

Experimental Studies on Steel and Basalt Fiber Reinforced Concrete

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ABSTRACT: Plain concrete have a very low tensile strength and a low strain at fracture. The plain concrete normally contains number of numerous micro cracks and under sustained loading conditions it fails in lack of tensile strength. Thus, in order to improve tensile and flexural strength of concrete, fibers are added. The fibers are not added to improve the strength, but it automatically increases its strength. The main role of FRC is to control the cracking and so providing some post-cracking ductility. This study includes the comparative effect of inclusion of basalt and steel fibers on the compressive, flexural and split tensile strength of M30 grade concrete and to find optimum fiber content. The fibers were placed in concrete randomly by (0%, 0.25%, 0.5%, 0.75%, 1%) of its total volume of concrete. For compressive, tensile and flexural strength testes of reinforced concrete, total fifty-four cubes and twenty-seven cylinder specimens were cast. For finding out flexural strength and modulus of elasticity, total nine prisms and nine cylinders were cast. The experimental test results shows considerable increases in compression, flexural and split tensile strength with the addition of fibers.

KEYWORDS: Basalt fiber, steel fiber, Compressive strength, Flexural strength, Split tensile strength, FRC-Fiber reinforced concrete

I. INTRODUCTION

Concrete has its own characteristics and that made its use more popular through the last hundred years. Excellent compressive strength, durability and easily available subcomponents has made concrete as a highly demanded building material. Plain concrete has a low strain at fracture and a low tensile strength. The plain concrete contains numerous micro cracks under loading conditions and thus it fails in lack of tensile strength. These deficiencies have led to considerable research over this area for developing new ideas to modifying the brittle properties of concrete. In this era of modern civil engineering, the constructions have their own structural and durability requirements, every structure have its own purpose and hence to meet this purpose, modification in traditional cement concrete has become mandatory. It has been found that some type of fibers added in concrete in certain proportions improves the mechanical properties, durability and serviceability of the structure. Thus fiber-reinforced concrete (FRC) is the most widely used solution for improving the strength properties of concrete. Fiber reinforced concrete contains short discrete fibrous material which increases its structural integrity. In concrete, the fibers are usually uniformly distributed and randomly oriented. The main role of FRC is to control the cracking and crack propagation, and to alter the behaviour of the material once the matrix has cracked, by bridging across these cracks and so providing some post-cracking ductility. The fibers are generally distributed throughout a cross-section, whereas steel bars are only placed where needed.

Basalt fibers are manufactured by melting pure raw material in single-stage process. These fibers has an elastic structure, environmentally safe and non-toxic. Basalt fibers have high heat stability and insulating characteristics. Basalt fiber is a high performance non-metallic, non-corrosive fiber with light weight, good fire resistance and strength. Steel fibres are filaments of wire, deformed and cut to lengths, for reinforcement of concrete, mortar and other composite materials. It is a cold drawn wire fibre with corrugated and flattened shape. Steel fiber is made using high-quality low-carbon steel wire. Steel fibres are usually used in concrete to control cracking and crack propagation due to

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both plastic shrinkage and drying shrinkage. Steel fibre has better ability to withstand repeatedly applied, shock or impact loading. Steelfibers also reduce the permeability of concrete and thus reduce bleeding of water.

II. RELATED WORKS

A number of studies have been performed on different types of fiber reinforced concrete. Satheskumaret al [1] made a comparative study of effect of basalt, glass and steel fiber on compressive and flexural strength of concrete. This work deals with the workability and strength studies on steel and basalt fiber reinforced self-compacting concrete of grade M25 with GGBS and super plasticizer. The powder content added was 70% of cement and 30% of GGBS. This was kept constant for all the mixes. The steel and basalt fiber percentage was varied from 0.6%, 0.8%, 1.0%, 1.2%, 1.4%, 1.6%, 1.8%, and 2.0 % by weight of concrete. The important conclusion of this study was that, there is no as much improvement in compressive strength but split tensile strength does. Mustapha Abdulhadi [2] made a comparative study of basalt and polypropylene fiber reinforced concrete on compressive and tensile behaviour. The fiber content was 0%, 0.3%, 0.6%, 0.9%, and 1.2% volume fraction by weight of cement without admixture. The result data clearly shows decrease in compressive strength for M30 Grade of concrete due to addition of basalt fiber and polypropylene fiber. The split tensile strength results shows that the optimum fiber content for basalt fiber is 0.6% and for polypropylene fiber is in the vicinity of 0.3%.

