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Experimental Study on Behaviour of Basalt Fibers Reinforced Concrete Beam

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Abstract: *This paper focus on study of behaviour of beam reinforced with basalt fiber reinforced polymer bars.As steel reinforcement are susceptible to corrosion in aggressive environment. An attempt is intent to use a new type of fiber reinforced polymer rebar in beam instead of steel bar as flexural reinforcement. To study bond strength 10 mm and 12 mm size of BFRP bars were used to perform pull out test. For flexural behaviour 10 mm and 12 mm size BFRP bars were provided in flexural zone and compared with convention RCC beam.*
Keywords: *Steel Reinforcement, BFRP bars, flexural strength, bond strength, pull out test*

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I. Introduction

In 21st century also construction industry is dealing with corrosion of steel reinforcement bars under aggressive environment. Especially, in developing economies the construction in infrastructure domain is strongly needed. Industrial construction and domestic construction are growing rapidly in these economies. Many researchers across the globe have applied different methods to tackle the issue of corrosion in steel (Fig. 1).Many approaches are available to control corrosion of steel reinforcement such as increased cover, zinc reinforcing bar coatings, polymer modified cementations reinforced bar coatings, cathodic protection, corrosion-inhibiting admixtures in the concrete, impermeable high-performance concrete, and epoxy-coating steel reinforcement bars. The construction industry demands for more durable reinforcement which can easily replace conventional steel. Researchers working in this domain are constantly looking for an alternative to steel. Advancement in manufacturing industry has introduced different type of rebar such as CFRP, GFRP, BFRP, etc.

The principal reason of introducing FRP bars is to eradicate the losses incurred due to the corrosion of steel. Basalt Fiber Reinforced Polymer (BFRP) rebars is new technology that holds good promise for the construction industry (Fig. 2). Basalt rock is heated to a molten stage and formed into the fibers. Then they are mixed with epoxy resins and moulded into the rebar. Basalt fibers are not toxic to water or air, will not react with any of the components of concrete and have a very high chemical resistance. Compared to other fibers such as S-glass, carbon or aramid used in concrete, they are also considered to be inexpensive.

Basalt Fiber Reinforced Polymer (BFRP) bars provides a good alternative reinforcement due to its non-corrodible characteristic. Usage of this material will bring significant improvement in life cycle of the developed infrastructure. But before using this alternative material it is strongly recommended to understand the structural behaviour of element. So, the purpose of this study is to compare the flexure behaviour of beam casted by using conventional steel reinforcement and BFRP (Basalt Fiber Reinforced Polymer) rebar. As structural behaviour of any element is also influenced by bond strength between reinforcement and concrete, an attempt is also made to study bond strength for conventional steel and BFRP rebar.


Fig.1 Corrosion in reinforcement Fig.2 Basalt Fiber Reinforced Polymer bars

II. Objectives

The objective of this study was to examine the possibility of using BFRP reinforcement bars in concrete structures and to provide a good understanding of the structural behaviour of the concrete beams reinforced with BFRP bars as follows: -

1. To study the bond strength of the basalt reinforcement bar
2. To study the flexural behaviour of BFRP reinforced concrete beams

III. Literature Review

This experiment work was focused on limited area so literature review includes research work in regard to bond strength and flexural behavior of beam reinforced with FRP bars.

Deshmukh et al. (2017)described a new type of reinforcing bars, developed from basalt rocks, which are stronger than steel rods and at the same time are not prone to corrosion.Richard et al. (2007)found no significant differences in stiffness and strength between basalt fabric reinforced polymer composites and glass composites reinforced by a fabric of similar weave pattern. Yongshenget al. (2010)developeda new type of smart basalt fiber-reinforced polymer (BFRP) bar and investigated their sensing performance by using the Brillouin scattering-based distributed fiber optic sensing technique.

Duic et al. (2018) found that at a low reinforcement ratio, BFRP rebar reinforced beams exhibited more flexural and shear cracking than counterpart steel rebar reinforced concrete beams.Mathieu Boucher-Trudeau Patrick Paultre (2015) studied the parameters including the spacing of the hoops (75 or 150 mm), the intensity of the constant axial load (10 or 35% of the gross section capacity), and the presence of one or no carbon fiber–reinforced (CFRP) layer.Ilangovan (2016) investigated the effect of externally bonded FRP upon the strength characteristics of R.C columns.Gu (2017)provided the guidelines for the design of CRCP reinforced by BFRP. Liu (2015) found that the main failure mode of BFRP reinforced recycled concrete deep beam without web reinforcement was the shear failure and with the increase of shear span ratio, the shear failure transforms to flexural-shear failure.

Tefer (2006) suggested that when concrete will be stronger than about 30 MPa than there was a switch of bond shear failure from concrete into the surface layer of the FRP reinforcement bar. Harajli (2010) preferred ribbed FRP bar than threaded as FRP bars may be weaker and softer than steel bars. Brik (2003) had tested bond strength of BFRP bar as per ASTM and concluded that less bond strength was observed due to slipping of bars.

IV. Experimental Program

4.1 Material and Mixtures

The mixture proportions and properties of concrete used in the test program are given in Table 1.OPC 53 grade cement, aggregate – maximum size of 9.5 mm and 19 mm, river sandand potable water were used to prepare conventional concrete.Acoarse aggregate consisted of 20 mm and 10 mm (grit) down size with a ratio 60% and 40% of total quantity, respectively. As steel Fe 500 and BFRP rebar were used in RCC and BFRP beamrespectively.A RCC and BFRP beam is reinforced with 10 mm and 12 mm diameter bars as per design.

Table 1: Mixture Proportions

Material	Water(lit/m^3)	Cement (kg/ m^3)	F.A (kg/ m^3)	C.A (kg/ m^3)	Compressive Strength (N/mm^2) 28 days
Quantity	186	372	637.85	1187.95	
proportion	0.5	1	1.71	3.20	40.36

4.2 Tensile Strength of Steel bar

Fig.3 shows stress-strain behaviour and result for grade Fe500 for 10 mm diameter bar.

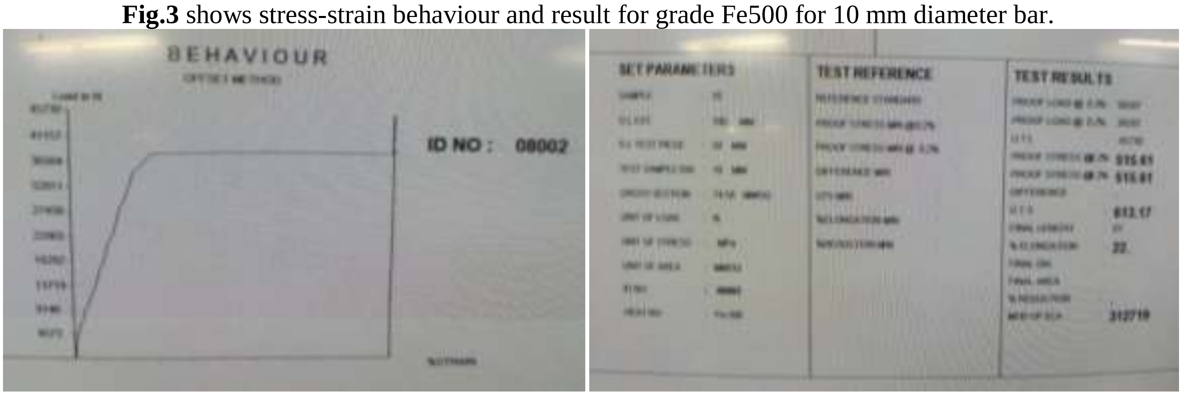


Fig.3 View of tension test result for 10 mm diameter bar

4.3 Description of test specimens

The specimens considered for this experimental programme were designed as singly reinforced RCC beam as per designed according to IS 456:2000 to find flexural strength. As per availability of laboratory facility length of beam was considered as 1m while C/C distance in regard to testing in UTM was considered as 900 mm. At bottom tensile reinforcements were provided with 2-10 mm and 2-12 mm diameter respectively in RCC and BFRP beam both. Fig.4 represents cross section of beam.

