# Behavior of Concrete Beams Reinforced With Fibrous Polymer (FRP) Composite Bars

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## I. INTRODUCTION

### 1.1 GENERAL

Conventional concrete structures are reinforced with non prestressed and prestressed steel. The steel is initially protected against corrosion by the alkalinity of the concrete, usually resulting in durable and serviceable construction. For Many structures subjected to aggressive environments, such as marine structures and bridges and parking garages exposed to deicing salts, combinations of moisture, temperature, and chlorides reduce the alkalinity of the concrete and result in the corrosion of reinforcing and prestressing steel.

Recently, composite materials made of fibers embedded in a polymeric resin, also known as fiber-reinforced polymers (FRP), have become an alternative to steel reinforcement for concrete structures. Because FRP materials are nonmagnetic and noncorrosive, the problems of electromagnetic interference and steel corrosion can be avoided with FRP reinforcement. Additionally, FRP materials exhibit several properties, such as high tensile strength, that make them suitable for use as structural reinforcement (ACI Committee 440)

### 1.2 PROPERTIES OF FRP

The physical and mechanical properties of FRP reinforcing bars are presented in this chapter to develop a fundamental understanding of the behaviour of FRP bars.

#### 1.2.1 Density

FRP bars have a density ranging from one-sixth to one-fourth that of steel. The reduced weight leads to lower transportation costs and may ease handling of the bars on the project site.

#### 1.2.2 Effects of high temperatures

The use of FRP reinforcement is not recommended for structures in which fire resistance is essential to maintain structural integrity.

Because FRP reinforcement is embedded in concrete, the reinforcement cannot burn due to a lack of oxygen; however, the polymers will soften due to the excessive heat.

### 1.4 BEHAVIOUR

The physical and mechanical behaviour of FRP reinforcing bars are presented in this chapter to develop a fundamental understanding of the behaviour of these bars.

## II. PROPERTIES OF MATERIALS

### 2.1 GENERAL

The Experimental program consists of materials. Investigation of material properties, Arrival of Mix proportion for the selection grade of concrete, Casting of specimens casting and testing of specimens for mechanical properties such as compressive strength, tension strength and flexural strength

### 2.2 PROPERTIES OF MATERIALS

#### 2.2.1 Conventional Steel (10.6mm)

Fig 2.1 - Tension test

## III. CASTING OF TEST SPECIMENS

### 3.1 Test Specimens

A total of 12 full-scale reinforced concrete beams were constructed and tested. The beams were 2000 mm long, 120 mm wide and 250mm deep. The test parameters are the type of reinforcing bars and reinforcement ratio. Nine beams were reinforced with FRP bars and two control beams were reinforced with conventional steel. In beams reinforced with FRP bars, for each reinforcement ratio and type, three identical specimens were made. For FRP reinforced beams, three different reinforcement ratios using 1, 2, and 3 No.10 mm diameter bar (For all beams, the bars were arranged in one rows with 15-mm clear spacing. steel bars were used as top reinforcement (2 bars) as well as stirrups (@ 150mm) for all beams.

Table 1 shows the details of the test specimens. The specimens' designation refers to the type of reinforcing bars. The numbers 1, 2, or 3 refer to the number of bars used in each beam. Figure 1 shows the concrete dimensions and reinforcement details for the tested beams.

Table 3.1 Details of test specimens

| SPECIMEN | REINFORCEMENT CONFIGURATION | NO OF BEAMS |
|---|---|---|
| FRP | 3NO.10mm in 1 row | 3 |
| FRP | 3NO.10mm in 2 row | 3 |
| FRP | 3NO.10mm in3 row | 3 |
| STEEL | 3NO.10mm in3 row | 3 |

Figure 3.1Reinforcing details for the tested beam

Figure 3.2 Arrangement of cover with reinforcement


Figure 3.3 casted beam

W-conventional concrete,

1-Replacement one FRP bar,
2-Replacement two FRP bar,
3-Replacement three FRP bar,

Figure 3.4- Beams at the time of curing

## IV. EXPERIMENTAL PROGRAMME

### 4.1 GENERAL

The following specimens were cast and experiment were conducted on the concrete specimens to study certain aspect of concrete and FRP used in RCC work

### 4.2 STRENGTH TEST

The following strength test were performed

- Compressive strength
- Bond strength
- Flexural strength

#### 4.2.1 Compressive strength

Mix design for M 30 grade of conventional concrete is arrived by IS method. 6 cube were

Cast and 3 were tested for 7 days strength and remaining 3 were tested on 28th day.

