AN EXPERIMENTAL STUDY ON STRENGTH PARAMETERS OF BASALT FIBER REINFORCED CONCRETE

Shubham Patel , Ravindra Raj[2]

1. M.Tech Scholar Department of Civil Engg. BTIRT, Sagar (M.P.)

2. Asst.Prof. Department of Civil Engg. BTIRT, Sagar (M.P.)

ABSTRACT

Chopped Basalt fiber has recently gained popularity in concrete reinforcing applications due to its environment friendly manufacturing process and excellent mechanical properties. This study investigates the compressive, flexural and splitting tensile strength of BFRC with plain M-25 grade of concrete. The influence of 0%, 1%, 2% and 3% basalt fiber content added to concrete by weight of cement. Fiber cut length is 10mm and diameter 7 micron, is investigated to evaluate the strength properties of concrete. Based on laboratory tests, it has been observed that at 2% addition of basalt fiber by weight of cement had a little effect on compressive strength of concrete: however, significantly enhanced its flexural and splitting tensile strength.

Keywords- BFRC, Reinforced concrete, Flexural Strength, Splitting Tensile Strength, Basalt Fiber, Compressive Strength, etc.

1. INTRODUCTION

Cement concrete is a most widely used construction material in the world over which generally consists of cement, aggregates (fine and course) and water. It is the material, which is used more than any other man made material on the earth in construction industry. It is not easy to point out another material of construction which is as adaptable as concrete. It is the material of preference where strength, performance, serviceability, durability, fire resistance and abrasion resistance are required. It is so strongly associated now with every human activity that it touches every human being in his day to day living. It is one of the outwardly simple but actually complex construction materials. Many of its complex behaviors are yet to be identified to employ cement concrete advantageously and economically in the field. The behavior of concrete with respect to creep, bond, fatigue, fracture mechanism and polymer modified concrete, cellular concrete, fibrous concrete are some of the points of active research in order to have a deeper understanding of the complex behavior of concrete ***(Patel and Chandak 2016).***

In the concrete, cement chemically reacts with water and produces binding slurry that binds other component of concrete together and creates hard material. The reaction process is called 'hydration of cement' in which water is absorbed by the cement. In this process of hydration some amount of lime [$Ca(OH)_2$] is also liberated. The coarse and fine aggregates act as filler in the concrete mix. The major factors which determine the strength of concrete mix is amount of binding material used and the ratio of water to cement in the concrete mix. However, there are some factors which limit the quantity of cement and ratio of water / cement to be used in the concrete. This hydration process of cement in the concrete is exothermic and large amount of heat is liberated during process. Higher will be the cement content more will be the heat liberation leading in distress to concrete overall. Water is the most important constituent of the concrete mix, once the concrete is hardened, the entrapped water in the concrete mix is used by cement for hydration and some water is evaporated, thus leaving pores in the cement matrix. Some fraction of these pores of cement concrete matrix is filled with hydrated products of cement paste. It has been experiential observation that higher the ratio of water / cement in the concrete mix, higher is the porosity of concrete structure resulting in increased permeability of the concrete structure***(Awasthi and Choubey 2015).***

Use of Portland cement in making of concrete started about 190 years ago. The concept of high strength mean higher durability developed with low-grade cement included surety of performance and Portland cement became unique construction material of construction industry. After the World War II, the need of speedy construction requires the development of high-grade cement providing early high strength at the field. The high-grade cements have been enhancing by changing the ratio of Tricalcium Silicate (C_3S) to Dicalcium Silicate (C_2S) and increasing the binding properties of the cement with due respect of time. These percentage changes of silicate have resulted in high early strength rather than high strength cement. It has been found out that structure constructed using high grade cement during 1945-50 have distress within span of 15 to 20 years. ***(Abdullah et. al. 2012)*** When the detailed analysis of concrete structure was carried out, it was revealed that

1. As the hydration of cement takes place gradually in the mix, lime is also liberated gradually. A small quantity of liberated lime in the concrete mix is used to maintain pH of the concrete mix and the major portion remains unused/ surplus and makes pores in concrete matrix.

2. The high-grade of cement releases higher amount of surplus lime resulting pores in concrete matrix.

3. Further, higher heat of hydration, higher water content and high porosity increases the vulnerability of concrete mass when it is exposed to an extreme range of external and internal destructive environmental condition. This disturbs the soundness of the concrete and result in reduced durability of concrete structure.

