Research Result

An Experimental Study of Characteristic Strength of Basalt Fiber Reinforced Concrete

Rajneesh Kumar Dwivedi[1] and Kamlesh Kumar Choudhary[2]

[1]M.Tech Scholar, Saraswati Institute of Engineering & Technology, Jabalpur, INDIA
[2]Professor, Saraswati Institute of Engineering & Technology, Jabalpur, INDIA

ABSTRACT

Fiber reinforced concrete (FRC) is composite concrete that contains fibrous material that enhances its structural integrity. In this work to 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 its 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. 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, filament ballast fiber, Flexure strength test, splitting tensile strength test, compressive strength test.

1. 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 takes into account various micro-cracks. 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. Conventional concrete is modified by random dispersal of short discrete fine fibers of asbestos, steel, sisal, glass, carbon, poly-propylene, nylon, etc. Asbestos cement fibers so far have proved to be commercially successful. Fibers include synthetic fibers and natural fibers each of which lend varying properties to the concrete. The improvement in structural performance depends on the strength characteristics, volume, and spacing. Dispersion and orientation, shape and their aspect ratio (ratio of length to diameter) of fibers. A fiber-reinforced concrete requires a considerably greater amount of fine aggregate than that for conventional concrete for convenient handling. For FRC to be fully effective, each fiber needs to be fully embedded in the matrix, thus the cement paste requirement is more. For FRC the cement paste required ranges between 35 to 45 per cent as against 25 to 35 per cent in conventional concrete The behavior of fiber reinforced concrete (FRC) is shown in Fig. 1.

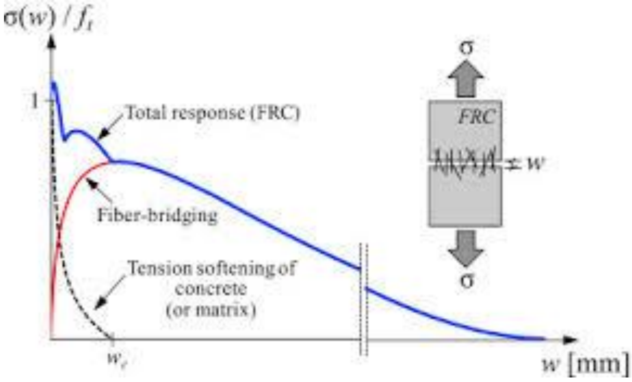

Fig. 1 Concrete The behavior of fiber reinforced concrete

The tensile cracking strain of cement mats about 1/50 of that of yield of steel fibers consequently when FRC is loaded, the matrix cracks long before the fibers are fractured. Once the matrix is cracked tie composites continue to carry increasing tensile stress, provided the pullout resistance of fibers at the first crack is greater than the load at the first cracking. The bond or the pullout resistance of the fibers depends on the average bond strength between the fibers and the matrix, the number of fibers crossing the crack, the length and diameter of fibers, and the act cot ratio. Steel fibers tend to intermesh and form balls during mixing of concrete. Different types of commercially available fibers used in concrete and examples of these fibers are carbon fibers , glass fibers, steel fibers, polypropylene fibers, and basalt fibers.

Applications: Fiber reinforced concrete is useful in hydraulic structures, airfield pavements, highways, bridge decks, heavy duty floors, and tunnel linings.

2. 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.

1. 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.

2. 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).

3. 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.

4. MATERIALS USED

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. 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.

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

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. For industrial production of basalt staple fibers two methods are mentioned: the "Junker's type" and the "centrifugal-multirole system". For advanced applications basalt fibers are produced as filaments. These filaments are produced by a spinneret process. 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.

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

5. METHODOLOGY

A total of 20 cylindrical specimens and 10 beam specimens were cast and tested. In each batch, each cylinder was prepared for compression test for 28 days, 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/m³

   Quantity of coarse aggregate = 1117.58 – 447.03

   = 670.55 kg/m³

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/m³	kg/m³	kg/m³	kg/m³	0.40 % of CA (kg/m³)
372	161	713.3	670.55	447.036
1	0.43	1.92	1.8	1.2

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.

6. TEST PROGRAMME

Test Matrix of BB: Basalt Bundle and BF: Basalt Filament

The test matrix was measured in this job. In each batch, 3 cylinders were prepared for compression tests (3 cylinders each for 7 day and 28 day test),3 cylinders were prepared for split tensile tests and 6 beams were cast for flexural tests. Each specimen in Table 6.13 was named based on the fiber type and fiber volume. The first term denotes the type of fiber (PC: Plain Concrete; BB: Basalt Bundle; and BF: Basalt Filament), the following number denotes the length of fiberin 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