The compressive strength of concrete is one of the most important properties of concrete. The strength in compression has definite relation with other properties of concrete i.e. these properties are improved with the improvement in compression strength .The aim of this experiment is to determine the maximum load carrying capacity of tests specimens. The concrete Cubes of size 150x150x150mm were placed on compression testing machine and were find the compressive strength.

**Compressive Strength in N/mm$^2$ =Ultimate load/Cross section area of specimen**

Fig 4.1Fresh concrete cubes in moulds

Fig 4.2 Compressive test of concrete cube

#### 4.2.2 BOND STRENGTH /PULL OUT TEST

This test is used to determine the bond strength between the FRP rod and concrete. The cylinder of size 150mm diameter and 300mm length is cast with the main road at the center and cured .After curing it is dried for a day to remove moisture from FRP. Now the specimen ready for pull out test .keep the specimen with FRP bar portion as top and clamp the main FRP rod with anchor. Now the load is applied through UTM. The maximum load at which the slip occurred is noted for calculation.

Mix design for M 30 grade of conventional concrete is arrived by IS method. 6 cylinders were Casted. 3 cylinders were conventional steel and 3 were FRP.Both specimens were on 28th day.

**Bond strength = Ultimate load/Total area of the rod**

= P/A

$A = (\pi d^2/4) + (\pi dl)$

P = ultimate load

A = Total area (i.e.) Surface area + Cross section area

D = Diameter of steel rod (10mm)

### 4.2.3 FLEXURAL STRENGTH ON FRP WITH REINFORCED BEAM

Concrete is relatively strong in compression and weak in tension. Direct measurement of tensile strength of concrete is difficult. Concrete beams of size 125mmX250mm and length 2000mm were cast to determine flexural strength of concrete. The systems of loading used in finding out flexural strength at two point loading.

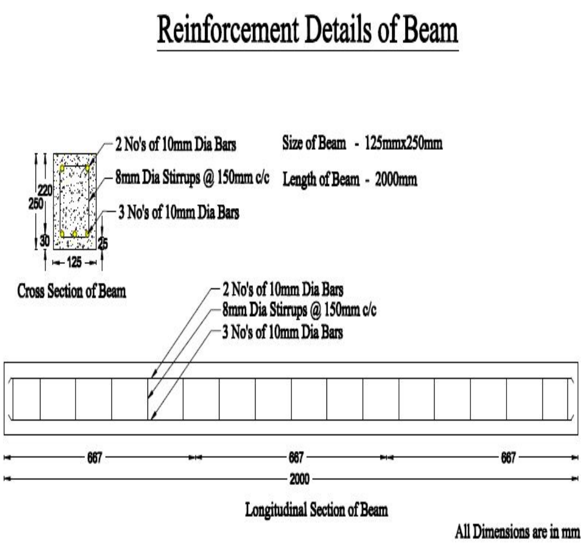


Fig 4.4 Reinforcement Details

## V. RESULTS AND DISCUSSIONS

### 5.1 GENERAL

Various properties of material were studied, result were compared and checked for compressive strength, flexural strength, bond strength at 7,28, days and the results obtained were tabulated as follows

### 5.2 COMPRESSIVE STRENGTH

The values of compressive strength of conventional concrete at the end of different curing periods (7 days, 28 days) are given in Table 5.1. These values are plotted in figs 5.1, 5.2, which show the variation of compressive strength at different curing ages respectively.