Amit Rana [3] made some studies on steel fiber reinforced concrete. In this project he was finding out the optimum quantity of steel fibres required to achieve the maximum flexural strength for M25 grade concrete. Hook end steel fibres was used in this project. From the experimental work, it was found that with increase in steel fiber content in concrete there was an increase in 1.1% of its flexural strength. Compressive behaviour of steel fibre reinforced concrete is studied by R. D. Neves et al [4]. It involves an experimental study to investigate the influence of matrix strength, fibre content and diameter on the compressive behaviour of steel fibre reinforced concrete. Concrete compressive strengths of 35 and 60 MPa, 0.38 and 0.55 mm fibre diameter and 30 mm fibre length, were considered. The volume of fibre in the concrete was varied up to 1.5%. Test results indicated that the addition of fibres to concrete enhances its toughness and strain at peak stress, but can slightly reduce the Young's modulus. Simple expressions are proposed to estimate the Young's modulus and the strain at peak stress, from the compressive strength results, knowing fibre volume, length and diameter.

An experimental study was conducted by Nasir Shafiq et al [5] on the effectiveness of chopped basalt fiber on the fresh and hardened properties of high strength concrete. In this study two series of mixes were used. The addition of chopped basalt fibers did not help to improve the compressive strength of HSC. However, fibers have improved tensile and flexural tensile strength of HSC, also the area under the stress strain curves increased. Ketan.G.R et al [6] studied about the performance of basalt fibre in high strength concrete. The mechanical properties of concrete, namely, cube compressive strength, split tensile strength, flexural strength, and durability of concrete are found out. The fiber content was 0 % and 1% and the concrete specimens were tested at different age level of 7 and 14 days. The results indicated that while adding fibre in high strength concrete the strength of high strength concrete is decreasing on 7 days and 14 days.

E. Arunakanthi et al [7] made some experimental studies on fiber reinforced concrete. Glass fibre and steel fibers are used in the concrete in this study. The FRC is added in 0.5, 1, 2 and 3% for M20 grade concrete. The result shows that in compressive strength, flexural strength and split tensile strength, the addition of steel fiber the strength is increasing linearly, but in glass fiber up to 1% it is increasing and from 2% it is decreasing. Finally concluded that glass fiber can be add up to the 1%. Usama Abbas [8] studied about the materials development of steel and basalt fiber-reinforced concretes. The aim was to develop a ductile high tensile strength concrete with residual flexural tensile strength in the range of 10-15 MPa and to replace conventional steel reinforcement completely with fibers in load carrying structures. There was not much difference in the obtained compressive strengths for both concrete types. The steel fiber-reinforced concretes showed a significantly better flexural performance in the hardened state than the basalt fiber-reinforced concretes.

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III. OBJECTIVES, SCOPE AND METHODOLOGY

1. Objectives:-The primary objective of this investigation was to determine the fresh and hardened properties of basalt fiber and steel fiber reinforced concrete specimens for different fiber dosages and these properties were compared with those of control (plain) concrete.

2. Scope: - The fiber dosages chosen for the study were 0%, 0.25%, 0.5%, 0.75% and 1% of total volume of concrete. The hardened properties of concrete investigated are in terms of compression, tension, flexural strength and modulus of elasticity.

3. Methodology: - Materials required for the experiments were procured and their properties were found. The mix design of M30 grade concrete was done as per IS 10262-2009. The fresh properties of concrete for different fiber dosages were found using slump value. Specimens for determining mechanical properties with fiber percentages 0%, 0.25%, 0.5%, 0.75%, 1% of its total volume of concrete were cast. Optimum fiber content was obtained from compression and split tensile strength. Flexural strength and modulus of elasticity was also found for corresponding optimum fiber contents.

IV. EXPERIMENTAL INVESTIGATION

1. Material properties

1.1 Cement

Cement used in this investigation was Portland Pozzolanicement (PPC) of “ACC” brand of super grade. The various properties such as fineness, normal consistency, specific gravity, initial setting time, final setting time and compressive strength were examined. Table 1 shows the various properties tested conducted as per Indian Standard.

Table 1: Physical properties of cement

Properties	Value	IS Specification
Fineness	6 %	-
Normal consistency	34 %	-
Specific gravity	3.0	-
Initial Setting time in minutes	130 min	> 30 min
Final Setting time in minutes	315 min	< 600 min
Compressive strength	34.5 MPa	

1.2 Coarse aggregate

The coarse aggregate of maximum nominal size 20 mm is used for preparing the mixes in this study. The properties of coarse aggregate confirms to IS 383:1970 (Part III) specifications. On performing sieve analysis, it was found that the coarse aggregate confirms to IS specification, i.e. it lies within the required zone.

