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Flexural Behaviour Of Concrete Beams Reinforced With Gfrpreinforcements

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***ABSTRACT* –Existingconcrete structures may, for a variety of reasons, be found to perform unsatisfactorily. This could manifest itself by poor performance under service loading, in the form of excessive deflections and cracking, or there could be inadequate ultimate strength. Additionally, revisions in structural design and loading codes may render many structures previously thought to be satisfactory, noncompliant with current provisions. In the present economic climate, rehabilitation of damaged concrete structures to meet the more stringent limits on serviceability and ultimate strength of the current codes, and strengthening of existing concrete structures to carry higher permissible loads, seem to be a more attractive alternative to demolishing and rebuilding. This paper investigates the flexural behaviour of GFRP reinforced concrete beams. A total 6 beams (3GFRP beams and 3 steel beams) with (250×150) mm rectangular cross section and of span 2000 mm were casted and tested.**

Index terms -GFRP, reinforcement, flexure, two point loading, load-deflection.

I. INTRODUCTION

Steel rebar has weakness of susceptible to corrosion when it is exposed to salts, moisture and aggressive chemicals. When corrodes, steel rebar swells and increases the tensile load on the concrete, which begins to crack and spall, creating openings that lead to further and faster deterioration of the steel and concrete. Steel has no corrosion resistance, frequently it comes to the job site already rusting. This necessitates costly repair and maintenance. Numerous coatings and penetrants have been introduced over the decades to help seal out moisture from concrete, and steel rebar. But it isn't always possible to prevent corrosion in the long term. Further, steel rebar's likely to conduct electrical and magnetic fields makes it undesirable in concrete specified for certain power-generation, medical/scientific-imaging, nuclear and electrical/electronic applications.

Fiber-reinforced polymer (FRP) bars are being increasingly used in concrete structures due to their light weight (1/4th weight of steel rebar), high stiffness to weight ratio, good fatigue properties, ease of handling, lower maintenance cost, lower transportation fee, easy cutting, proper bonding to concrete. Tensile strength of FRP rebar is typically 1.5 to 2 times higher than steel. It also provides excellent fatigue resistance, making it suitable for cyclic loading situations. The benefits of GFRP rebar are high corrosion resistance, superior tensile strength, thermal expansion, electric and magnetic neutrality. Utilising these inherent benefits, GFRP rebar has a cost effective application

as a concrete reinforcing bar in the following environments on a life-cycle cost basis: reinforced concrete exposed to corrosive environments, structures built in or close proximity to sea water, applications subjected to other corrosive agents, applications requiring low electric conductivity or electromagnetic neutrality, Mining/ tunneling / boring applications, Weight sensitive structures, Thermally sensitive applications. FRP rebar appear to be promising alternative to steel reinforcement in concrete structures.Canadian and American Concrete Institute currently codified code for design of reinforced concrete using FRP reinforcing bars. Diameter from 3 mm to 40 mm are available.