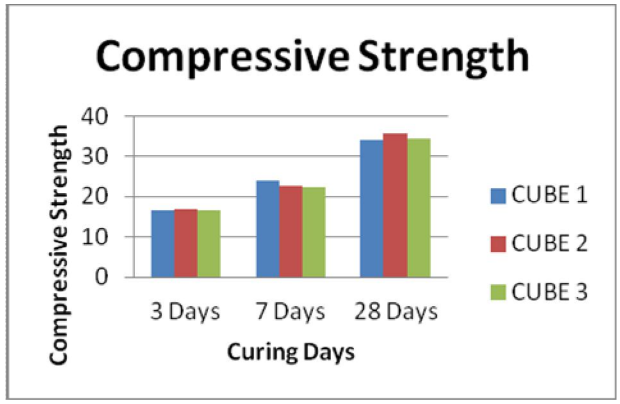


Fig 5.1 Graphical representation of compressive strength

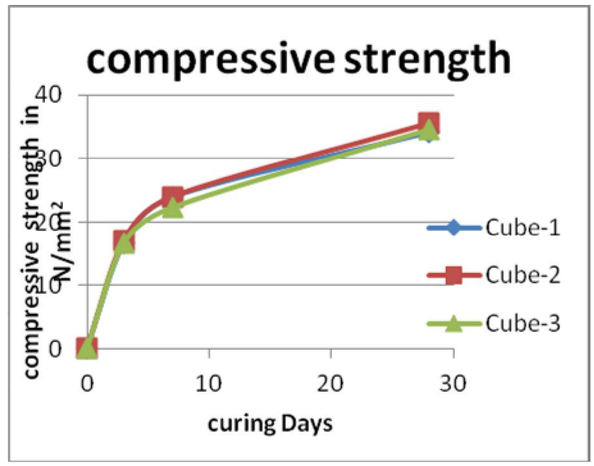


Fig 5.2 Graphical representation of compressive strength

5.3 Direct pullout bond tests of FRP reinforcement

This method consist embedding rebar a specific distance into a concrete cylinder, size 150x300mm of a concrete block. Once cured, the bar is pulled out using a universal testing machine while displacements and loads are measured. Although this is a common practice for determining bond behavior, it is widely believed that this method will yield unconservative bond stress values.

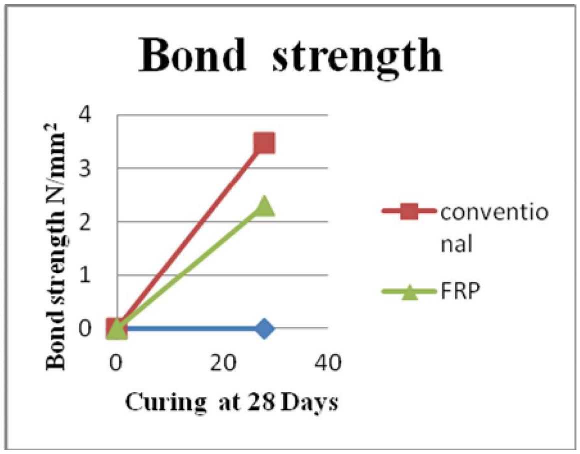


Fig 5.3Graphical Representation of bond strength

5.4FlexuralStrength

The values of flexural strength of convention concrete at the end of curing period (28 day) are given table 5.3, 5.4, 5.5, 5.6.the load vs deflection values are plotted