1.3 Fine aggregate

The fine aggregate used in the study confirms to Zone III grading curve of IS 383:1970 (Part III). The specific gravity of fine aggregate is 2.5 and void ratio is 0.50.

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1.4 Basalt Fiber

The fibers used were chopped basalt fibers which are placed uniformly and randomly distributed in the concrete matrix. The five different fiber content were chosen 0%, 0.25%, 0.5%, 0.75%, 1.0% of total volume of concrete for each mix. Chopped basalt fibers are shown in Figure 1.

1.5 Hooked end steel fiber

The fibers used were hooked end steel fibers of 30mm length and aspect ratio of 50 was used. The fibers are placed uniformly and randomly distributed in the concrete matrix. The five different fiber content were chosen 0%, 0.25%, 0.5%, 0.75%, 1.0% of total volume of concrete for each mix. Hooked end steel fibers are shown in figure 1.

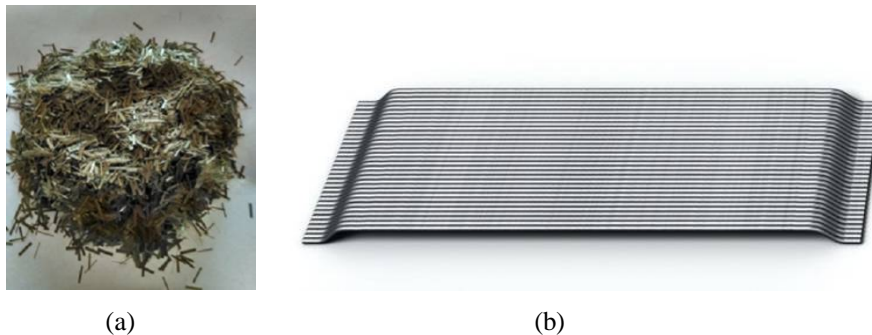


Figure 1: (a) Chopped basalt fibers and (b) Typical Hooked End Steel fibers

1.6 Super plasticizer

In modern construction practice, it is essentially impossible to make high performance concrete at an adequate workability in the field without the use of any super plasticizers. In this study, as per IS: 9103-1999 Conplast SP430 with specific gravity 1.22 was used as super plasticizer.

2. Experimental procedure

The experimental procedure involves the comparative study of effect of basalt fiber and steel fibers on compressive, split tensile and flexural strength of M30 grade concrete. For compressive and tensile strength test of concrete, fifty-four cubes and twenty-seven cylinders were cast. The fibers were placed in concrete randomly by (0%, 0.25%, 0.5%, 0.75%, 1%) of its total volume of concrete. Each specimen was tested after 7 days and 28 days of curing period. For each percentage of fiber total three cubes and three cylinders were casted to take average results. The test results will help to find out the optimum fiber content for both steel fiber and basalt fiber. Prisms and cylinders were then cast with optimum fiber content for finding out flexural strength and modulus of elasticity. Finally comparative results are made for both fibers. Figure 2 shows the slump test for conducted on fresh concrete and Figure 3 shows the specimens prepared for testing hardened properties.

The mixture proportioning was done according to the Indian Standard Recommended Method IS 10262-2009. The target mean strength of M30 concrete was 38.5 MPa was achieved for the control mixture, with the total cement content 380 kg/m³, fine aggregate 665 kg/m³ and coarse aggregate 1350 kg/m³, the water to cement ratio kept as 0.45 for all mixtures. The total mixing time was 5 minutes; the samples were then casted and left for 24 hours before demoulding. The specimens are then placed in a curing tank until the day of testing. Cement, sand, coarse aggregate and fibers were properly placed and mixed together in accordance with IS code before water was added and was properly mixed together to achieve homogenous material. Water absorption capacity and moisture content were considered and it is appropriately subtracted from the water/cement ratio used for mixing. Figure 4 shows the test setup for compressive strength, split tensile, modulus of elasticity and flexural strength. All the cube specimens were of dimension 150mm and cylinder specimen were of dimension 150mm diameter and 300mm height. All the cube specimens were tested after 7 days and 28 days of curing for compressive strength. 27 cylinders were tested for split

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tensile strength and 9 cylinders for finding modulus of elasticity of optimum fiber content. Also 9 numbers of prisms (100mmx100 mmx500 mm) are prepared for finding the modulus of rupture of concrete.



Figure 2: slump test



Figure 3: Specimens prepared for testing hardened properties.