2. LITERATURE REVIEW

Branstonet. al.(2016) has studied about Chopped basalt fibre has recently gained popularity in concrete reinforcing applications due to its environmentally friendly manufacturing process and excellent mechanical properties. The aim of this research is to evaluate the relative merit of two types of basalt fibre (bundle dispersion fibres and minibars) in enhancing the mechanical behaviour of concrete. Concrete specimens were cast with three different quantities of each fibre, and then evaluated based on flexural and drop-weight impact testing. Interfacial properties were also investigated by scanning electron microscopy. The results indicated both types of fibre increased pre-cracking strength, but only mini-bars enhanced the post-cracking behaviour, likely due to protection from the polymer.

High et. al. (2015) investigated the use of basalt fiber bars as flexural reinforcement for concrete members and the use of chopped basalt fibers as an additive to enhance the mechanical properties of concrete. The material characteristics and development length of two commercially-available basalt fiber bars were evaluated. Test results indicate that flexural design of concrete members reinforced with basalt fiber bars should ensure compression failure and satisfying the serviceability requirements. ACI 440.1R-06 accurately predicts the flexural capacity of members reinforced with basalt bars, but it significantly underestimates the deflection at service load level. Use of chopped basalt fibers had little effect on the concrete compressive strength; however, significantly enhanced its flexural modulus.

Jiang et. al. (2014) showswith high ductility and sufficient durability, fibre reinforced concrete (FRC) are widely used. In this study, the effects of the volume fraction and length of basalt fibre (BF) on the mechanical properties of FRC were analyzed. Coupling with the scanning electron microscope (SEM) and mercury intrusion porosimeter (MIP), the microstructure of BF concrete was studied also. The results show that adding BF significantly improves the tensile strength, flexural strength and toughness index, whereas the compressive strength shows no obvious increase. Furthermore, the length of BF presents an influence on the mechanical properties. Compared with the plain concrete, the compressive, splitting tensile and flexural strength of concrete reinforced with 12 mm BF increase by _0.18–4.68%, 14.08–24.34% and 6.30–9.58% respectively. As the BF length increasing to 22 mm, corresponding strengths increase by 0.55–5.72%, 14.96–25.51% and 7.35–10.37%, separately. A good bond between the BF and the matrix interface is observed in the early age. However, this bond shows degradation to a certain extent at 28 days. Moreover, the MIP results indicate that the concrete containing BF presents higher porosity.

Ilker et al. (2012) adopted a numerical method for predicting the moment capacity of FRP concrete beams. Comparisons with experimental results show that the proposed numerical technique can accurately estimate moment capacity of RC beams reinforced with FRP bars. It was also noticed that the ACI-440.1R-06 formulae reasonably predicted the moment capacity of FRP reinforced concrete beams. Finally, it was shown that a large increase in FRP reinforcement produces a slight increase in the moment capacity of FRP over reinforced concrete beams. A parametric study concluded that concrete compressive strength has no effect on the moment capacity of FRP under reinforced concrete beams but a significant influence for the over reinforced equivalent.

Mohamed et al. (2011) studied the influence of fibres on the flexural behaviour and ductility of GFRP reinforced concrete beams. Their tests showed that using GFRP as internal reinforcement for RC beams results in reasonable flexural strength. Furthermore, their results indicated that ACI 440.1R-06 strongly underestimated the moment capacities of FRP RC beams.

Kassem et al. (2011) reported that the crack width in FRP reinforced concrete beams varied linearly with the applied moment up until failure. The crack width was smaller for the beams with greater reinforcement ratios. Similarly, *(Theriaul et al. 1998)* noted that the residual crack width decreases as the reinforcement ratio increases. The beams reinforced with sand-coated bars exhibited a greater number of cracks as opposed to those reinforced with ribbed-surface bars. This suggests that the tested sand-coated bars provided a better bond with the concrete than the ribbed surface bars.

Masmoudi et al. (1999) tested a number of FRP reinforced concrete beams subjected to static loading. The beams were tested in order to investigate the effects of reinforcement ratio on ultimate capacities and modes of failure. They observed from this study that as the reinforcement ratio increases, the ultimate moment capacity increases, but that this increase is limited by the concrete compression failure strain for the reinforced concrete beams. The results from the flexural tests of concrete beams reinforced with FRP rebars indicated that the use of GFRP rebars in concrete structures is possible and that optimal design is achievable if not only an appropriate reinforcement ratio is used, but also the appropriate height-to-span ratio is computed *(Benmokrane et al., 1995).* Other researchers, such as (*Habeeb and Ashour 2008)* and (*Ashour and Habeeb 2008)*, noticed that over-reinforcing the bottom layer of either the simply or continuously supported GFRP beams is a key factor in enhancing the load capacity of concrete beams. Comparisons between the experimental results and those obtained from simplified methods proposed by the ACI 440 Committee show that ACI 440.1R-06 equations can reasonably estimate the load capacity of GFRP reinforced concrete beams under test.