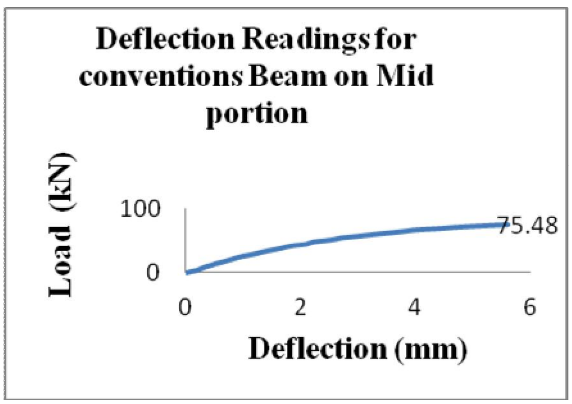


Fig 5.4 Graphical Representation of Flexural Strength on Convention Beam

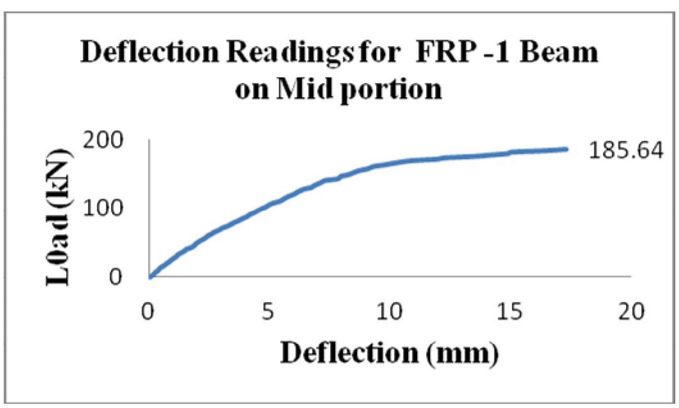


Fig 5.5 Graphical Representation of Flexural Strength of FRP-1 beam

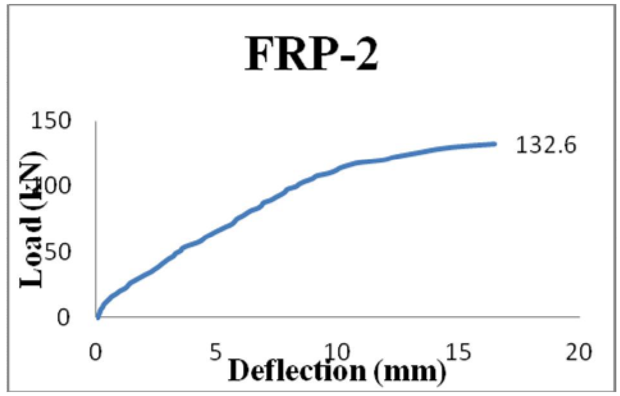


Fig 5.6 Graphical Representation of Flexural Strength of FRP-2 beam

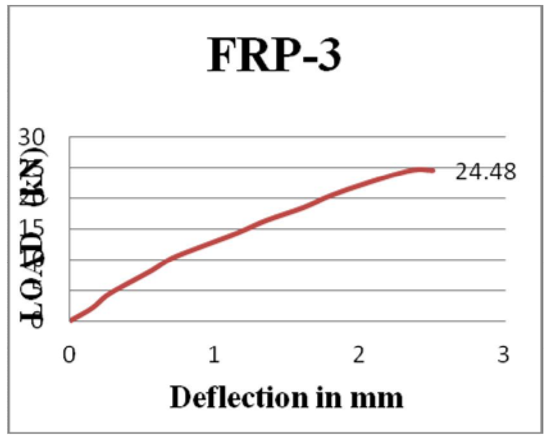


Fig 5.7 Graphical Representation of Flexural Strength of FRP-3 beam

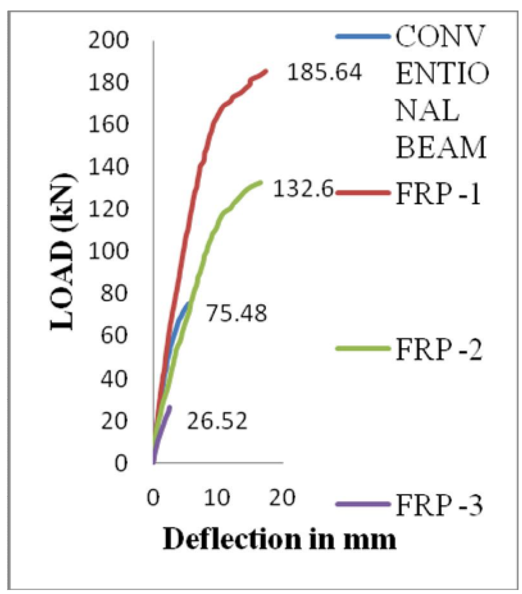


Fig 5.8 Graphical Representation of Flexural Strength of FRP and Conventional Beam

## VI. CONCLUSIONS

Certain conclusions drawn from this thesis are as detailed below:

1) Concrete beams Reinforced with GFRP sections experienced higher load carrying capacity and ductility compared with the conventional reinforced concrete beams by replacing one main bar
2) The modulus of elasticity of the GFRP bar reinforced concrete section is less than conventional RC structure
3) Increasing the reinforcement ratio decreases the deflection at service load limit due to higher stiffness and lower FRP bar stress. At the service load level, the measured deflection was reduced by approximately 30% and 60% due to the increase of reinforcement ratio 100% by replacing one, two and three no's of main FRP reinforcement respectively.
4) The Material cost comparisons for the FRP Reinforced bar 60% higher than the conventional reinforcement were at the same time long-term benefit due to the anticipated superior durability of the FRP reinforced concrete structures.
5) The maximum load carrying capacity of conventional concrete beams at 28 days is found to be 63.24kN. For FRP 1 specimen, the maximum load carrying capacity is 185.64kN at 28 days. Thus it can be concluded that the ultimate strength of FRP1 specimen is three times more than that of conventional concrete.
6) The number of cracks for beam reinforced with GFRP section was lower than the conventional beam. In addition, the average crack spacing of the GFRP reinforced concrete beam was also larger compared with the conventional beam.
7) The deflections in beams reinforced with GFRP bars are larger than compare to convention bars. This is due to the low modulus of elasticity and the different bond characteristics of the GFRP bars. To ensure adequate flexural stiffness for deflection, the flexural design of FRP reinforced concrete beams requires over-reinforcement.
8) The mode of failure for beams reinforced with GFRP sections were slightly different compared with the conventional beam .The GFRP reinforced concrete beams failed either by concrete crushing at the compression zone or rupture of the GFRP reinforcement. Failure due to rupture of GFRP reinforcement is not recommended because it may results in catastrophic failure of the structures.
9) The use of FRP s reinforcement beam. Proved to be beneficial in enhancing the stiffness, ultimate load, and cracking Performance of the reinforced concrete beam.

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