BF 10-3 – B- Basalt, F - Filament, 10 mm long at 3 kg/m3

BB 10-6 – B- Basalt, B - Bundle, 10 mm long at 6 kg/m3

Table 4: Test matrix

Mix design codes	Specime n name	Fiber length (mm)	Fiber quantity		Number of cylinders for 28 day compression test	Number of cylinders for 28 day split tensile test	Number of Beam
			(kg/m 3)	% Volu me			
MIX-M25	PC	NA	0	0	1	1	1
M1-MIX	BF-10-3	10	3	0.12	1	1	1
M2-MIX	BF-10-6	10	6	0.25	1	1	1
M3-MIX	BF-10-9	10	9	0.37	1	1	1
M4-MIX	BF-20-3	20	3	0.12	1	1	1
M5-MIX	BF-20-6	20	6	0.25	1	1	1
M6-MIX	BF-20-9	20	9	0.37	1	1	1
M7-MIX	BF-30-3	30	3	0.12	1	1	1
M8-MIX	BF-30-6	30	6	0.25	1	1	1
M9-MIX	BF-30-9	30	9	0.37	1	1	1
M10-MIX	BB-10-3	10	3	0.12	1	1	1
M11-MIX	BB-10-6	10	6	0.25	1	1	1
M12-MIX	BB-10-9	10	9	0.37	1	1	1
M13-MIX	BB-20-3	20	3	0.12	1	1	1
M14-MIX	BB-20-6	20	6	0.25	1	1	1
M15-MIX	BB-20-9	20	9	0.37	1	1	1
M16-MIX	BB-30-3	30	3	0.12	1	1	1
M17-MIX	BB-30-6	30	6	0.25	1	1	1
M18-MIX	BB-30-9	30	9	0.37	1	1	1

* - Specimens were mixed and cast twice for the following reasons.

(a) Slump for the mix was less than 100 mm for higher fiber dosages.

(b) To keep the water-cement ratio constant at 0.5 for all the mixes.

Table 5 Specimen classification

Term	Symbol	Meaning
1	B	Basalt
2	B	Bundle
	F	Filament
3	10/20/30	Length of fiber (mm)
	3/6/9	Percentage of fiber (by weight) in the mix

7. 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	39
M1-MIX	BF-10-3	38
M2-MIX	BF-10-6	40
M3-MIX	BF-10-9	41
M4-MIX	BF-20-3	42
M5-MIX	BF-20-6	44
M6-MIX	BF-20-9	47
M7-MIX	BF-30-3	45
M8-MIX	BF-30-6	48
M9-MIX	BF-30-9	49
M10-MIX	BB-10-3	38
M11-MIX	BB-10-6	39
M12-MIX	BB-10-9	41
M13-MIX	BB-20-3	43
M14-MIX	BB-20-6	40
M15-MIX	BB-20-9	42
M16-MIX	BB-30-3	45
M17-MIX	BB-30-6	47
M18-MIX	BB-30-9	48

1. 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 mm basalt filament 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.

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 Filaments : Split tensile strength

Mix design codes	Specimen name	Mean split tensile strength (MPa)
MIX-M25	PC (Plain concrete)	3.48
M1-MIX	BF-10-3	3.94
M2-MIX	BF-10-6	3.75
M3-MIX	BF-10-9	3.55
M4-MIX	BF-20-3	3.83
M5-MIX	BF-20-6	3.95
M6-MIX	BF-20-9	4.37
M7-MIX	BF-30-3	3.71
M8-MIX	BF-30-6	3.91
M9-MIX	BF-30-9	4.32

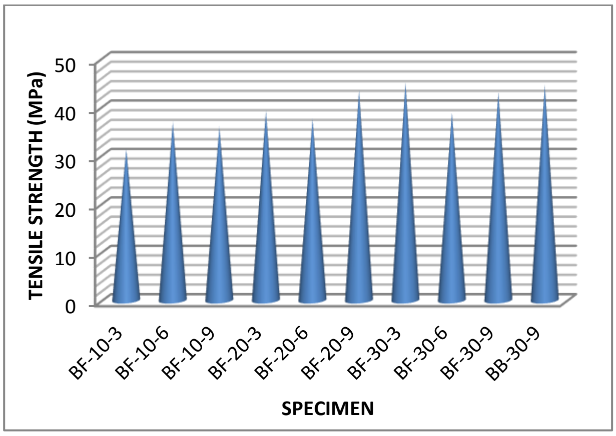

Figure 2: Basalt Bundles: Split tensile strength

Table 8: Basalt Bundles: Split tensile strength

Mix design codes	Specimen name	Mean split tensile strength (MPa)
MIX-M25	PC (Plain concrete)	3.48
M10-MIX	BB-10-3	3.92
M11-MIX	BB-10-6	3.73
M12-MIX	BB-10-9	4.11
M13-MIX	BB-20-3	3.85
M14-MIX	BB-20-6	3.97
M15-MIX	BB-20-9	4.53
M16-MIX	BB-30-3	3.69
M17-MIX	BB-30-6	3.91
M18-MIX	BB-30-9	4.32