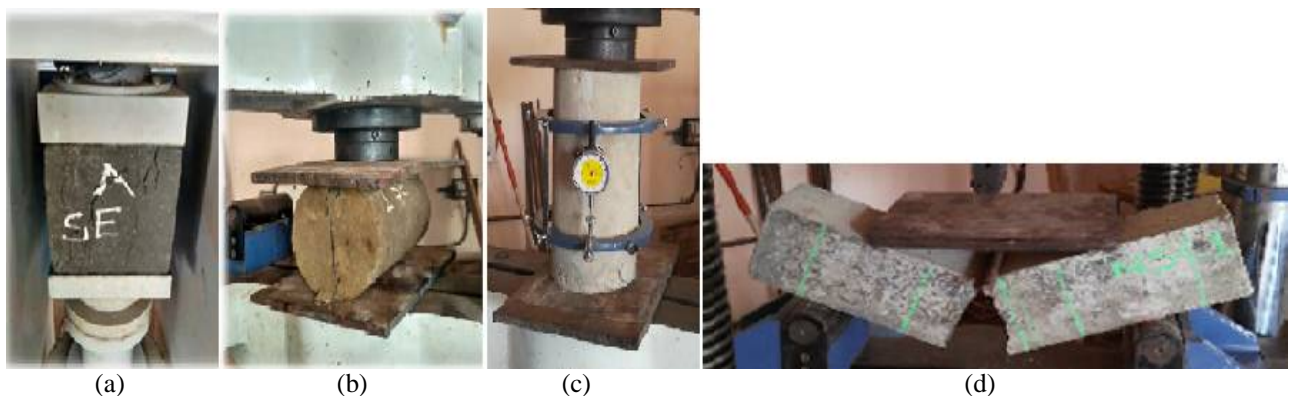


Figure 4: Test setup for (a) compressive strength, (b) split tensile, (c) modulus of elasticity and (d) flexural strength.

V. RESULTS AND DISCUSSIONS

1. Slump test for workability (As per IS: 7320-2008)

Slump values for different mixes are shown in Table 2. The slump values are adjusted by varying the percentages of super plasticizer added. The optimum content of super plasticizer added is 0.85 L per 100kg of cement.

Table 2:Slump values for different mixes.

Mix designation	Slump value (mm)
Zero % fiber content	75
0.25% of basalt fiber	74
0.5% of basalt fiber	71
0.75% of basalt fiber	70
1.0% of basalt fiber	68
0.25% of steel fiber	73
0.5% of steel fiber	72
0.75% of steel fiber	70
1.0% of steel fiber	67

2. Compressive Strength Test

The compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. It can be measured by plotting applied force against deformation in a compression testing machine. Compressive strength was measured after 7 and 28 days of curing. Figure 5 shows the compressive strength of basalt and steel fiber specimens. The results obtained from compression test, it is clear that optimum fiber content for basalt fiber is 0.75% and for steel fiber is 0.5% of total volume of concrete. The increase in compressive strength with 0.75% basalt fibres was 9.3% and for 0.5% steel fiber it was 11.9% after 28 days of curing. Figure 5 and 6 shows compressive strength of basalt...

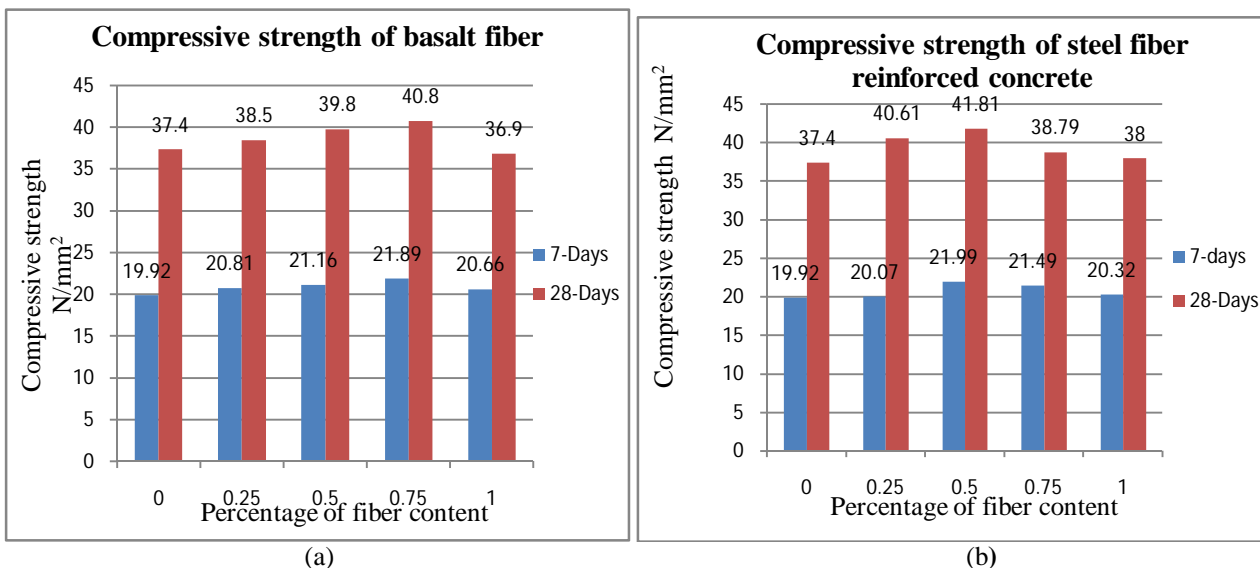


Figure 5:(a) Compressive strength of basalt fiber specimens and (b) Compressive strength of steel fiber specimens.

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2. Split tensile strength

Split tensile strength was obtained by testing cylindrical specimen in UTM testing machine of capacity 600kN as per IS 5816. The Figure 6 showing split tensile strength of basalt and steel fiber reinforced concrete specimens.

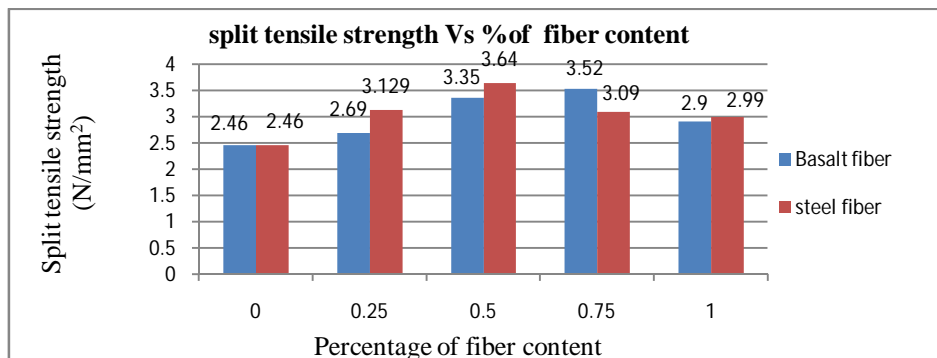


Figure 6: Split tensile strength of basalt and steel fiber reinforced concrete specimen after 28 days of curing.

From the results obtained from split tensile test, it is clear that optimum fiber content for basalt fiber is 0.75% and for steel fiber is 0.5% of total volume of concrete. The increase in split tensile strength with 0.75% basalt fibres was 43% and for 0.5% steel fibers was 48%.

3. Modulus of rupture and Modulus of elasticity

Flexural strength, also known as modulus of rupture, or bend strength, or transverse rupture strength is a material property, defined as the stress in a material just before it yields in a flexure test. The transverse bending test is most frequently employed. The flexural strength represents the highest stress experienced within the material at its moment of yield.

Modulus of rupture and modulus of elasticity was found for the concrete reinforced with optimum fiber content of steel and basalt fiber. Table 2 shows modulus rupture and modulus of elasticity of all the concrete specimens.

Table 6: Modulus rupture and Modulus of elasticity of concrete specimens

Beam specimen	Modulus of rupture N/mm ²	Modulus of elasticity MPa
NSRC	6.8	30863
BFRC	7.415	32094
SFRC	7.63	32665

VI. CONCLUSIONS

Based on the work presented in this study, the conclusions can be summarized as follows:

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1. It has been observed that the workability of concrete decreases with the addition of Fibers. But this difficulty can be overcome by using plasticizers or super-plasticizers.
2. The workability of plain concrete reduced on addition of basalt fibers, which again decreased on addition of steel fibers.
3. Optimum fiber content for BFRC and SFRC obtained were 0.75% and 0.5% of total volume of concrete respectively.
4. The increase in compressive strength of concrete with optimum basalt fibres was 9.3% and for steel fiber was 11.9% after 28 days of curing.
5. The increase in split tensile strength of concrete with optimum basalt fibres was 43% and for steel fibres was 48%.
6. SFRC has 12.5% and BFRC has 9.5% greater flexural strength than plain M30 grade concrete.
7. Also it was found from the failure pattern of the specimens, that the formation of cracks is more in the case of concrete without fibers than the fiber reinforced concrete.
8. It shows that the fibers in the concrete reduce the crack width and acts as the crack arrestors.
9. The ductility characteristics have improved with the addition of fibers. The failure of fiber reinforced concrete is gradual as compared to that of brittle failure of plain concrete.
10. Thus, steel fiber reinforced concrete is better in overall comparing with basalt fiber reinforced concrete.

VII. ACKNOWLEDGEMENT

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