve[6], column behaviour[7] portrayed the promising future of the fiber reinforced polymers. Based on the results in those experiments currently in various countries like Australia, Canada, and America etc.., the fiber reinforced polymer bars are used extensively in the construction of various structures.

The present study involves the preparation of the Glass fiber reinforced polymer (GFRP) bars and testing them for their properties. The properties of the bars thus obtained are used in the design of singly reinforced concrete beams reinforced with GFRP bars. Design of GFRP reinforced beams is done using the manual "REINFORCING CONCRETE STRUCTURES WITH FIBER REINFORCED POLYMER- design manual 3". The design of the steel reinforced concrete beam is done using the "IS 456:2000- PLAIN AND REINFORCED CONCRETE- CODE OF PRACTICE". Based on the detailings obtained in the design, the beams are casted and are tested after 28 days of curing. The moment of resistance, flexural strength, deflection at mid span, and load carrying capacity are studied.

Keywords: Tensile strength, corrosion, RCC, steel bars, GFRP bars, flexural strength, deflection.

I.Introduction

The weak tensile strength of plain concrete is over- come by reinforcing it. A widely used reinforcing material is steel. The steel when exposed to atmosphere, gets corroded and deteriorates. Hence in past few decades research is done extensively to develop an alternate material which would resolve the problem of tension of concrete and is also durable. One such material used as the reinforcement is Fiber Reinforced Polymer. It is relatively a new composite material with which concrete is reinforced to enhance the tensile strength of the concrete. Widely used fibers in the manufacture of the FRP materials are Carbon, Aramid and glass. Carbon and aramid fibers possess very high strength. But are very costly. Hence their use is restricted. Glass fiber is widely used material because of its good tensile strength, durability, non- corrosiveness, less weight, inertness to ordinary chemical reagents. Resins are used with the fibers to mould the fibers into desired shapes. In the current project the bars are prepared from the fibers which are used as the main reinforcement. Then after the flexural behaviour of the beams are studied.

II. Materials and Equipment

Glass fibers- The properties of the glass fibers as provided by manufacturer are

Name of the product: SE 1200, 17 mic, 300 Tex.

TABLE I .properties of the glass fiber

Property	Value
Tex (g/km)	300
Yield (N/mm^2)	1650
Filament diameter in microns	17
Poission ratio	0.21
Youngs modulus (GPa)	74

In order to mould the fibers in to a particular shape the the resin is added to the fibers. The resin used here is polyester.

Polyester- It is petroleum industry byproduct. In the presence of the catalyst and the accelerator it will become hard.

Table II. Typical properties of the polyester

Property	Value
Specific gravity	1.10-1.40
Tensile strength(MPa)	34.50-103.50

[1]Corresponding Author

Tensile modulus (GPa)	2.10-3.45
Cure shrinkage (%)	5.00-12.00

The widely used catalyst is Methyl ethyl ketone peroxide (MEKP) and the accelerator is cobalt and the same are used. In the current project

1% by volume of MEKP is added to the resin to get an appreciable amount of working time with polyester and 1% by volume of the cobalt is used

CAUTION: both MEKP and the cobalt should not be brought into direct contact with each other. Their direct contact could be highly explosive.

Rope Making Machine- The rope making machine fabricated for the preparation of the GFRP bars is as shown below.

Figure 1. Fabricated rope making machine

III. Preparation of bars

With the rope making machine the different types of bars can be made. In the current project Single stranded bars are prepared. The typical outlook of the single stranded bars is as shown below

Figure 2. Final outlook of the single stranded bar

A. Procedure of preparation of bars

The bars are prepared by the following steps

1. The frames are kept at a distance from each other. This distance is constant for any number of bars
2. The glass fibers are now winded to the rope making machine as required.
3. Polyester is poured into a bowl.
4. To the polyester resin 1% of MEKP and 1% of cobalt is added. At this percentage of MEKP and cobalt the working time of the polyester resin was 15 minute s.
5. The polyester resin is applied to the winded wire. The fibers are stiffened by twisting them. For twisting the handle behind the frame 2 is turned in clock wise direction for a fixed number of turns (to maintain uniform stiffness in all the bars)
6. During twisting the excess amount of polyester will flow away. This should be properly removed and the care should be taken that the surface of the bars prepared is smooth.
7. The bars are then left to curing for 24 hours and then the bars are removed from the frames and is kept at safe place till they are tested and are used in the beams

Figure 3. GFRP bars set to curing

A. Testing of the GFRP bars

The GFRP bars are tested to access the

properties of bars and these properties are used in the design of the beams.The testing of the GFRP bars is done in the 100T computerized UTM machine

Figure 4. 100T computerized UTM machine

Figure 5. steel casing for the ends of the test specimens

The bars thus made is mounted on to the UTM and the Tension test is carried out.

