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An Influence of Basalt Fiber on Mechanical Properties of Concrete

Manibalan P, Baskar R

Abstract*: The efficacy of fiber reinforced concrete in various application of civil engineering is unassailable. It is a heterogeneous material that includes the fibrous substance which increases its structural integrity and cohesion. In recent years, continuous basalt fibers extruded from naturally basalt rock are attracted attention due to its high temperature and abrasion resistance. Basalt fibers has emerged as a contender in fiber reinforcement composites. This paper aims to evaluate the outcome of basalt fiber on the mechanical strength of concrete and also identify the content that have a optimum influence on concrete. Compressive, split tensile and flexural strength of basalt fiber reinforced concrete is increased than the control concrete. The experimental study shows that the mechanical strength of concrete is increased up to 0.9% of basalt fiber in volume fraction. From the result it is observed that the optimum content of Basalt fiber is 0.9% and the ability of basalt fiber to arrest the cracks area indicated as reason for escalation in mechanical properties.

Keywords* : Basalt Fiber, mechanical property, reinforcement, optimum, compressive, split tensile, flexure strength.

I. INTRODUCTION

In the recent age, a highly developed infrastructure is playing a vital role for economic growth and prosperity. Many modern structures are necessary to develop the infrastructure with a challenge of cost effectiveness. Concrete has wide range of usage in the construction. In addition concrete is the second most consumed substance in the world. About 10 billion ton of concrete are produced every year [1]. It is the man made material and very strong in compression due to the micro and fine meso porosity of cement paste binder. But it is specified with low tensile strength. Nowadays innovations in concrete are mandatory for an infrastructure in strength and cost aspect. However a new concrete need to enhance its properties in mechanical aspects as strength and toughness. Microstructure of concrete is responsible for its mechanical strength, which can be improved by adding fibres. Fiber reinforced concrete is ideally suited for concrete application that to reduce the plastic and drying shrinkage, improved durability and increased service life. During impact loading, the impact strength of concrete is increases with increase of compressive strain [2]. Fibre reinforced concrete have been introduced about 50 years to enhance the strain capacity in flexural behaviour of concrete, since it continuous for new arrival fibres.

Several fibers have been used so far to enhance the features of control concrete based on their application. Fibers are steel, glass, carbon, cellulose, polypropylene, acrylic, cotton, etc, Which is used in the concrete to propagate and block cracks [3]. But steel fiber rusts easily and in addition of steel fiber will increase the structural weight of the concrete. Basalt fiber which is light in weight is used as a fiber reinforcement and it possess good modulus of rupture. Further increases in strength are achieved by addition of fly ash [4]. Basalt fiber is relatively a new material which is originated from the basalt rock. Basalt is a mafic extrusive igneous rock formed from the rapid cooling of lava and abundant available rock in the earth. High silica content in the basalt rock made a consideration for fiber production and it is responsible for the improvement of mechanical strength [5]. The manufacture of basalt fiber requires the melting of the crushed and washed basalt rock at about 1500 °C. The molten rock is then extruded through small nozzles to produce continuous filaments of basalt fiber. Basalt fiber, first patented in 1924 by a French scientist and used in various structure such as reinforcing concrete bridge deck in Northern Ireland and runway at Bordeaux Merignac.Basalt fiber are used in various application rather than civil due to its unique properties. Mechanical properties of concrete are the base of successful research of any new arrival material. Therefore in this study, the use of basalt fiber in lower volume of a concrete mixes to determine its properties is used.

II. EXPERIMENTAL PROGRAM

Experimental program involve the material selection, mix proportioning, specimen size, casting, curing and test procedure for examine the compressive, tensile and flexural strength is described elaborately in forthcoming section.

A. Selection of material

As per the confirmation of IS 12269, OPC - Ordinary Portland cement of 53 grade is used for the concrete mixtures. Materials involved in the casting of basalt fiber reinforced concrete includes cement, fine aggregate, coarse aggregate, basalt fiber and chemical admixtures. The specific gravity and fineness modulus of OPC obtained from the laboratory test conforming to IS 456 – 2000. Locally available river sand with 0.3 mm in diameter is used as a sand for the experiment investigation.

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* Correspondence Author
Manibalan P*, Research Scholar, Department of Structural Engineering, Annamalai University, Tamilnadu, India. Email: manibalancivil92@gmail.com
Baskar R, Professor, Department of Structural Engineering, Annamalai University, Tamilnadu, India. Email: rajaram_baskar@rediffmail.com

IS 383 – 1970 gives the physical properties of sand and it is tested with a determination of specific gravity as 2.61 and fineness modulus as 2.68. Two size of coarse aggregate are preferred for good workability in fresh concrete. Coarse aggregate is passed through a 20mm and 10mm sieve are used.

Mostly aggregate particles have voids which influence the value of specific gravity and it is determined as 2.70. Water -cement ratio of 0.35 is kept constant for making concrete constituent but different dosage of super plasticizer to achieve the target slump. The Naphthalene sulphonated based super plasticizer is used to attain the desired workability [6]. Basalt fiber of length 6mm and diameter about 2µm is added in the concrete mixes. The proportion of Basalt fiber is designed as 0, 0.3, 0.6, 0.9 and 1% in the total volume of concrete.

B. Mixing and Curing

The concrete mix proportions are designed by using the material properties and conforming with IS 10262:2009. The ratio of cement, fine aggregate and coarse aggregate is carried out to attain the target mean strength at 28 days curing. The mixing of raw material is started with dry mix constituent namely cement, fine aggregate and coarse aggregate of suitable proportion. Further, fiber is added and continues the dry mix for two minutes. Finally the diluted the chemical admixture with water is added and mixes the plastic concrete for 2 minute to confirm the even dispersion of fiber in concrete. Fresh concrete is poured in 150x150x150mm size mould for compressive strength, 300x150x150mm size mould for split tensile strength and 500x150x150mm size mould for flexural strength. The mixture is filled in the mould of three layers and every layer is compacted by using standard tamping rod. After casting, the specimen are demolded after 24h and cured at 20^0C for 28 days.

C. Testing Methods

IS 516 – 1959 shows the test procedure for the determination of compressive and split tensile strength and the test are carried out with utmost care. Three replicate tests are used to confirm the results, therefore three cubes are prepared for each proportion of fiber. The split tensile strength and compressive strength report is the mean of three replicate test values for each mix at 7, 14 and 28 days is determined. The specimen is loaded at a rate of 150kN/min by a 2000kN capacity of uniaxial compression testing machine. Flexural test is an indirect method to evolve the tensile strength of concrete. IS 516:1959 gives the size of prism and loading pattern for the prism to determine its flexural strength. The test is carried out at 7, 14 and 28 days and report the mean of three replicate test values.

III. TEST RESULT AND DISCUSSION

A. Compressive Strength

The compression test has been carried out as shown in Fig. 1 and test result of all specimen at 7, 14 and 28 days are given in Table I. Also, the Fig.2 shows the variation of compressive strength at different ages. Several researchers discussed about the effect of basalt fiber in concrete for various condition. Since the research is mandatory due to its different aspect ratio and proportion. For the Portland cement concrete [7] showed that the effect of 12mm basalt fiber is added as 0.5% in the volume of concrete caused reduction and increment in the effect of 22mm basalt fiber in the volume fraction of 0.5% on the compressive strength at 28 days. Relative increment in the compressive strength of concrete in the volume fraction of 0.5% of BF is proved [8]. *TehminaAyub et al* stated that the effect of 25mm basalt fiber in 3% volume fraction caused 9.45% reduction in comparison of normal concrete [9].They also reported that the mechanical strength of the concrete are increased by adding the basalt fiber of 1 to 3% in volume fraction. Therefore this study used the 6mm length basalt fiber in concrete of proportion as 0.3, 0.6, 0.9 and 1%. The result of compressive strength proved that the improvement in strength compared to the control concrete by 6mm basalt fiber. Basalt fiber reinforced concrete has yielded a higher strength at 0.9% proportion and it is increased about 14.5% of control concrete. However the compressive strength is decreased in BF(1) proportion of about 8.29% than the BF(0.9) concrete. The compressive strength of basalt fiber concrete is improved even at BF(0.3) and BF(0.6) proportion as 1.89% and 7.28% than the control concrete.

