International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 10, Issue 8, August 2021)

Determination of Compressive and Flexural Strength of Mixed Concrete using Basalt Bundles

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***Abstract*-- Engineered cementitious composite (ECC) is a cement-based material consisting of cement, sand, water, a chemical admixture and short discrete fibers [1]. ECC is known for its enhanced tensile ductility, with the tension strain ranging from 3% to 8% and the width of multi-cracks usually being less than 200 µm. Due to these special advantages, ECC is widely used, especially in structures that require an enhanced tensile capacity, such as retaining walls, dams, aqueducts, bridge decks and building dampers [2]. Engineered cementitious composite (ECC) is a cement-based material consisting of cement, sand, water, a chemical admixture and short discrete fibers [1]. ECC is known for its enhanced tensile ductility, with the tension strain ranging from 3% to 8% and the width of multi-cracks usually being less than 200 µm [2]. Due to these special advantages, ECC is widely used, especially in structures that require an enhanced tensile capacity, such as retaining walls, dams, aqueducts, bridge decks and building dampers [3].**

Fiber reinforced concrete (FRC) is composite concrete that contains fibrous material that enhances its structural integrity.In this dissertation, an investigation of compressive strength and flexural strength of mixed concrete using basalt fibers (bundles). Cement is widely most used in the recent construction industry because of it's easily availability and cheap in the market. The properties of mixed concrete made of chopped basalt fiber were investigated. The basalt fiber (bundles) specimens were cast using basalt fibers of varying fiber dosage (3 kg/m3, 6 kg/m3, and 9 kg/m3).The results indicated that the 30 mm basalt bundled fiber at 6 kg/m3 was the optimum fiber length and fiber volume for basalt bundled fibers. For the calculation and analysis of M25 grade of concrete has been designed on the parameter of IS code 10262-2009.[8] The mixture with admixture and water cement magnitude relation is 0.50. A total of 20 cylindrical specimens and 10 beam specimens were cast and tested. In each batch, 2 cylinders were prepared for compression test (2 cylinders each for 28 day test), 2 cylinders were prepared for split tensile test, and 10 beams were cast for flexural test. It provided the optimum increase in flexural strength, compressive strength, and split tensile strength when compared with plain concrete.

***Keywords*--M25 Grade of Concrete, Bundles ballast fiber, Flexural strength test, compressive strength test, Beam.**

I. INTRODUCTION

Plain cement concrete is the mixture of coarse aggregate, fine aggregate, cement without steel. It is an important constituent of a building that is laid on the soil surface to avoid direct contact of reinforcement of concrete with water and soil. Concrete is weak in tensile effect because it take into account various micro-cracks.[8] The micro-cracks begin to spread in the matrix when load is applied on the Plain cement concrete. Accordingly, plain concrete members cannot protract tensile stresses developed due to the applied forces without the addition of reinforcing elements (re-bar or wire mesh) in the tensile zone. The circulation of micro-cracks and macro-cracks, however, still cannot be in detention or slowed by the sole use of continuous reinforcement. Randomly dispersed fibers in concrete help in reducing the crack width thus, reduces the permeability of concrete. The addition of randomly spaced irregular fibers helps in arresting the propagation of the micro-cracks and macro-cracks. In accumulation to crack control, fibers also improve the properties of plain concrete such as resistance to impact, fracture resistance and resistance to dynamic loads. Basalt fibers show several advantages including modulus of elasticity, specific strength and nontoxic, low cost [4], noncombustible [5] and high thermal insulating properties [4].The chemical and mechanical properties depend on the composition of the raw material. Different fiber composition and concentration give difference in thermal and chemical stability and also showed variance in mechanical and physical properties [4].Chemical structure of basalt fiber is nearly related to glass. The most important components of basalt fibers are SiO_2, Al_2O_3, CaO, MgO, Fe_2O_3 and FeO. The different oxides compose a large cross linked molecule with primary bonds [5]. Basalt fibers are chemically composed of pyroxene, clinopyroxene, olivine and plagioclase minerals [9]. Basalt materials are classified according to their SiO_2 content. If the basalt has scarcity in silica, it is categorized as alkaline basalt. Further, if the basalt rich in silica, it is called acidic basalt [5].

Compared to the other natural fiber, it has excellent mechanical properties; lightweight, easily affordable and eco friendly makes it an ideal material for civil engineering application. The addition of basalt fibers can improve the deformation and energy absorption capacity, toughness index, flexural strength, abrasion resistance and reduce dry shrinkage of fiber reinforced concrete (FRC) significantly [5].

II. Objective Of View

The most important aim of the present work of thesis is to determination of compressive strength and flexural strength of mixed concrete using basalt bundles and filaments.

The following are the objectives of this thesis.

Compare the performance of split tensile strength, flexural strength and compressive strength of the plain concrete with bundled fiber specimens and the basalt filament fiber specimens.

Compare the performance of split tensile strength, flexural strength and compressive strength of the plain concrete with bundled fiber specimens of various fiber dosages (3 kg/m3, 6 kg/m3, and 9 kg/m3).

III. Problem Statement

The most important problems faced in reinforced concrete construction are the decay of reinforcing steel, which considerably affects the durability and life of concrete structures. By chance dispersed basalt fibers as a substitute to welded wire mesh for slabs on grade can effectively reduce the problem of decay as they are resistant to corrosion. In accumulation to good chemical resistance, light weight and high tensile strength of basalt fibers also acquire high thermal resistance and they do not conduct electricity.

1. On the other hand, there have only been a limited number of researches found in open literature concerning chopped basalt filament fiber reinforced concrete.
2. There are no previous research was conducted using basalt bundled fibers. Hence, this study is the performance of split tensile strength, flexural strength and compressive strength of the plain concrete with bundled fiber specimens using different length and volume.

IV. Materials Used

A. Cement is a well-known building material and has occupied an indispensable place in construction works. There are a variety of cements available in the market and each type is used under certain conditions due to its special properties [8]. A mixture of cement and sand when mixed with water to form a paste is known as cement mortar whereas the composite product obtained by mixing cement, water, and an inert matrix of sand and gravel or crushed stone is called cement concrete. The distinguishing property of concrete is its ability to harden under water. The cement commonly used is Portland cement, and the fine and coarse aggregates used are those that are usually obtainable, from nearby sand, gravel or rock deposits.

B. Aggregates can be classified in three different ways as given below:

1. Depending on particle size, aggregates can be classified either as in aggregate (75-micron to 4.75-mm) or coarse aggregate (4.75-mm to 80-mm).
2. Depending upon the bulk density, aggregates can be classified as normal weight (1520 kg/m to 1630 kg/m), lightweight (less than 1220 kg/m) and heavyweight above 2000 kg/m3).
3. Depending on the source, the aggregates could be either naturally available or synthetically manufactured. The former category includes naturally occurring sand, pebbles, gravel or crushed stone while the latter includes located clay aggregates, etc.

Table-1
Physical Properties of Fine & Coarse aggregate

Aggregate type		**Fineness Modulus**	**Water Absorption (%)**	**Specific gravity**
Fine aggregate		2.76	0.81	2.58
Coarse aggregate	**20mm**	2.68	0.81	2.64
	12.5mm	2.93	0.81	2.65

International Journal of Recent Development in Engineering and Technology
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C. Basalt fibers can be produced from the melt of basalt stones. In principle two different kinds of basalt fibers are distinguished—staple fibers and filaments .For both types different production methods have been reported. The production of staple fibers is possible directly from small and molten basalt stones. However, these staple fibers possess asymmetrical properties and only a low mechanical performance in mentioned .The product of this process consists usually of several hundred monofilaments building up the roving. This process is quite similar to the production of glass fibers.