Figure 6. GFRP bar mounted onto the UTM machine

IV. Design of the beam

A. DESIGN OF BEAM REINFORCED WITH STEEL BARS (*designed using IS 456:2000*)[8]

The available beam dimensions are 100mm x150mm. The grade of the concrete and steel are M30 and Fe500 respectively. The properties of the GFRP bars are as shown in table 3.

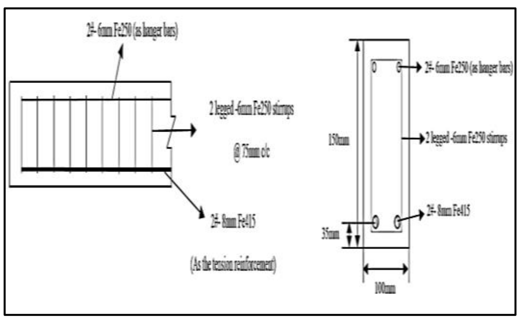


Figure 7. The assumed details of the c/s

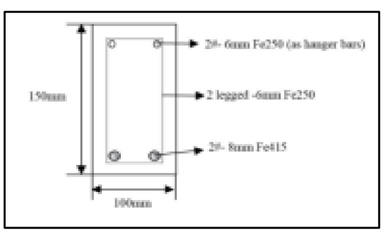


Figure 8. The detailing of the beams after the design

B. DESIGN OF BEAM REINFORCED WITH GFRP BARS (*designed using "REINFORCING CONCRETE STRUCTURES WITH FIBER REINFORCED POLYMER- design manual 3)*[9]

The assumed detail of the cross section of the strengthened beam is as follows

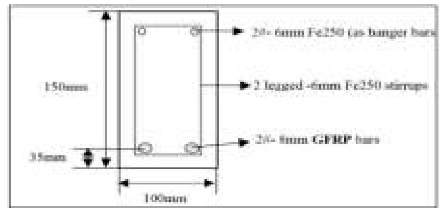


Figure 9. The assumed c/s details (GFRP reinforced)

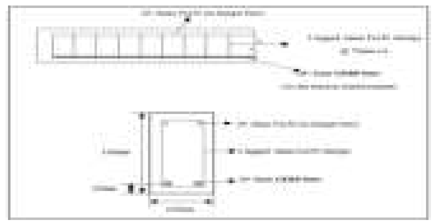


Figure 10. Reinforcement detailing after carrying out the design

V. Casting and curing the beams

6 beam samples (3 steel reinforced and 3 GFRP reinforced) of size 1300mmX 100mm X150 mm are casted

1. The reinforcement cage as per the detailing provided in the figure 8 and figure 10 is prepared.

Figure 11. Beam moulds and reinforcement cages

2. The mix of concrete is made using the procured aggregates, cement, water.

3. The concrete us poured into the moulds and is compacted well.

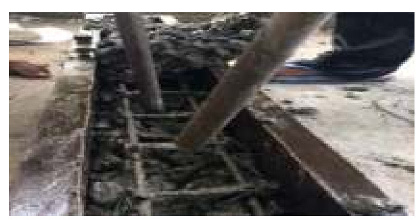


Figure 12. Pouring concrete into mould & compacting

4. The concrete is left to harden for 24 hours and then the moulds is removed. The concrete beam is then placed in the curing tank available in the concrete technology laboratory

Figure 13. Placing the beams into the curing tank

6. Flexural test was conducted on the beams after

28 days of curing.

VI. Testing the beams

The testing of the beams were conducted on the 100 tonnes loading frame

Figure 14. Arrangement of the test specimen

The procedure carried was as follows

1. After removing the beams from the curing tank they are allowed to dry
2. The markings are made on the beams at the points where the loads are to be acted
3. Then the beams were mounted onto the loading frame
4. LVDT are placed at the center of the beam to record the deflection of the beam
5. The load is applied on the beam and the values were

recorded in the computer. The software used for recording the readings is "IEICOS 20 CHANNEL DATA LOGGER-MDAS-20"

VII. Results

GFRP BARS- After testing the GFRP bars the following results were obtained (the results in the table are the average of the three best samples whose values are closer to each other).

Table 3: Properties of the single stranded GFRP bars

PROPERTY	GFRP BARS
Diameter (mm)	5.655
C/s area mm^2	25.135
Mass (kg)	0.03
Density(kg/m^3)	1975
Initial gauge length (mm)	360
Final gauge length (mm)	364.6
% elongation	1.27
Strain	0.0125
Tensile Strength (N/mm^2)	586.955
Modulus of Elasticity (N/mm^2)	48051

BEAMS- The flexural strength of the beam and the deflection as calculated and as obtained in the test are tabulated in table no.5

Table 4. Theoretical values obtained

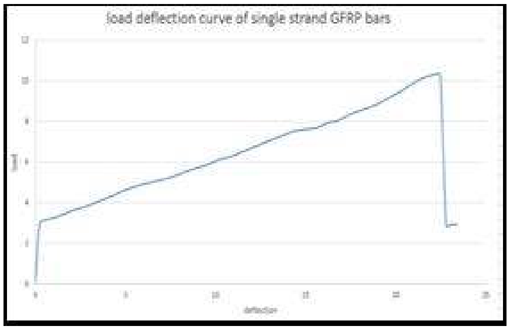
Property/ parameter	Steel reinforced beams	GFRP reinforced beams
Load (tonnes)	1.45	1.21
Load (N)	14224.5	11870.1
Moment of resistance ($\times 10^6$N-mm)	4.28	3.58
Flexural strength (N/mm^2)	11.41	9.5464

Table 5.Experimental values obtained

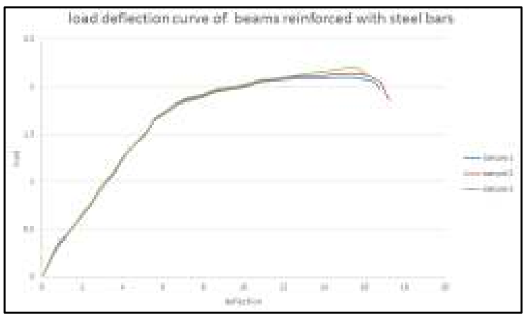
Property/parameter	Sample no	Steel reinforced beams		GFRP reinforced beams	
		Test	Avg.	Test	Avg.
Load (tonnes)	1	2.05	2.1366	1.4	1.46
	2	2.15		1.47	
	3	2.21		1.52	
Load (N)	1	20110	20960	13734	14355
	2	21091		14420	
	3	21680		14911	
Moment of resistance ($\times 10^6$N-mm)	1	6.03	6.28	4.12	4.30
	2	6.32		4.32	
	3	6.5.		4.473	
Flexural strength (N/mm^2)	1	16.088	16.766	10.98	11.48
	2	16.87		11.536	
	3	17.34		11.928	
Deflection	1	16.65	16.97	14	14.44
	2	16.72		14.54	
	3	17.52		14.79	
Area under load displacement curve	1	16.102	16.218	10.3975	11.828
	2	16.195		12.0138	
	3	16.358		13.0737	

VIII. GRAPHS

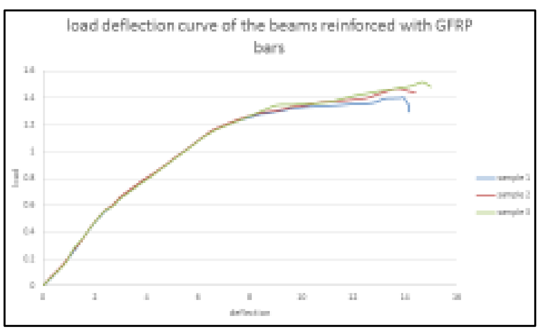
IX. Inference



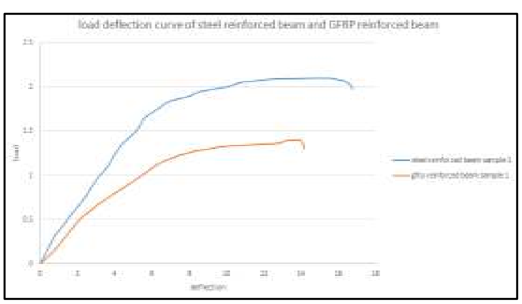
Graph 1. Load deflection curve of single strand GFRP bar