Adam C. Berg et al describes the use of FRP materials as reinforcements and formwork for a concrete highway bridge deck. Based on the analysis of the short-term material and labour costs it appears that RP reinforcements for bridge decks may be cost-effective, notwithstanding their currently high initial costs. Ashour reported test results of 12 concrete beams reinforced with GFRP bars subjected to a four point loading system. The flexural failure is mainly occurred due to tensile rupture of GFRP bars either within the mid-span region or under the applied point load. The shear failure is initiated by a major diagonal crack within the beam shear span. Balendran et al presented the results of an experimental study of flexural behaviour of sand coated FRP bars in concrete. Results of the beam tests indicated that the ultimate strength of sand coated GFRP reinforced specimens was 1.4 -2 times greater than that of the mild steel reinforced specimens but exhibited a higher deflection. BiswarupSaikia et al investigated GFRP reinforced beams designed based on limit state principles have been examined to understand their strength and serviceability performance. Dong-Woo Seo et al presented an experimental study on the tensile performance of "FRP Hybrid Bars". The effect of hybridization on tensile properties of FRP Hybrid Bars was evaluated by comparing the results of tensile test with those of non-hybrid FRP bars. The results of this study indicated that the elastic modulus of the hybrid GFRP bar was increased by up to approximately 5 to 204 percent by the material hybridization. Ehab M. Lotfy presented the results of an experimental investigation of the axial behaviour of small scale square reinforced concrete columns with FRP bars. Results from a series of tests on small scale specimens showed that increasing main reinforcement, transverse reinforcement ratios in the column ends and increasing characteristic strength of concrete have a significant effect on the behaviour of reinforced concrete columns with GFRP.Esam El-Awady et al presented an experimental and analytical investigation of the torsional behaviour of FRP-reinforced concrete beams. Eighteen test beams reinforced by FRP and normal steel bars were constructed and tested under combined torsion and flexure. Francesca Ceroni et al summarized the factors influencing durability of RC elements with FRP rebars depending on reinforcement characteristics and their interaction with concrete. FakhreddinDanesh et al investigated the the effects of parameters like FRP bar ratio and compressive strength of concrete on the flexural capacity and ductility of column. Francesco Micelli et al made an effort to develop an experimental protocol to study the effects of accelerated aging on FRP rods. The experimental data showed that resin properties may strongly influence the durability of FRP reinforcement, environmental combined cycles did not take to significant damage of conditioned rod-specimens, GFRP rods are sensitive to alkaline attack when resin does not provide adequate protection to fibers. HanyTobbi et al studied on members reinforced internally with FRP bars and subjected to compressive axial load. Hui Wang et al studied the performance of FRP rebar reinforced concrete columns under fire condition by the finite element method. Julio F. Davalos et al studied the durability performance of FRP bar concrete interface bond, purposely focused on the surface material degradation of FRP bar by using a concrete mix with high compressive strength. Ramadass et al studied experimentally on concrete beams reinforced with FRP bars. The results of this study reveal that modification is required for the model by IS: 456(2000) to predict the shear strength of members with FRP bars as internal reinforcement. Saraswathy et al concluded that failure of the GFRP reinforced concrete beams was mainly due to its reduced post cracking stiffness and the slip between rebar and the concrete matrix. ShahriarQuayyum et al studied 177 beam bond test data, failed by concrete splitting, was collected to investigate the effect of concrete confinement on the bond strength with FRP rebar. Thomas et al evaluated the performance of hybrid rebars as longitudinal reinforcement in normal strength concrete beams. Yi Chen et al presented accelerated aging test results of a durability study onFRPreinforcing bars for concrete structures.

II. PROPERTIES OF MATERIALS USED

A. *Properties GFRP*

GFRP has low electrical and thermal conductivity.It is highly resistant to chloride ion and chemical attack.Its tensile strength is greater than that of steel yet it weighs only one quarter as much. Manufacturer is KomARLtD, Russia. 8mm diameter bar was used as flexure reinforcement and shown in Fig.1.

B. *Properties Of Steel(Fe 415)*

Fe 415 is high yield strength steel cold twisted deformed bar as per IS 1786 and that yield stress or 0.2% proof stress of Fe 415 is 415 N/Sqmm.Tensile strength is more than 10% of the actual 0.2% proof stress but not less than 485 N/Sqmm.Trade name is TISCON TMT Rod and shown in Fig.2.

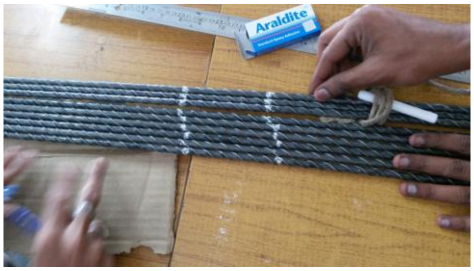

Fig.1 8mm dia GFRP rebars

Fig.2 8mm dia Fe415 steel Bar

C. *Properties Of Coarse Aggregate*

The particle shape of aggregate contributes to the effectiveness of producing a high performance concrete.Crushed rock creates a better bond between the paste and the aggregate than a gravel does.The mineral makeup of the aggregate also influences the modulus of elasticity of concrete.20mm size is used and shown in Fig. 3.

D. *Properties Of Sand*

River sand after water has been mixed into it most have adequate strength and plasticityan shown in Fig.4.