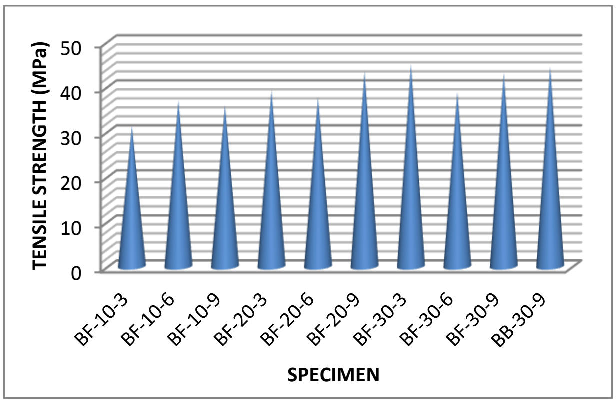

Figure 3: Basalt Bundles: Split tensile strength

2. 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

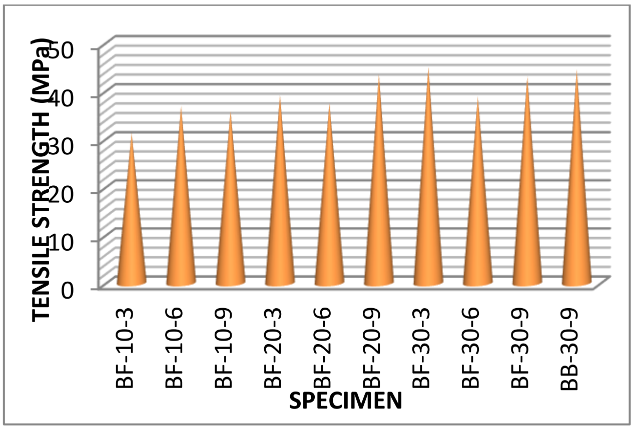

Figure 4: Basalt Bundles: Compressive strength (MPa)at 28 Days

Table 9: Basalt filaments: 28 day Compressive strength (MPa)

MIX DESIGN CODES	SPECIMEN NAME	COMPRESSIVE STRENGTH (MPA)
MIX-M25	PC (PLAIN CONCRETE)	31.21
M10-MIX	BB-10-3	36.85
M11-MIX	BB-10-6	35.81
M12-MIX	BB-10-9	39.06
M13-MIX	BB-20-3	37.49
M14-MIX	BB-20-6	43.42
M15-MIX	BB-20-9	44.95
M16-MIX	BB-30-3	38.78
M17-MIX	BB-30-6	43.01
M18-MIX	BB-30-9	44.40

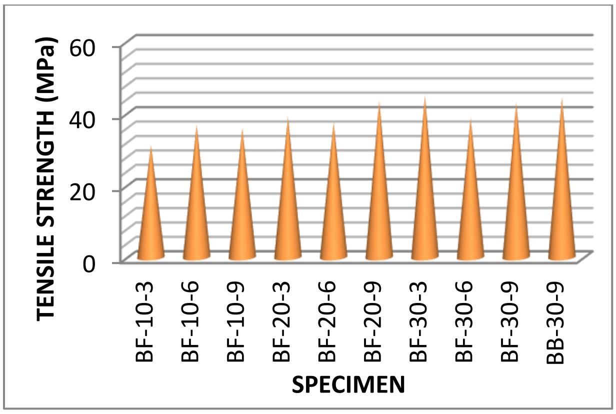

figure 5 :basalt bundles: compressive strength (mpa) at 28 days

8. COCLUSION

In this research work 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 and filaments 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, split tensile and compressive strength.

In Basalt bundles optimum fiber dosage and length for basalt fibers, which provided the most excellent performance in flexural, split tensile 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, and a 15 % increase in split tensile strength compared to the plain concrete control specimen.

In Basalt filaments optimum fiber dosage and length for basalt fibers, which provided the most excellent performance in flexural, split tensile and compressive strength are 20 mm filaments fiber at 9 kg/m3 . It showed a 23 % increase in flexural strength, 25 % increase in compressive strength, and a 6 % increase in split tensile strength compared to the plain concrete control specimen.

REFERENCES

[1]. Leonid Dvorkin, Oleh Bordiuzhenko ,Vadim Zhitkovsky, Svyatoslav Gomon, and Sviatoslav Homon (2021) "Mechanical Properties and Design of Concrete with Hybrid Steel and Basalt Fiber"E3S Web of Conferences264,02030(2021)https://doi.org/10.1051/e3sconf/202126402030 CONMECHYDRO - 2021

[2]. E. Güneyisi, Y.R. Atewi, M.F. Hasan (2019), "Fresh and

rheological properties of glass fiber reinforced self-compacting concrete with nanosilica and fly ash blended" Constr. Build. