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A Feasibility Study on Using Gfrp Composites Bar in Rc Flexural Member

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Abstract

Steel reinforcements are commonly used for Reinforced Concrete (RC) beams all around the world to take flexural tension. But, the durability of the structure is reduced due to reinforcement steel corrosion. Avoiding reinforcement corrosion and finding alternative material to take flexural tension is the contemporary research work in the field of structural engineering. In the present study, RC beams are reinforced with Glass Fibre Reinforced polymer (GFRP) composites bar at tension zone and flexural test was carried out to determine the bending moment resistance of the beam. GFRP bars were prepared in the industry with the help of pultruded U-section box formwork. GFRP bars were coated with sand using epoxy resin to increase the bond between bars and the RC beam. Three GFRP reinforced concrete beam specimens of size 700 mm × 200 mm × 200 mm were prepared. Also, same size of normal steel reinforced cement concrete beam member was prepared. After 28 days curing, three point bending test was carried out for all the four beams. Flexural capacity of beams with GFRP bars were compared with RC beam with steel bars. The results revealed that the flexural capacity of RC beams with GFRP bars is more than that of RC beam with steel bars. Also, theoretical analysis was carried out to determine the flexural strength of RC beam with steel and GFRP bars and compared with experimental results.

Keywords: GFRP Composites; RC Beam; Flexural Capacity.

1. Introduction

Simply supported RC beam is subjected to compression at top and tension at bottom due to external forces acting on a beam and self-weight. Concrete is week in tension and another material is required to take care on bending tension. Steel is strong in both compression and tension and hence, steel reinforcement is embedded inside the concrete at bottom of the beam. On the other hand, corrosion in steel reinforcement is a major problem in reinforced concrete structures. So many technologies are followed to reduce/ avoid rebar corrosion.

In the present study, GFRP composites were used for the preparation of GFRP rebar and used as tension reinforcement. Many research works carried in the same field. Radhouane Masmoudi et al (1998) have studied the flexural behavior of concrete beams reinforced with deformed fiber reinforced plastic reinforcing rods [1]. Houssam Toutanji and Yong Deng (2003) have determined the deflection and crack-width prediction of concrete beams reinforced with glass FRP rods [2]. Muhammad and Ali (2008) considered high temperature effect on RC beams with CFRP bars and compared with normal temperature [3]. Slobodan et al. (2010) investigated RC beams strengthened with Near Surface Mounted (NSM) reinforced FRP composites. NSM is a new technique in which bars or strip shaped FRP elements are embedded at tension zone of a beam as additional reinforcement [4]. Aly Abdel Zaher Elsayed et al (2015) have studied the behavior of beams reinforced with different types of bars from glass fiber reinforced polymer, carbon fibre reinforced polymer (CFRP) and high tensile steel (HTS) under static load [5]. Recently, Aravind (2017) and Hamza (2017) have used GFRP laminates [6] and steel mesh [7] for the strengthening of RC flexural members respectively.

Advantages of using GFRP composite materials are reduced disruption, light weight density, fast and ease of installation, durability, extended long life, fatigue and shock resistance, easy transportation and cost saving. Some of the major demerits of using GFRP composites are, need skilled person for the preparation of laminate/ bar. Epoxy resins are mixed with hardener and used to attach GFRP composites with concrete surface. There is a chance for delamination due to high temperature. This type of failure occurs in external retrofitting of RC beam. To avoid this issue GFRP bars are used as reinforcement and embedded in concrete.

2. Materials and Methods

This section consists of material properties, GFRP rebar fabrication, casting, curing and testing of RC flexural members. Fabrication/ preparation of GFRP bars in the industry is an important task in this research work.

2.1 Material Properties:

For this research work, the materials like GFRP fibers, resin, epoxy catalyst, P.V.A release agent, cement, coarse aggregate, water, HYSD steel bars and timber are used.

2.1.1 Fibre

The most common type of fibers used as reinforcement are carbon and glass. Fibers are of many patterns such as long roving (Figure 1), woven roving mesh (Figure 2) and chopped strand mat. In the present study, E-glass fiber mesh and long roving are used for the preparation of GFRP bar.

Fig 1: Long roving GFRP

Fig 2: Woven Roving GFRP

2.1.2 Resin and hardener

There many types and grades of resin used for GFRP bar/ laminates fabrication works. In the present study, General Purpose polyester Resin (GP) polyester resin as shown in Figure 3 was used for fabrication work. The setting time of normal GP resin along with the 1.5% of catalyst is 10 to 20 minutes. The standard specific gravity of resin is 1.1. Catalyst shown in Figure 4 is used to fasten the drying process of GP resin. In this study 1.5 % of catalyst is being used to make GFRP rebar and formwork.

2.1.3 Poly-Vinyl Alcohol release agent

Poly-Vinyl Alcohol release agent is shown in Figure 5 are applied on the surface of the mould. Poly-Vinyl Alcohol is added with water with a proportion of 1:10 and mixed thoroughly before the application.