Fig.3 Coarse Aggregate 20mm

Fig.4 Fine Aggregate

E. Properties Of Cement (OPC)

OPC53 Priya Cement is used. Fineness / particle size of Portland cement affects rate of hydration, which is responsible for the rate of strength gain. Approximately 95% of cement particles are smaller than 45 micron with the average particle size about 15 micron.

III. CASTING OF SPECIMENS

Three beams of size 150 mm width, 250mm depth and 2000mm length were casted with three numbers of 8mm steel rebars and with three numbers of 8mm diameter GFRP rebars. Concrete grade was M25 with nominal mix 1:1:2 was adopted. Wooden mould used for casting beams is shown in Fig.5. Companion specimens like cubes, cylinders and prisms were casted and cured with beam specimens for 28 days and shown in Fig. 6 to 9.

Fig. 5 Wooden Beam Mould

Fig.6 Cubes 150 mm Size

Fig.7 Cylinders 150mm diameter and 300mm height

Fig.8 Prism 500mm X 100mm X 100mm

Fig.9 Beams 150mmX250mmX2000mm

IV. TESTING OF BEAMS AND COMPANION SPECIMENS

The companion specimens were testedand cube compressive strength, stress-strain curve, split tensile strength and flexural strength of concrete were obtained on 28th day after 28 days curing from casting.Companion Specimens test results are tabulated in Table. 1.

Sl.No.	**Companion specimen at 28 days**	**Steel Beams**	**GFRP Beams**
1	Compression strength of cube f_{ck},N/mm^2	30.31	25.97
2	Split tensile strength on cylinder f_t ,N/mm^2	2.43	2.63
3	Flexural testing on prism, N/mm^2	6.57	6.53
4	E_c on testing cylinder, N/mm^2	2.1x 10^4	1.97 10^4

A. Testing Of BeamsTo Two-Point Loading

Beams were loaded with two point loading for middle one-third span as shown in Fig. 10.

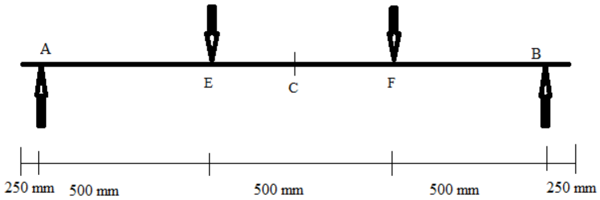

Fig. 10 Two loading of beams for Flexure

A.1 Load-Deflection Behaviour

Deflectionsat centre (Δc) and under loading (ΔE, ΔF) weremeasured using LVDT at each increment of load.Load and deflections measured for GFRP rebar reinforced Beam

(GB) and for steel rebar reinforced beam (SB) is tabulated in Table. 2 and 3 respectively.

Table. 2 Load and deflections measured for GFRP rebar reinforced Beam (GB)

Sl. No.	**Load, P (KN)**	**Deflection of beam at centre, Δ_c (mm)**	**Deflection under load**	
			at Δ_E (mm)	**at Δ_F(mm)**
1	0	0.00	0.00	0.00
2	100	0.90	0.85	0.85
3	150	1.45	1.35	1.31
4	200	2.68	2.08	2.10
5	250	3.67	2.67	2.68
6	300	4.20	3.38	3.26
7	350	5.10	3.86	3.77
8	400	5.43	4.35	4.31
9	450	6.33	4.86	4.86
10	500	6.90	5.33	5.33
11	550	7.34	5.76	5.81
12	600	7.76	6.10	6.15
13	650	8.20	6.75	6.83

Table. 3 Load and deflections measured for Steel rebar reinforced Beam (SB)

Sl. No.	**Load, P (KN)**	**Deflection of beam at centre, Δc (mm)**	**Deflection under load**	
			at ΔE (mm)	**at ΔF (mm)**
1	0	0.00	0.00	0.00
2	100	0.44	0.45	0.26
3	150	1.38	1.13	1.18
4	200	2.12	1.75	1.82
5	250	3.25	2.45	2.45
6	300	3.83	2.96	3.00
7	350	4.50	3.50	3.45
8	400	5.40	4.35	3.20
9	450	7.65	6.40	5.00