Fig. 1. Testing of Compression Strength

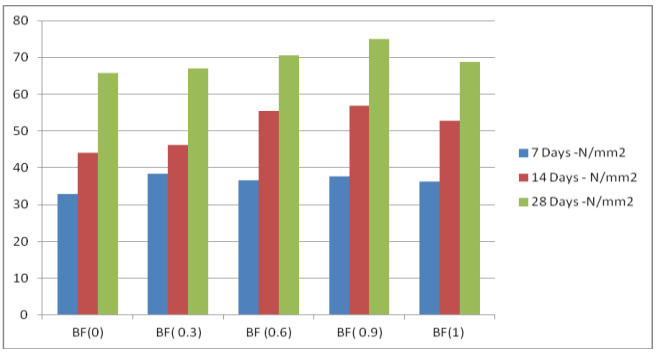

Fig. 2. Variation of Compression Strength at different ages

Table- I: Compressive Strength

Designation	Compressive Strength (N/mm^2)		
	7 Days	14 Days	28 Days
BF(0)	32.88	44	65.86
BF(0.3)	38.33	46.22	67.11
BF (0.6)	36.66	55.55	70.66
BF(0.9)	37.77	56.97	75.11
BF(1)	36.22	52.84	68.88

B. Splitting Tensile Strength

Fig. 4 shows the improvement in split tensile strength of basalt fiber concrete for 7, 14 and 28 days. The splitting tensile strength of basalt fiber reinforced concrete is rises apparently with increases in fiber fraction, while compared to control concrete.

Previous studies stated that the influence of fiber result in improvement of tensile strength of concrete. *C.Jiang, Ke Fan, Fan Wu, Da Chen* stated about 22mm basalt fiber given a better tensile strength than the 12mm fiber [7]. However with the increase in fiber length, it has a problem of uneven distribution in cementitious composites. In this study a 4mm fiber shown a better tensile strength rises at various fiber fraction. The results in Table II and Fig. 4 showed that splitting tensile strength of 0.9% proportion of basalt fiber concrete is increased 58.66% than control concrete. Further increment of basalt fiber will reduce the tensile strength which shown in a result of 13.44%. However the BF1 shown a significant improvement in tensile strength than the control concrete, BF-0.9 is fixed as an optimum content. BF(0.3) and BF(0.6) showed a slight improvement as 26.66% and 30.66% than the control concrete. The distribution of fiber in the micro crack will increased the tensile behavior of concrete and also restrains the development of cracks.

Fig. 3. Testing of Splitting Tensile Strength

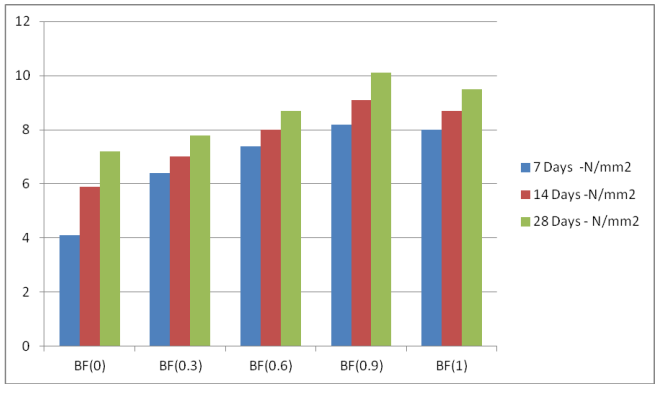

Fig. 4. Variation of Splitting Tensile Strength at different ages

Table- II: Splitting Tensile Strength

Designation	Splitting Tensile Strength (N/mm^2)		
	7 Days	14 Days	28 Days
BF(0)	4.386	4.952	5.306
BF(0.3)	4.952	6.225	6.721
BF(0.6)	5.589	6.574	6.933
BF(0.9)	5.659	7.145	8.419
BF (1)	5.518	6.791	7.287