2.1.4 RC beam ingredients

The coarse aggregate selected for the purpose of making the beam are typically having an angular shape, well graded which is suited for the concrete purposes and having the size of 20 mm maximum and 12 mm minimum. Maximum size of fine aggregate used for concrete is 5 mm. Cement used for the concrete preparation was Ordinary Portland cement (OPC) satisfy British Standard Code provisions. Steel bars of 14 mm high yield strength deformed are used for the RC beam preparation with grade/ strength of Fs 460 MPa. Ordinary potable water was used for casting and curing.

2.2 GFRP Rebar fabrication

For rebar fabrication, GFRP fibers, General Purpose resin, epoxy catalyst, Poly-Vinyl Alcohol release agent, cement, fine aggregate, coarse aggregate, water and HYSD bars are used. GFRP rebar are prepared based on pultrusion method, mechanically the GFRP long roving's are pulled and mixed with the resin and cooled mechanically to form rebar. In this work, GFRP rebar fabricated manually. An wooden mould was made with 7 numbers of 14 mm round grooves in it, as shown in Figure 6 and the long fiber are dipped with the resin known as resin bath and pultruded into the grooves, thus the round shape was achieved. Then it is kept for cooling about 20 minutes.

Fig 3: GP resin

Fig 4: Hardener

Fig 5: Poly-Vinyl Alcohol

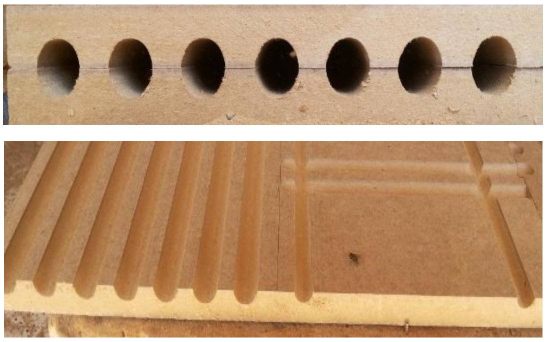

Fig 6: Wooden mould with groves

Fig 7: GFRP bar

To increase the bond between GFRP bar and concrete, sand coating was applied on bars. Figures 7 and 8 show the GFRP plain and sand coated bars respectively. The Fibre is then cut into the 700 mm length for testing and to form the FRP reinforcement arrangements. Shear reinforcements also prepared based on using the same pultruded technology and reinforcement cage was prepared as shown in Figure 9. Also, form work for beam casting work also prepared using GFRP composites and shown in Figure 10.

Fig 8: Sand coated GFRP bar

Fig 9: GFRP Formwork with rebar arrangements

2.3 Beam casting

Two beam specimen of size 200 × 200 mm with a length of 700 mm were cast using the GFRP rebar and two RC specimens with the same size are also cast. The casting of the beam specimen concrete consists of the materials such as cement, fine aggregate and coarse aggregate in the ratio of 1:1:3 respectively. The details of the beam specimen are given in the Table 1. The GFRP specimens will be acting as the formwork and the FRP rebar's which will be acting as the bottom reinforcement. To develop a bond and to strengthen the concrete beam GFRP cross links provided and tied with the help of GFRP tie rods. Each beam specimen is compacted well while casting. The formwork is removed after hardening of beam and cured for 28 days keeping the specimens in water. Companion cubes with size 150 × 150 × 150 mm also cast to determine the bond strength between GFRP bar and concrete by pull-out test.

Table 1. Details of Beam			
Beam ID	**Beam size in mm**	**Beam Type**	**Type of reinforcement**
B1	200 × 200 × 700	GFRP reinforced concrete beam	GFRP bars
B2	200 × 200 × 700	GFRP reinforced concrete beam	GFRP bars
B3	200 × 200 × 700	Steel reinforced concrete beam	Steel bars
B4	200 × 200 × 700	Steel reinforced concrete beam	Steel bars

Figure 10 shows the reinforcement cage for steel reinforced concrete beam. Concrete is pouring and compacting well as shown in **Figure 11**. After demoulding, all the four beams were kept in water tank for 28 days curing as shown in Figure 12.

Fig 10: Reinforcement cage

Fig 11: Concreting

Fig 12: Curing

2.4 Beam Testing

The beam tests were using 100T UTM in the materials testing laboratory, Caledonian College of Engineering. Single point load was applied at mid span of the beams as shown in Figure 13. Simply supported conditions are maintained for all the beams with a span of 600 mm. Load was applied monotonically on the beam and corresponding deflection at mid span were noted.

Fig 13: Flexural test on RC beam

3. Results

Based on the experimental test, ultimate load carrying capacities of the beams were noted. From the results, it was noticed that the ultimate failure load for GFRP beam was more than that of Steel reinforced concrete beams. The ultimate load taken by the GFRP beam was 54.41 kN and 52.50 kN and the maximum force or load taken by the steel RC beam was 48.34 kN and 43.69 kN. Table 2 shows the ultimate loads for various beams.