Masmoudi et al. (1999) concluded that the maximum observed crack width in beams reinforced with FRP reinforcing rods is 3 to 5 times that of identical beams reinforced with steel bars. It was also found that the residual crack width decreases as the reinforcement ratio increases; however, the results have shown that the residual crack width is not affected, after the first cycle of loading/unloading, by the number of loading/unloading cycles.

3. OBJECTIVE OF THE STUDY

The following are the main objectives of the study:-

1) To determine the fresh properties of concrete by slump cone test.

2) To evaluate the Compressive strength strength of concrete of grade M25 with addition of basalt fiber in proportion of 0%, 1%, 2% and 3% by weight of cement

3) To evaluate the Split tensile strength of concrete of grade M25 with addition of basalt fiber in proportion of 0%, 1%, 2% and 3% by weight of cement.

4) To evaluate flexural strength of concrete of grade M25 with addition of basalt fiber in proportion of 0%, 1%, 2% and 3% by weight of cement.

The data will be collected from the cylinders and beams specimen of grade M25 designed as per the new guidelines of IS 10262:2009. The cylinders and beams will be prepared and tested to make curves could be generated for both tensile strength and flexural strength of specimens.

4. RESULTS

4.1 Workability

Slump test was carried out on each mix to ascertain workability of BFRC as well as control mixtures. The results of slump tests for M-25 grade concrete with and without Basalt Fibers are shown in table 4.1

Table 4.1 Slump Cone Test Values for BFRC

FIBER CONTENT (%)	SLUMP (mm)
0	73
1%	67
2%	62
3%	59

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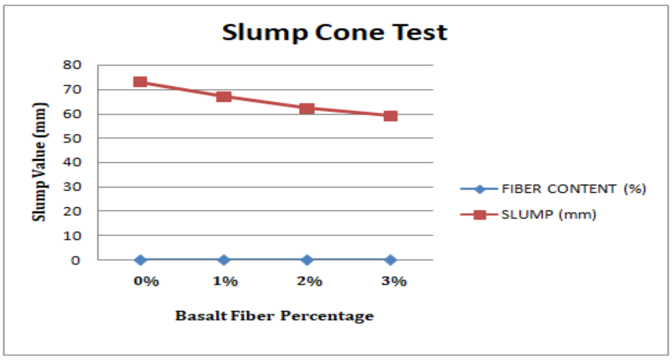


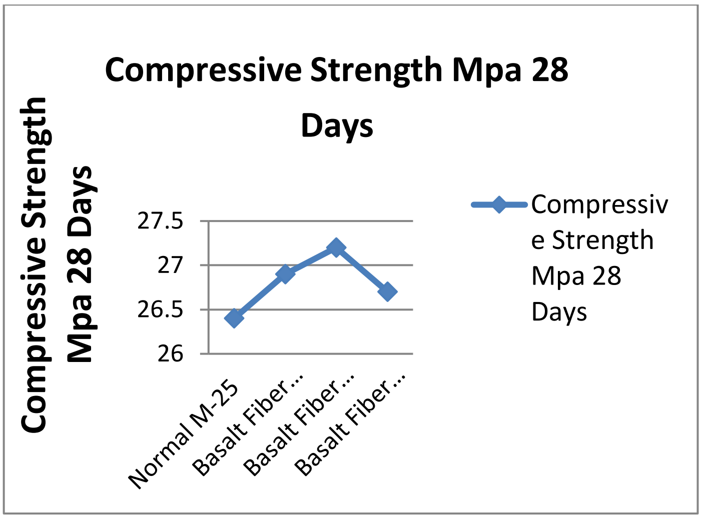
Graph 4.1 Slump Cone Test Values at Different Percentage of BF

4.2 Compressive Strength

Total 9 cubes were casted of Basalt fiber of different percentage (0%, 1%, 2% and 3%). 3 cubes were also casted with plain cement concrete. All the specimens were cured at 28 days. In present study average compressive strength of Basalt fiber reinforced concrete is slightly increased up to 2% of basalt fiber.