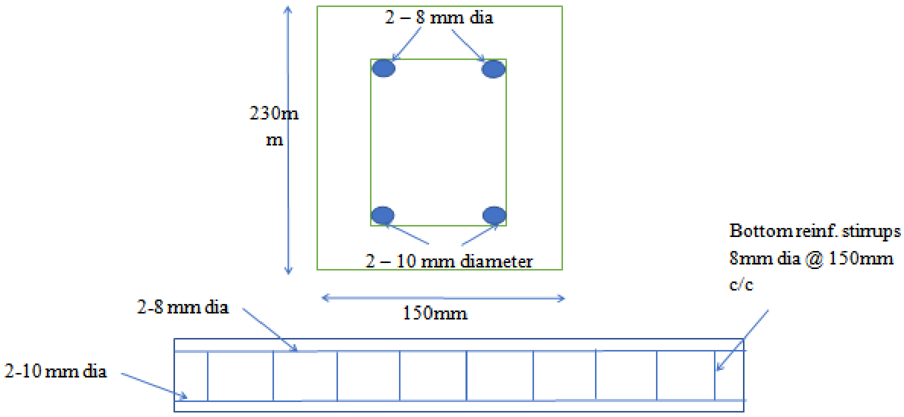


Fig.4 C/S of beam

4.4 Casting of test specimens

Following Fig. 5 represents different stages of casting RCC and BFRP beam.

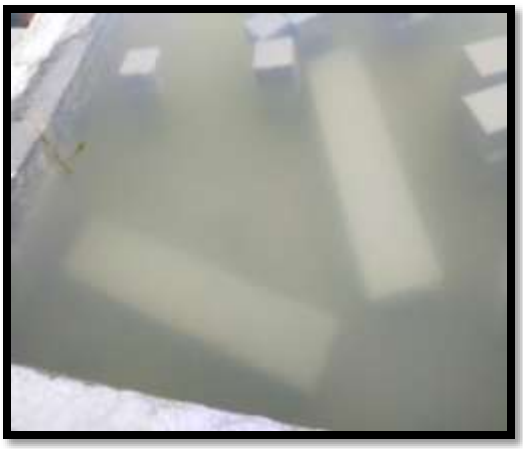
	
5 (a) Reinforcement Cage in formwork	5 (b) Placing of concrete in specimen
	
5 (c) Finished specimen after casting	5 (d) Curing of Specimen

Fig. 5 Different stages of casting RCC and BFRP beam

V. Test Results And Discussion

Pull Out Test

It is significant to understand the importance of the polymer matrix used in manufacturing of BFRP rebar. The polymer matrix is the main part of protecting the fibers from environmental and mechanical damage, and of transferring stresses between the reinforcing fibers and the surrounding concrete. Therefore, polymer matrix characteristics are important in durability issues and bond strength between FRP bars and the concrete. This is analogous to the important role of concrete in a steel reinforced concrete structure.

The pull-out test was performed to find bond stress as per IS 2770 Part I – 1967, reaffirmed 2007 is used in this test. Below Fig. 6shows the preparation of specimen for pull out test and arrangement of specimen in universal testing machine. Table 2shows the result for bond stress of steel bar Fe 500 and BFRP bar.

Fig.6 Pull out test

Table 2 Bond Strength

Sr. No.	Material	Dia. (mm)	Surface Area (mm^2)	Slip Avg. Load (N)	Bond Stress= $\frac{L}{S.A.}$
1	Steel Fe500	10	4712.4	23562	5
2	Steel Fe500	12	5624.9	30374	5.4
3	BFRP	10	4712.4	23090	4.9
4	BFRP	12	5624.9	29249	5.2

VI. Flexural Strength Of Beams

The specimen is loaded with two-point load system to develop constant moment region. The test carried out for the flexure of conventional RCC beam and BFRP beams were not carried out up to the failure load so the ultimate capacity of both the material was not been notice. But it is observed that BFRP beam did not indicate yield position compared to conventional RCC beam.