Table 2. Ultimate loads for beams			
Beam ID	**Beam Type**	**Ultimate loads in kN**	**Moment carrying capacity in kNm**
B1	GFRP reinforced concrete beam	54.41	4.08
B2	GFRP reinforced concrete beam	52.50	3.94
B3	Steel reinforced concrete beam	48.34	3.63
B4	Steel reinforced concrete beam	43.69	3.28

Average load carrying capacity of beam with GFRP and HYSD steel bars are 53.52 kN and 46.02 kN respectively. Based on the span and load bending moment at mid span of the simply supported beams subjected to concentrated load at mid span with steel and GFRP bars were determined using the formula,

$$Bending\ Moment\ at\ mid\ span, M = {W.L}/{4}$$

Where, W – Concentrated load acting at mid span of the beam

L – Effective span = 0.6 m

Average bending moment at mid span of the beam with GFRP and HYSD steel bars are 4.01 kNm and 3.455 kNm respectively.

4. Discussion

In the present study, GFRP bars were fabricated in the industry and used as reinforcement in RC beam instead of HYSD steel bars. In total, 4 beams were cast and among all, 2 beams with GFRP bars and remaining 2 beams with HYSD steel bars. Figure 4 shows bar chart for all the four beam types with corresponding ultimate loads.

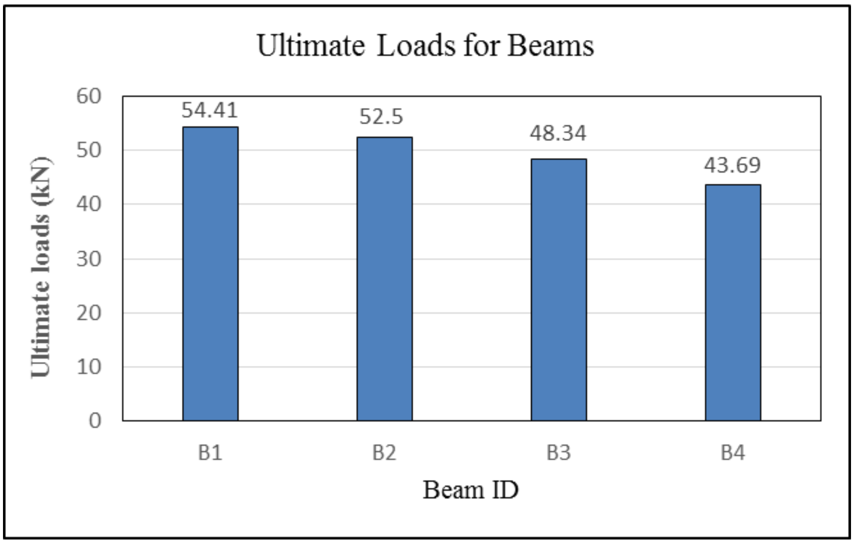

Fig 14: Flexural test on RC beam

Ultimate loads were noted from experimental results. Based on the experimental results, the following discussions are made.

- The ultimate load taken by the beams reinforced with Glass Fibre Reinforced Polymer bars were 54.41 kN and 52.50 kN.
- Similarly, ultimate load taken by the beams reinforced with High Yield Strength Deformed bars were 48.34 kN and 43.69 kN.
- Average load carrying capacity of beam with GFRP and HYSD steel bars are 53.52 kN and 46.02 kN respectively.

- Average load carrying capacity of RC beams with GFRP bars is 16.30 % more than that of RC beams with HYSD bars.
- Average bending moment at mid span of the beam with GFRP and HYSD steel bars are 4.01 kNm and 3.455 kNm respectively.

5. Conclusions

The following conclusions were made based on the methodology and experimental results.

- In the present study, GFRP bars were fabricated in the industry using wooden mould, GFRP composites, and general purpose resin and poly-vinyl alcohol release agent by pultrusion process.
- The process of fabrication GFRP bars is easy, economic and time saving when huge quantity of GFRP bars are required.
- The ultimate load taken by the beams reinforced with Glass Fibre Reinforced Polymer bars were 54.41 kN and 52.50 kN. Similarly, ultimate load taken by the beams reinforced with High Yield Strength Deformed bars were 48.34 kN and 43.69 kN.
- Average load carrying capacity of beam with GFRP and HYSD steel bars are 53.52 kN and 46.02 kN respectively. Average load carrying capacity of RC beams with GFRP bars is 16.30 % more than that of RC beams with HYSD bars.
- Average bending moment at mid span of the beam with GFRP and HYSD steel bars are 4.01 kNm and 3.455 kNm respectively.
- The comparison revealed that RC beams with GFRP bars are taking more loads when compared with beam with steel bars.

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