Table 4.2 Compressive Strength of BFRC

Mix	Compressive Strength Mpa		
	7 Days	14 Days	28 Days
Normal M-25	-	-	26.4
Basalt Fiber 1%	-	-	26.9
Basalt Fiber 2%	-	-	27.2
Basalt Fiber 3%	-	-	26.7



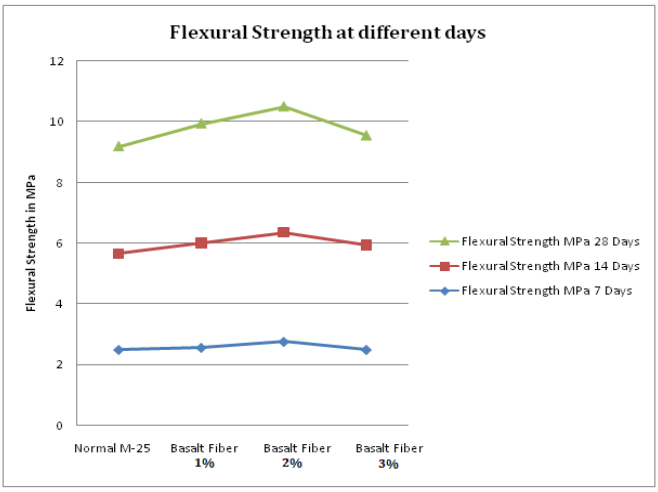
Graph 4.2 Average Compressive Strength of BFRC Cubes at 28 days

4.3 Flexural Strength

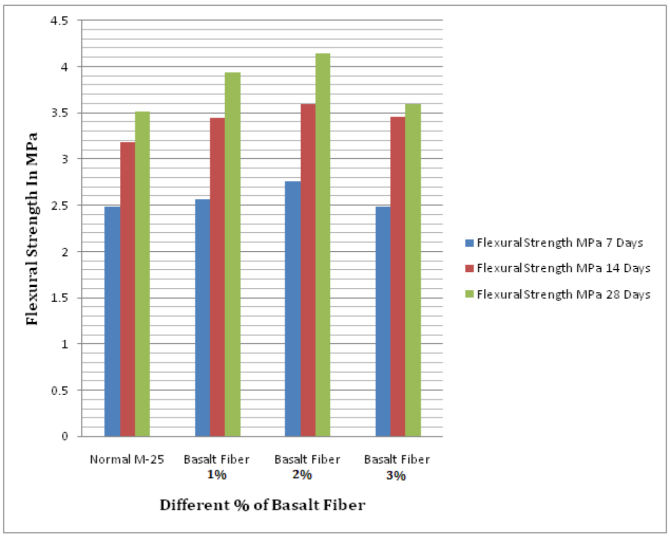
Total 27 beams were casted of Basalt fiber of different percentage (0%, 1%, 2% and 3%). 9 beams were also casted with plain cement concrete. All the specimens were cured at different curing intervals 7, 14 and 28 days. In present study average flexural strength of Basalt fiber reinforced concrete is increased up to 2% of basalt fiber. Specimens are considered with three samples of required percentage.

Table 4.5 Flexural Strength for BFRC Beams

Mix	Flexural Strength Mpa		
	7 Days	14 Days	28 Days
Normal M-25	2.49	3.18	3.52
Basalt Fiber 1%	2.56	3.45	3.94
Basalt Fiber 2%	2.76	3.60	4.15
Basalt Fiber 3%	2.49	3.46	3.60



Graph 4.3 Average Flexural Strength of BFRC Beams at 7, 14 and 28 days



Graph 4.4 Bar chart of Average Flexural Strength of BFRC Beams at 7, 14 and 28 days

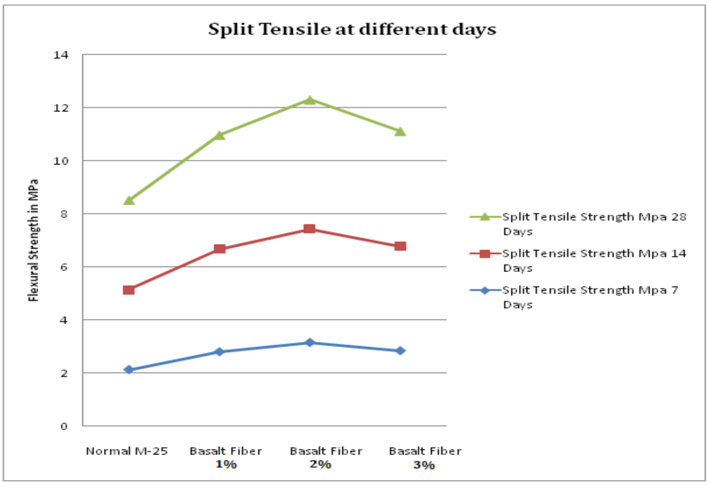
In this graph Blue, Red and Green color shows the Flexural Strength of Beams on 7, 14 and 28 days in Mpa of BFRC used as a partial replacement of cement in different percentages (1%, 2%, and 3%).