Load versus central deflection graph was plotted for GB and for SB and shown in Fig. 11. Deflection profile along length of beam for GB and SB is shown in Fig. 12 for 450kN. From experimental study, it is observed that load carrying capacity of GB is 48.6% more than SB. From Fig. 11, it is observed that initially GB exhibits slightly high deflection than SB. It is also observed that in latter stages of loading deflection of GB is less when compared to SB. It can be noted that load-deflection curve of SB shows bi-linearitywheras GB shows straight profile.The load-deflection of SB shows yield at 400kN and the profile shows nonlinearity. The load-deflection graph of GB shows linearity with no yield.At 450kN, the deflection of GB is 17.25% less than SB.

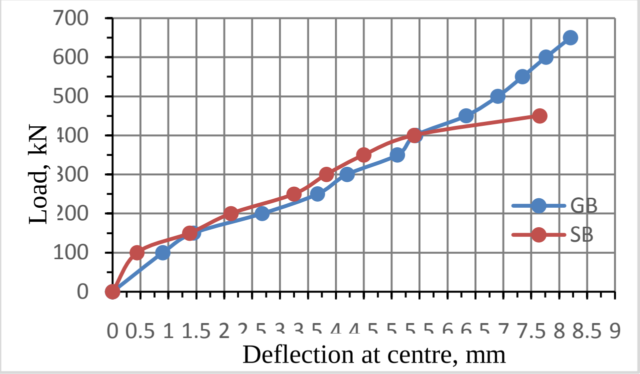

Fig. 11 Load versus central deflection for GB and for SB

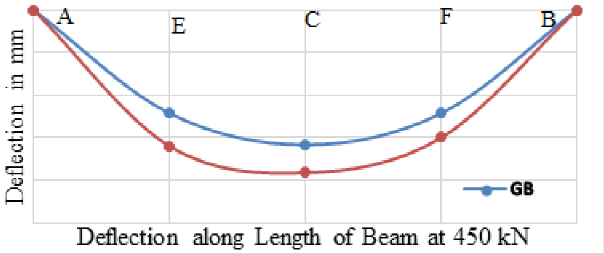

Fig. 12 Deflection profile along length of beam for GB and SB for 450kN.

A.2 Stress-Strain Characteristics

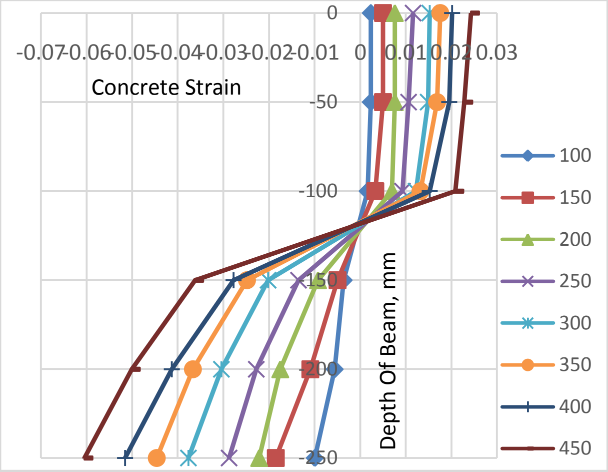

Fig. 13 Strain variation across depth of beam for various loading increment till 450kNof SB

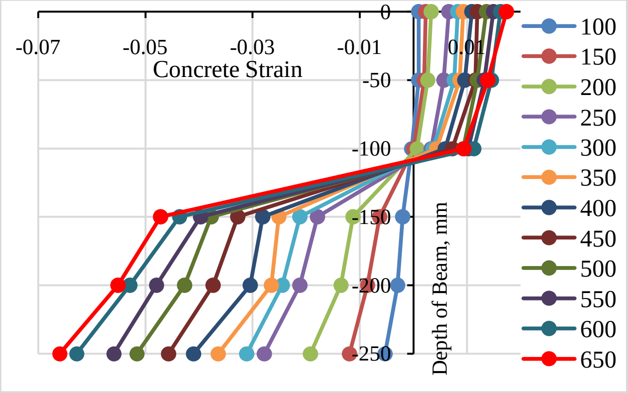

Fig. 14 Strain variation across depth of beam for various loading increment till 650kN of GB