C. Flexure Strength

Flexural testing as shown in Fig. 5 is done and result of basalt fiber reinforced concrete at 7, 14 and 28 days are shown in the Table III. The incorporation of basalt fiber and cement matrix showed the load at initial stage and restrain the development of crack by increasing the flexural strength [10]. Fig. 6 shows the variation of flexural strength. *Jabsheed Ahamed* stated that the effect of 1% basalt fiber caused 31.94% increment than the control concrete at 28 days and also reported that the effect of 1%, 2% and 3% basalt fiber reinforced concrete in a improvement of flexural strength than the control concrete. In this study the flexural strength of BF-0.9 is increased 40.27% than the control concrete at 28 days. However BF(1) drops the flexural strength than the BF-0.9 as 5.71% and significant improvement than the control concrete. Based on the above result, It is observed that the optimum content of 6mm basalt fiber in M50 grade concrete as 0.9% proportion of fiber in the volume of concrete.

Fig. 5. Testing of Flexural Strength

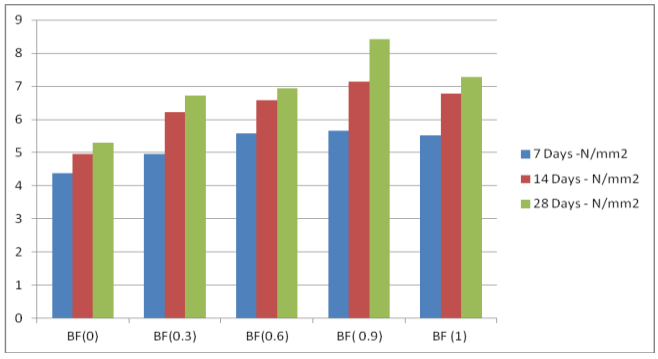

Fig. 6. Variation of Flexural Strength at different ages

Table- III: Flexural Strength

Designation	Flexural Strength (N/mm^2)		
	7 Days	14 Days	28 Days
BF(0)	4.1	5.9	7.2
BF(0.3)	6.4	7.0	7.8
BF(0.6)	7.4	8.0	8.7
BF(0.9)	8.2	9.1	10.1
BF(1)	8.0	8.7	9.5

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IV. CONCLUSION

The mechanical properties of basalt fiber reinforced concrete are studied and determined the optimum content of fiber in volume fraction.

Effectiveness of basalt fiber in the higher dosage tends to create the workability problem in concrete.

To overcome from workability problem, the dosage of super plasticizer is altered accordingly to the proportion of basalt fiber in the concrete. Compared with the control concrete, concrete reinforced with the basalt fiber given the higher compressive strength, tensile strength and flexural strength in 0.9% proportion.

The length of the fiber is also responsible for crack resistance in the concrete. In this research the basalt fiber of 6mm length is evenly dispersed to arrested the crack and increased the mechanical strength of the concrete.

The compressive strength of BF(0.9) is given the less increment of 14.5% than the control concrete, whereas the tensile strength and flexural strength of BF(0.9) concrete is increases by 58.66% and 40.25% than the control concrete. This shows that the fiber gives the better performance in tensile strength than the compressive strength. However the compressive strength, tensile strength and flexural strength of BF(1) decreases by 8.29% 13.44% and 5.71% than the BF(0.9) concrete. But it shows the noticeable increment in strength with the comparison of control concrete.

Further increase in basalt fiber proportion leads to uneven distribution and accumulate into a group, thereby the strength is reduced than the control concrete. Test result also showed that the difference of strength gaining at 7, 14 and 28 days. The compressive strength, tensile strength and flexural strength of BF(0.9) at 7days is 98.86%, 48.77% and 23.17% of the 28 day strength. This exhibit the long term properties of basalt fiber reinforced concrete which inhibit the cracks and enhance the strength. Finally this study concluded that the 0.9% of basalt fiber exhibited better properties in fresh state and hardened state of concrete.

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AUTHORS PROFILE

Manibalan P Research Scholar, Department of Structural Engineering, Annamalai University, Tamilnadu, India. Email: manibalancivil92@gmail.com

Baskar R Professor, Department of Structural Engineering, Annamalai University, Tamilnadu, India. Email: rajaram_baskar@rediffmail.com