Study of Ductility properties by effective replacement of Steel with Basalt Fibre Reinforced Polymer

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Abstract— Concrete structures are usually reinforced because plain concrete has strong limitations to resist tension. One of the familiar reinforcing material is steel; it suits well as reinforcement but has quite well known pros and cons. Fibre Reinforced Polymer (FRP) have over the past years became an interesting choice as a reinforcement for concrete. There are widely researched range and types of FRP namely: Aramid FRP (AFRP), Carbon FRP (CFRP) and Glass FRP(GFRP). FRP shows various advantages out of which few are: high tensile strength, high strength-weight ratio, no corrosion and also light in weight. These many of such benefits suggest the structural designers to research & implement on a large scale the replacement of steel with different FRPs as a choice of reinforcing material for concrete. One of the choice that we have made is Basalt Fibres Reinforced Polymer (BFRP) which is rather a new material to structural design, although it has been known for several decades. They are made from basalt rock, are very light and have tensile strength, over twice as high as steel. Tensile strength of BFRP tendon is about twice the tensile strength of steel reinforcement and elongation of BFRP tendons is much more than of steel

In this paper beam specimen (900mm x 230mm x 230mm) with four varying reinforcement of steel rebar, steel rebar + Basalt fibre (2% replacement by weight of cement), BFRP rebar and Composite reinforcement (BFRP rebar + Steel rebar, 65% + 35% respectively) have been tested for deflection. From the experimental results, it is observed that the beam with composite reinforcement where 65% of steel is replaced with BFRP rebar, it is the effective replacement and makes the beam most ductile against other specimens tested.

Keywords- Basalt, Basalt Fibre Reinforced Polymer (BFRP), Composite, Deflection, Ductility, Fibre Reinforced Polymer (FRP), High-tensile strength, Replacement, Steel.

INTRODUCTION

Concrete is the world's most used man-made construction material today. It is relatively cheap and easy to form when cast in India. The most common reinforcing material for Reinforced Concrete (RC) used until now and is still used today is steel. Using steel as reinforcement has numerous advantages; it is strong in tension and has a high modulus of elasticity. The thermal expansion is similar to concrete and it works well with concrete under loading.

The production process for steel is very stable and thus the material properties are also very stable, then steel is easy to form and work with. But using steel as reinforcement has also some disadvantages; it can corrode with time and has low fire resistance. The price of steel has also been rising over the last few years.

The main challenge for civil & structural engineers is to provide sustainable, environmental friendly and financially feasible structures to the society. Finding new materials that can fulfill these requirements is a must. FRP's have become increasingly more studied and utilized in the reinforcement and prestressing of structural members. However, most of the FRP materials to date have at least some type of major drawback which prevents them from becoming more widely utilized for structural applications. FRPs composed primarily of carbon (CFRP) for instance, demonstrate exceptional structural characteristics such as high Elastic Modulus and relatively good tensile strength. However, their performance under fire testing is less than desirable and its cost is prohibitive to its use in most applications. Another common FRP is fibreglass (GFRP). GFRPs exhibit good mechanical characteristics, but again serviceability concerns and cost (though considerably less than CFRPs) make it somewhat prohibitive in its implementation in real-world applications.

The relatively new development of an FRP composed of fibres of melted basalt rock (BFRP) is beginning to create excitement within the construction industry as a viable FRP alternative to CFRPs and GFRPs. Basalt is naturally occurring and is one of the most abundant materials on Earth. Though early investigations were performed in the United States in the 1920s about production methods for an FRP composed of basalt, successful and large-scale production was not achieved until the 1980s. Up until 1995, production methods were kept secret, and its use was solely for defense purposes. Within the past two decades however, BFRP research and production methods have been declassified, and are now produced for civilian purposes with mechanical properties similar to those of

GFRPs or CFRPs, but with generally better serviceability characteristics and at a significantly lower cost.

However, the FRP materials also have some disadvantages. They have low compression and shear strength compared to the same properties of steel. The comparative Index of all the same applies for the modulus of elasticity, which is considerably lower for the cheapest. So Basalt, which is leading in all the properties, have been chosen for the experiment.

Table 1: Comparative Index of FRP

Properties	E-Glass	S-Glass	Carbon	Aramid	Basalt
Density (g/cm^3)	2.5-2.6	2.5	1.8	1.5	**2.6-2.8**
Tensile Strength (MPa)	3100-3800	4020-4650	3500-6000	2900-3400	**4100-4840**
Elastic Modulus (GPa)	72.5-75.5	83-86	230-600	70-140	**93.1-110**
Max. Service Temp(Deg C)	380	300	500	250	**650**

OBJECTIVE

The main objective of this study is, BFRP as an effective replacement of steel in reinforced concrete. The main parameter observed is deflection.