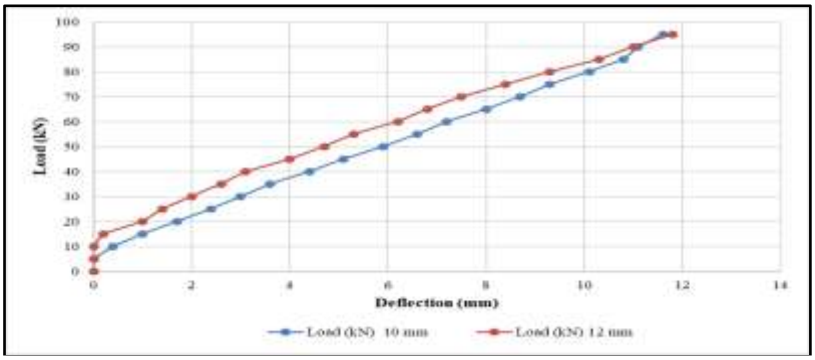


Fig. 7 L-D curve of beam reinforced with Steel bars

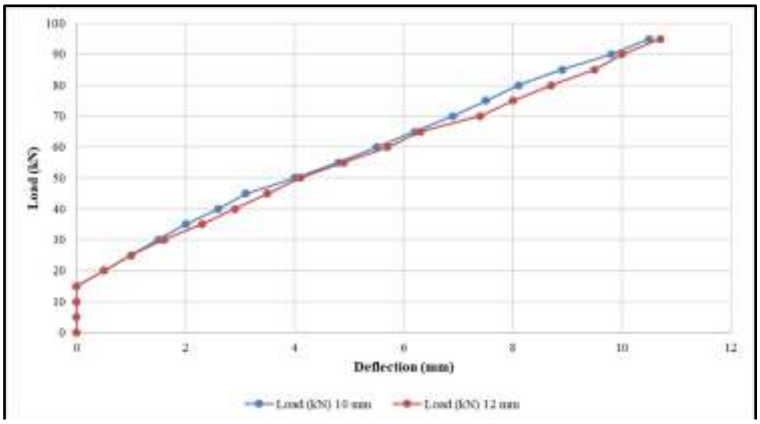


Fig. 8 L-D curve of beam reinforced BFRP bars

Load v/s Deflection

A 10 mm and 12mm diameter steel of Fe 500 and BFRP bars were used as tension reinforcement in this study. RCC and BFRP beams reinforced with steel reinforcement and BFRP rebar were tested for flexural failure to study their flexural behaviour. Therefore, as a preliminary study, two identical specimens of beams reinforced with BFRP bar for two different reinforcement diameters were tested to compare the flexural behaviour with the steel reinforced beams. For this study two –point loading system was used. Fig.9shows load v/s deflection curve for various beams.

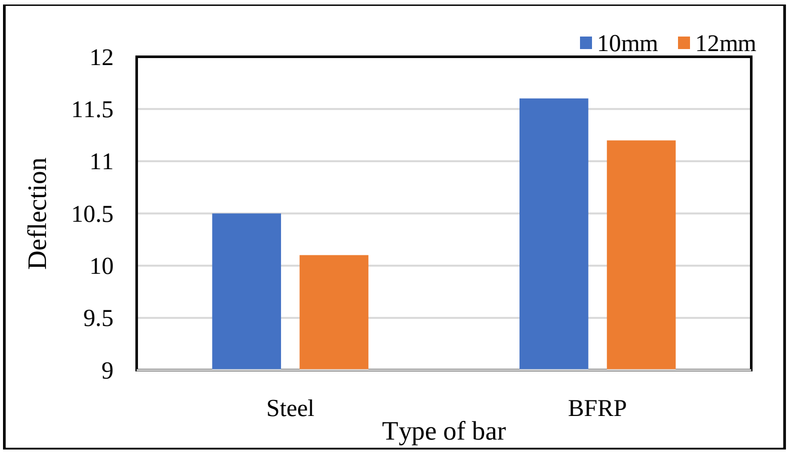


Fig. 9 FinalDeflection for Conventional and BFRP beam

VII. Conclusion

1. The tensile test specimens of BFRP started to show slipping at load 7000 kg during testing in UTM and final failure of specimen was not observed.
2. BFRP bond specimens showed comparable bond characteristics as steel reinforcement.
3. The deflection was more under smaller loads in BFRP reinforced beams compared to steel reinforced beams. The deflections of the BFRP reinforced concrete beams and the steel reinforced beams showed final deflection as 11.6 mm and 10.5 mm respectively with 10 mm diameter bar. While final deflection as 11.2 mm and 10.1 mm respectively with 12 mm diameter bar is noted.

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