Graph 2. Load deflection curve of beams reinforced with steel bars



Graph 3. Load deflection curve of beams reinforced with steel bars



Graph 4. Load deflection curve of steel reinforced beams and GFRP reinforced beam

From the results obtained it can be inferred that

1. The experimental value of moment of resistance of the beams reinforced with steel bars is 53.29% higher than that of the theoretical value as calculated using "IS 456:2000- PLAIN AND REINFORCED CONCRETE- CODE OF PRACTICE".

2. The experimental value of moment of resistance of the beams reinforced with steel bars is 12.2% higher than that of the theoretical value as calculated using "REINFORCING CONCRETE STRUCTURES WITH FIBER REINFORCED POLYMER- design manual 3".

3. The load carrying capacity, Moment of

Resistance, and flexural strength of the GFRP bars reinforced beams is 31.5 % lesser than that of the Steel bars Reinforced beam.

4. The Deflection of GFRP bars reinforced beams is

14.9% lesser than that of the Steel bars Reinforced beam.

5. The Energy absorption of GFRP bars reinforced beams is 27.06% lesser than that of the Steel bars Reinforced beam.

6. In both the types of beams the crack formation was sudden

7. The type of the failure in the GFRP bars reinforced beams is tension failure. But according to design manual "REINFORCING CONCRETE STRUCTURES WITH FIBER REINFORCED POLYMER- design manual 3" the type of failure

should be compression failure. Hence the design

procedure should be reconsidered.

X. Conclusion

The GFRP hold a promising hand in improving the durability of the concrete. In several parts of the world especially in USA, Canada, Australia, China they are widely used especially in the strengthening and have a huge application in the construction bridges.

From the above experiment it is evident

1. That inspite of the good tensile strength of the GFRP bars it is also inherited with the brittle failure. This problem can be decreased by the material hybridization through which the pseudo-ductile behavior of the bars can be achieved.

3. The obtained experimental value of the beams are higher when compared to that of the theoretical value.

4. The failure of the GFRP reinforced beam should be compression failure (according to the codal provision) but the beam failed in tension. This aspect of the project need to be reconsidered.

5. The Deflection of GFRP bars reinforced beams is lesser than that of the Steel bars Reinforced beam. The Energy absorption of GFRP bars reinforced beams is nearly 3/4th of the Steel Reinforced beam.

References

[1] Nawy, E., Neuwerth, G., Phillips, C. (1971), "Behavior of Fiber Glass Reinforced Concrete Beams", ASCE Journal of the Structural Division, Vol 97, No. ST9, September 1971.

[2] Brown, V.L., Bartholomew, C.L. (1993), "FRP Reinforcing Bars in Reinforced Concrete Members", ACI Structural Journal, Vol. 90, No. 1, January-February 1993

[3] Benmokrane B., Challal, O., Masmoudi, R. (1996), "Flexural Response of Concrete Beams Reinforced with FRP Reinforcing Bars", ACI Structural Journal, Vol. 93, No. 1, January 1996.

[4] Bakis, C.E., Bank, L.C., Brown, V.L., Cosenza, E., Davalos, J.F., Lesko, J.J., Machida, A., Rizkalla, S., Triantafillou, T. (2002), "Fiber- Reinforced Polymer Composites for Construction- State-of-the-Art Review", ASCE Journal of Composites for Construction, Vol 6, No. 2, May 2002

[5] Malvar, L.J. (1995), "Tensile and properties of GFRP Reinforcing Bars", ACI Structural Journal, Vol. 92, No.3, May- June 1995.

[6] D.H. Taveres et al.., (2008) "behaviour of reinforced concrete beams reinforced with GFRP bars" IBRACON structures and material journal-, September 2008

[7] Ehab M. Lotfy (2010)- "behaviour of Reinforced concrete short columns with fiber reinforced polymer bars", international Journal of civil and structural engineering, Vol 1, no.3, 2010

[8] "IS 456:2000- PLAIN AND REINFORCED CONCRETE- CODE OF PRACTICE"

[9] "REINFORCING CONCRETE STRUCTURES WITH FIBER REINFORCED POLYMER- design manual 3".