METHODOLOGY

Beams with various Reinforcements were the specimens. The mix of concrete used in this study is M35. Specimens with Steel Reinforcement, Steel + Basalt Fibre (2%), BFRP & Composite (Steel + BFRP, 35% + 65% respectively) were performed tests on. Tests were performed for deflection for all beam specimens at different curing period (7 days, 28 days and 91 days).

MATERIAL PROPERTIES

- **Cement (OPC)**

The Ordinary Portland Cement of 53 grades conforming to IS: 8112 is used. The cement used is fresh and without any lumps. Physical property of cement is as in Table 2.

Table 2: Physical Properties of (OPC) Cement

Characteristic	Value
Specific Gravity	3.15
Consistency	30%
Initial Setting time	90 min
Final Setting time	178 min

- **Basalt Fibre**

The chemical properties of Basalt Fibre is as in Table 3.

Table 3: Properties of Basalt Fibre

Parameters	**Results**
Thermal expansion coefficient, m/m°K*10¯6	8
Elongation %	3.15
Elastic modulus, GPa	110
Temperature resistance, ˚C	-260 + 700
Mechanical strength , MPa	4800

Figure 1: Basalt Fibre

- **Aggregate**

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. The fact is that the aggregate occupy 70-80 percent of the volume of concrete. One of the most important factors for producing workable concrete is good gradation shape and texture of aggregates. Minimum paste means less quantity of cement and less water, which are further mean increased economy, higher strength, lower shrinkage and greater durability.

Coarse Aggregate: The fractions from 20 mm to 4.75 mm are used as coarse aggregate. The Flakiness and Elongation Index were maintained well below 15%.The Characteristics are given in Table 4.

Fine Aggregate: The fractions from 4.75 mm to 150 microns are termed as fine aggregate. The river sand is used in combination as fine aggregate conforming to the Requirements of IS: 383. The characteristics are given in Table 4.

Table 4: Physical Properties of Aggregate

Characteristic	**Value (Course Aggregate)**	**Value (Fine Aggregate)**
Specific Gravity	2.86	2.6
Density	1620 Kg/m^3	1530 Kg/m^3
Fineness Modulus	7.07	3.16

- **Basalt Fibre Reinforced Polymer**

The properties and figure of BFRP are as shown in Table 5 & Figure 2.

Table 5: Properties of Basalt Fibre Reinforced Polymer.

Properties (12mm)	**Unit**	**Typical value**
Weight per 40’	kg	4.29
Shear Strength	MPa	219
Ultimate Strength	MPa	1155
Tensile Modulus	GPa	55
Elongation at break	%	1.88

(Source: JBC Supplier, Vishakhapatnam)

Figure 2: Basalt Fibre Reinforced Polymer

- **Water**

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water are required to be looked into very carefully.

- **Mould**

Mould of size 900mm×230mm×230mm were used to prepare the beam specimens for determining the deflection. Care was taken during casting and vibrator was used for proper compaction. All the moulds were cleaned and oiled properly. They were securely tightened to correct dimensions and prevent leakage of slurry.

EXPERIMENTAL CONSIDERATIONS

- **Design Mix:**

A mix M35 grade was designed as per Indian Standard method (IS 10262-2009) and the same was used to prepare the test samples. The mix design is finalized by conducting number of trial mixes and chemical percentage is adopted from the experiment of Marsh cone. The design mix proportion as in Table 6.

Table 6: Mix Design

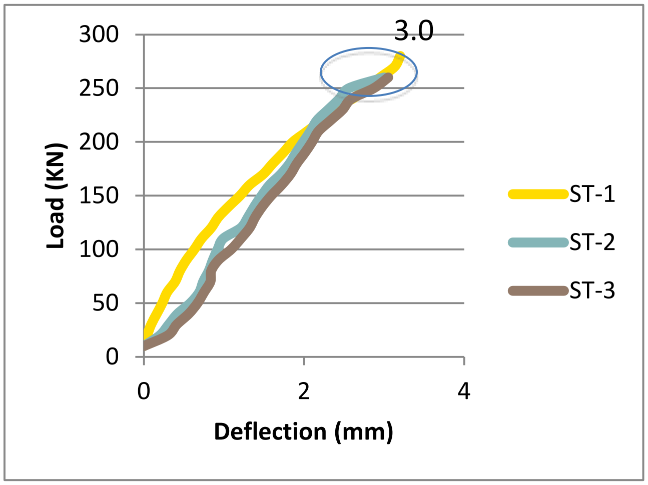
Mix	W/C	Cement	Fine Aggregate	Coarse Aggregate		Water	Chem Admix.
		Kg/m^3	Kg/m^3	20 mm	10 mm	lit/m^3	lit/m^3
M35	0.35	451	667	450	674	158	6.76

Figure 3: Casting of beam

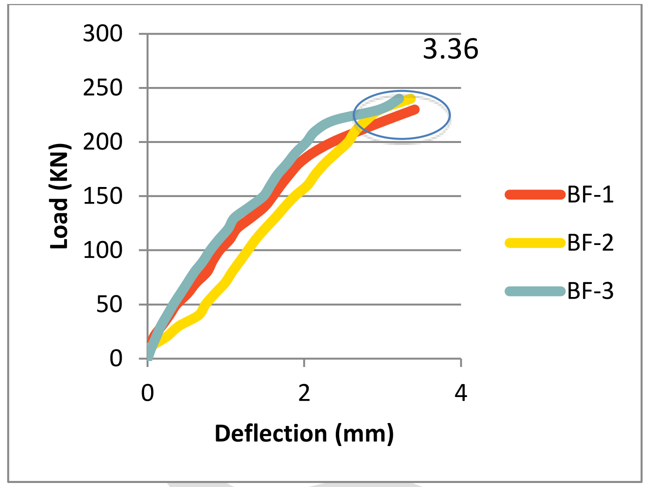
EXPERIMENTAL RESULT

- **Deflection**

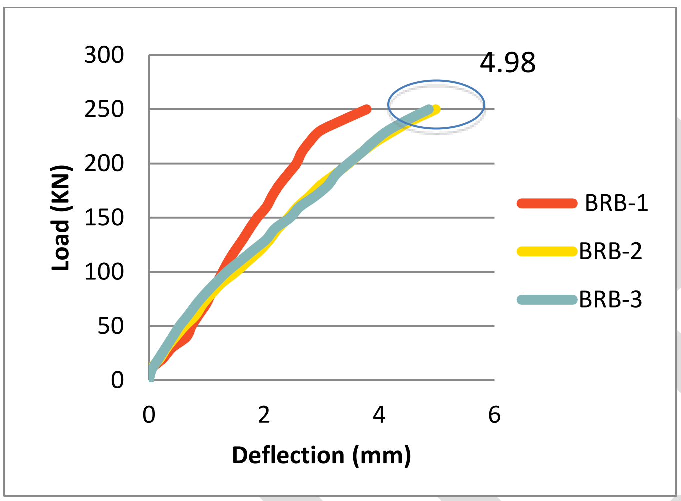
The test for deflection in beam with Reinforcements as Steel, Steel + Basalt Fibre, BFRP, Composite (BFRP + Steel, 65% + 35% respectively) at the end of 7 days and 28 days are given for M35 grade of concrete.



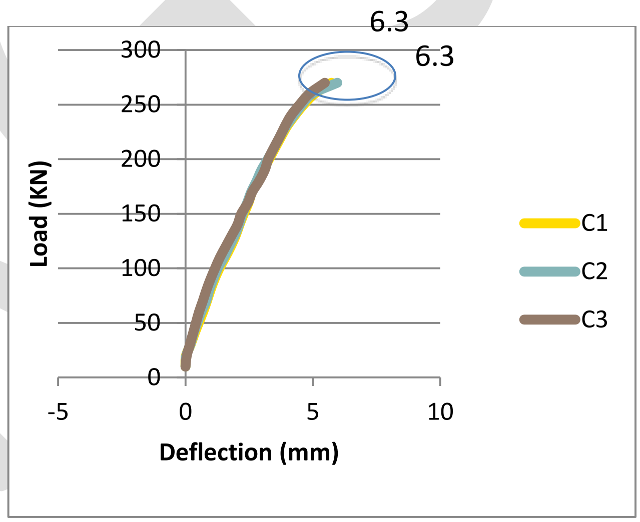
Graph 1: Deflection of Beam with Steel Reinforcement



Graph 2: Deflection of Beam with Steel Reinforcement + Basalt Fibre



Graph 3: Deflection of Beam with BFRP Reinforcement



Graph 4: Deflection of Beam with Composite Reinforcement

Figure 4: Crack Pattern

Figure 5: Application of Load

Figure 6: Crack Pattern

CONCLUSIONS

- Total Replacement of BFRP increases the deflection of the beam in turn making it more ductile.
- Addition of Basalt Fibre gives a very little increase in deflection than the beam with only steel reinforcement.
- Increment of 60% deflection is observed in beam with BFRP than the beam with only steel reinforcement.
- Composite reinforcement makes the beam more than 110% ductile than the beam with only steel reinforcement.
- Ductility is decreasing from Composite Reinforcement to BFRP to Steel + Basalt Fibre to Steel.
- It is found that composite reinforcement (35% steel % 65% BFRP) is effective replacement to make the beam more ductile.
- By looking at the result, using composite reinforcement can be an effective solution for replacement of steel in reinforced concrete.

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