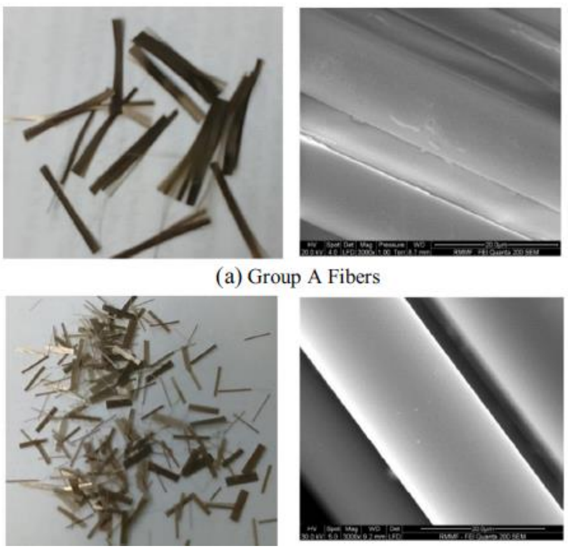

Fig. 1 Basalt fibers.[14]

Bundles Length: 10 mm, 20 mm, and 30 mm Diameter: 16micron as shown the properties of basalt fiber in table 2.

Table 2
Properties of Basalt Fibers

Properties	Values
Density(g/cm^3)	2.75
Tensile strength (MPa)	4800
Elastic modulus (GPa)	94
Elongation at break (%)	3.1

V. Methodology

A total of 10 cylindrical specimens and 10 beam specimens were cast and tested. In each batch, each cylinder was prepared for compression test for 28 day, each cylinder was prepared for split tensile test, and 10 beams were cast for flexural test.

Plain concrete specimens were prepared using 1:1.92 :(1.8+1.2) (cement: fine aggregate: coarse aggregate+ basalt fiber) mix proportion (by weight). The water-cement ratio was kept constant at 0.5 for the mixes. All FRC specimens were prepared using the same mix proportion. BFRC beam and cylinder specimens were cast using basalt fibers (16 µm in diameter) of varying fiber dosage (3 kg/m3, 6 kg/m3, and 9 kg/m3.

Mixing procedure of basalt fibers in M25

1. The required quantities of coarse aggregate, fine aggregate, cement, basalt fiber, and water were measured before each mix.
2. The mixer was rinse with water and drained before the first mix of each day so that it did not absorb water from the mix.
3. The coarse and fine aggregates were mixed dry for 3 minutes before adding cement.
4. The cement was added and mixed for another 2 minutes. Fiber was added slowly at a constant rate, while the mix was still dry and the concrete mixer was in motion to eliminate lumping of fibers in the mix.
5. At higher fiber dosages, the mixer had to be stopped a few times and the dry concrete mix was agitated manually with a trowel several times to remove the fibers lumped around the mixer blades.
6. The lumping of fibers was found to be more evident in case of basalt filaments compared to basalt bundled fibers. The dry mixing process continued until all the fibers dispersed uniformly.
7. Basalt bundled fibers dispersed evenly as individual strands in the dry mix even at high volume fraction (0.40 % by volume).

Quantity of Basalt fibers = 0.40 % of CA
Quantity of Basalt fibers = 0.40 % of 1117.58
= 447.03 kg/m^3
Quantity of coarse aggregate = 1117.58 – 447.03
= 670.55 kg/m^3

Table 3
The final trial batch quantities per cubic meter of concrete M25 using Basalt fibers are

Cement	Water	Fine aggregate	Coarse aggregate	Basalt Fiber
kg/m^3	kg/m^3	kg/m^3	kg/m^3	0.40 % of CA (kg/m$^{3)}$
372	161	713.3	670.55	447.036
1	0.43	1.92	1.8	1.2

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International Journal of Recent Development in Engineering and Technology
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8. Finally after the fiber had mixed thoroughly, water was added and the mixer was run for another 5 minutes.
9. The mixer was thoroughly cleaned with water after each mix.

VI. TEST PROGRAMME

Test Matrix of BB: Basalt Bundle

The test matrix was measured in this job. In each batch, 3 cylinders were prepared for compression tests for 28 day,3 cylinders were prepared for split tensile tests and each beam was cast for flexural tests. Each specimen in Table 5 was named based on the fiber type and fiber volume. The first term denotes the type of fiber (PC: Plain Concrete; BB: Basalt Bundle), the following number denotes the length of fiber in mm and the last number denotes the amount of fiber in kg/m3 of concrete used in the mix (% by weight). Table 4 explains the naming scheme.

For example,
PC – Specimen without fiber or plain concrete
BB 10-6 – B- Basalt, B - Bundle, 10 mm long at 6 kg/m3

Table 5
Physical Properties of OPC & CementitiousMaterials

Mix design codes	Speci men name	Fiber length (mm)	Fiber quantity		No.of cylinders for 28 day compres sion test	No. of Beam
			(kg/ m3)	% Volume		
MIX-M25	PC	NA	0	0	1	1
M1-MIX	BF-10-3	10	3	0.12	1	1
M2-MIX	BF-10-6	10	6	0.25	1	1
M3-MIX	BF-10-9	10	9	0.37	1	1
M4-MIX	BF-20-3	20	3	0.12	1	1
M5-MIX	BF-20-6	20	6	0.25	1	1
M6-MIX	BF-20-9	20	9	0.37	1	1
M7-MIX	BF-30-3	30	3	0.12	1	1
M8-MIX	BF-30-6	30	6	0.25	1	1
M9-MIX	BF-30-9	30	9	0.37	1	1

VII. RESULT AND OBSERVATIONS

Table 6
Workability of various concrete mixes design for slump cone test

Mix design codes	Specimen name	Slump cone test (in mm.)
MIX-M25	PC	42
M1-MIX	BB-10-3	38
M2-MIX	BB-10-6	39
M3-MIX	BB-10-9	41
M4-MIX	BB-20-3	43
M5-MIX	BB-20-6	40
M6-MIX	BB-20-9	42
M7-MIX	BB-30-3	45
M8-MIX	BB-30-6	47
M9-MIX	BB-30-9	48

Varying fiber dosage (3 kg/m³, 6 kg/m³, and 9 kg/m³)

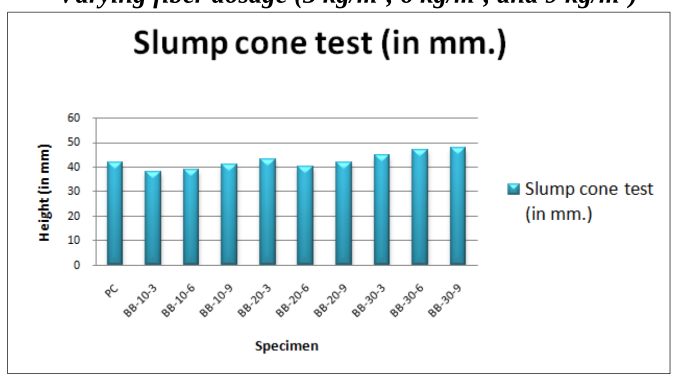

Fig. 2: Workability by Slump cone test using Basalt Bundles

Flexural Strength of beam

The test specimen of Flexural Strength of beam, there are three different length (10 mm, 20 mm, and 30 mm) of 16 µm basalt bundles using in cement concrete with varying fiber content (1%, 2% and 3% by weight). The results showed that the plain concrete and 10 mm basalt fiber reinforced specimens were brittle, regardless of the fiber content.

The disintegration of the specimen occurred simultaneously with the formation of first crack. The first crack was formed at 0.75 to 0.85 of the breaking load. The axial and flexural strength of the specimens reinforced with 10 mm and 30 mm filaments (1% - 3% by weight) were found to be 1.79 to 2.24 times more than that of the unreinforced specimens, respectively.

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The forms were made of polycarbonate and had clear dimensions of 150 mm x 150 mm in internal cross section and 600 mm in length,

Table 7:
Basalt Bundles: Flexural Strength of beam (MPa)

Mix design codes	Specimen name	Mean split tensile strength (MPa)
MIX-M25	PC (Plain concrete)	3.48
M1-MIX	BB-10-3	3.92
M2-MIX	BB-10-6	3.73
M3-MIX	BB-10-9	4.11
M4-MIX	BB-20-3	3.85
M5-MIX	BB-20-6	3.97
M6-MIX	BB-20-9	4.53
M7-MIX	BB-30-3	3.69
M8-MIX	BB-30-6	3.91
M9-MIX	BB-30-9	4.32

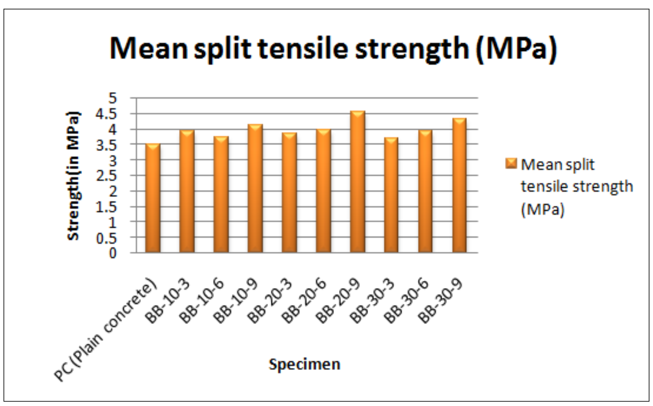

Figure 3: Basalt Bundles: Split tensile strength

Compressive strength

Flexural and compressive strength tests were conducted with 16 µm diameter and 10 mm long basalt fiber reinforced concrete. The results showed that the flexural strength and the compressive strength increased by 29% and 14%, respectively from plain concrete specimens by adding 3 kg/m3 of 16 µm diameter and 10 mm long basalt fiber to 29 MPa concrete. Adding 3 kg/m3 of 16 µm diameter and 10 mm long basalt fiber to 25 MPa concrete, increased the flexural strength up to 29% and compressive strength by 9% from plain concrete specimens. The test results of 28 day cylinder compressive strength of basalt bundled specimens.

Table 8:
Basalt filaments: 28 day Compressive strength (MPa)

Mix design codes	Specimen name	Compressive strength (MPa)
MIX-M25	PC (Plain concrete)	31.21
M1-MIX	BB-10-3	36.85
M2-MIX	BB-10-6	35.81
M3-MIX	BB-10-9	39.06
M4-MIX	BB-20-3	37.49
M5-MIX	BB-20-6	43.42
M6-MIX	BB-20-9	44.95
M7-MIX	BB-30-3	38.78
M8-MIX	BB-30-6	43.01
M9-MIX	BB-30-9	44.40

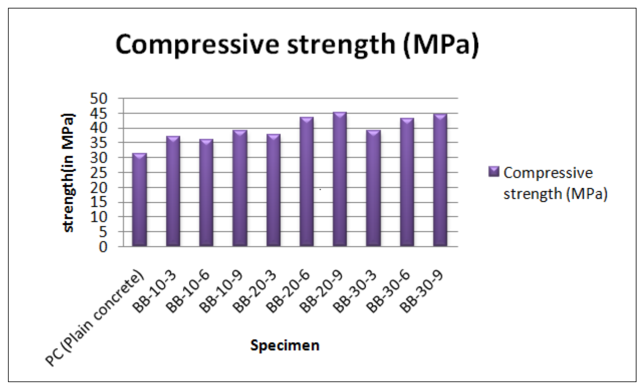

Fig. 4: Basalt Bundles: Compressive strength (MPa)at 28 Days

VIII. COCLUSION

In this research, the conclusions based on the results to obtain here, basalt fiber using the different specimen as compared to mix design M25 for different concrete mix proportions and different water-cement ratios.

Basalt bundles used in beam cylinder specimens in a brittle and sudden manner after the first crack, similar to Plain Concrete.

Though, there was progress in the peak strength of flexural and compressive strength.

In Basalt bundles optimum fiber dosage and length for basalt fibers, which provided the most excellent performance in flexural and compressive strength are 30 mm bundled fiber at 9 kg/m3. It showed a 20 % increase in flexural strength, 35 % increase in compressive strength compared to the plain concrete control specimen.

Based on the obtained experimental-statistical models of strength and super plasticizer content, a methodology for designing hybrid fiber reinforced concrete compositions was proposed.

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