4.4 Split Tensile Strength

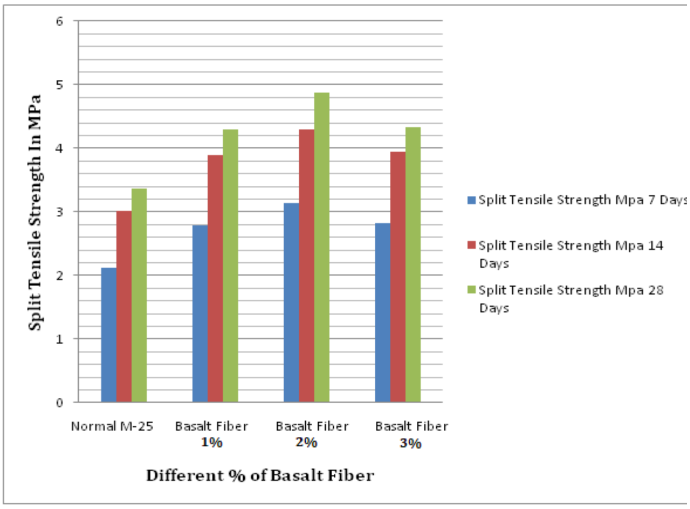
Total 27 cylinders, were casted of Basalt fiber of different percentage (0%, 1%, 2% and 3%). 9 cylinders were also casted with plain cement concrete. All the specimens were cured at different curing intervals 7, 14 and 28 days. In present study average split tensile strength of Basalt fiber reinforced concrete is increased up to 2% of basalt fiber. Specimens are considered with three samples of required percentage.

Table 4.7 Average Split Tensile Strength for BFRC Beams

Mix	Split Tensile Strength Mpa		
	7 Days	14 Days	28 Days
Normal M-25	2.12	3.02	3.36
Basalt Fiber 1%	2.79	3.89	4.29
Basalt Fiber 2%	3.14	4.29	4.88
Basalt Fiber 3%	2.83	3.95	4.34



Graph 4.5 Average Split Tensile Strength of BFRC Beams at 7, 14 and 28 days



Graph 4.6 Bar chart of Average Split Tensile Strength of BFRC Beams at 7, 14 and 28 days

In this graph Blue, Red and Green colour shows the Split Tensile Strength of Cylinders on 7, 14 and 28 days in Mpa of BFRC used as a partial replacement of cement in different percentages (1%, 2%, and 3%).

5. CONCLUSIONS

A detailed experimental study was performed to study the effect of addition of Basalt fiber in different percentages by weight of cement in M25 grade concrete. This study was intended to find the effective ways to utilize the high impact Basalt fiber as addition by weight of cement in concrete. Analysis of the results of the effect of using Basalt fiber as addition by weight of cement on the strength of concrete leads to the following conclusions-

(1) The incorporation of Basalt fiber in concrete causes gradual decrease in workability.

(2) 24% decrease in workability is observed when the fiber content is 2% added.

(3) In this experimental study it has been found that the Compressive strength of BFRC increases gradually up to 2.0% and shows optimum result at 2.0% after that Compressive strength of BFRC decreases with increase of Basalt fiber percentage.

(4) The increase of approx 1.0 % in Compressive strength is observed for BFRC (at 2% of fiber addition) in comparison to unreinforced sample.

(5) In this experimental study it has been found that the Flexural strength of BFRC increases gradually up to 2.0% and shows optimum result at 2.0% after that Flexural strength of BFRC decreases with increase of Basalt fiber percentage.

(6) The increase of 18% in flexural strength is observed for BFRC (at 2% of fiber addition) in comparison to unreinforced sample.

(7) In this experimental study it has been found that the Split Tensile strength of BFRC increases gradually up to 2.0% and shows optimum result at 2.0% after that Split Tensile strength of BFRC decreases with increase of Basalt fiber percentage.

(8) The increase of 45% in Split tensile strength is observed for BFRC (at 2% of fiber addition) in comparison to unreinforced sample.

(9) It is observed that failure of fiber reinforced concrete specimen do not show brittle failure. The progression of failure plane is gradual.

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