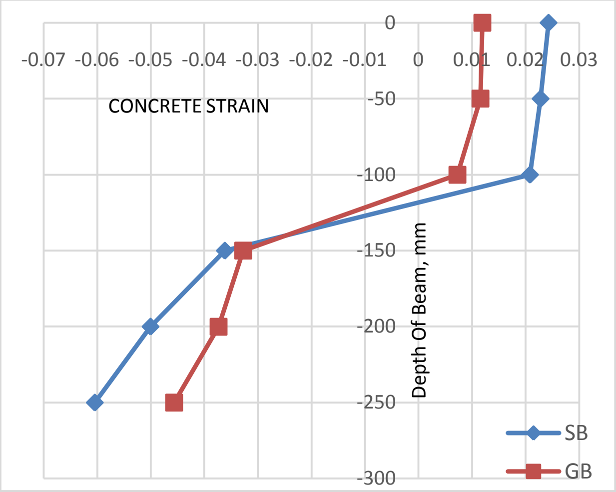

Fig. 15 Strain variation across beam depth at failure load of SB (450kN)

For SB, netural axis depth from extreme compression fibre (xu) is 118.26mm at its ultimate load 450kN. For GB, netural axis depth is 108.33mm at its ultimate load 650kN and is109.1mm at load 450kN (ultimate load of SB). From this, the ratio (xu/d) is 0.523 for SB and is 0.48 for GB at its corresponding ultimate load. Fig. 15 shows comparision of Strain variation along beam depth t 450kN (ultimate load of SB). It can be noted that beam reinforced with glass fibre reinforced rebar shows less concrete strain, about 50 % less compressive strain and about 25% less tensile strain. Fig. 16 shows strain in steel reinforcement of SB and in GFRP rebar in GB. It can be noted that even at higher load strain in GFRP rebar has less strain.

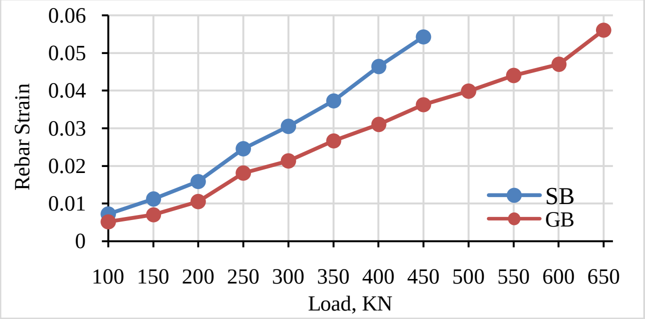

Fig.16 Rebar Strain at various loading

A.3 Ruputre Characteristics

Failure of GB is shown in Fig. 17 and Fig.18 shows failure of SB at its corresponding ultimate load. Table. 4 gives the initial crack laoad and ultimate load of SB and GB. Initial crack load of GB is 17.65% higher than SB and ultimate load of GB is 48.6% higher than SB.

Fig. 17 Failure of GB under flexure

Fig. 18 Failure of SB under flexure

Table. 4 Initial Crack Load And Ultimate Load Of SB And GB

Specimens	Initial crack load, kN	Ultimate crack load, kN
Steel beams (SB)	35.5	59.6
GFRP beam (GB)	41.7	88.5

V. CONCLUSIONS

From the experimental study carried out on concrete beams reinforced with steel and GFRP rebar to two point loading, the following conclusions were made. Initial crack load of SB is 35.5KN and GB is 41.7KN. GB shows 1.18 times higher first crack load more than SB. Ultimate load of SB is 59.6KN and GB is 88.5KN. Load carrying capacity of

GB is 1.5 times higher than SB. When compared to standard steel rebar, the initial cost of GFRP rebar is found generally higher and is roughly comparable to epoxy-coated steel rebar. But on life cycle cost (LCC) basis it can be quite economical and performs better than steel rebar.

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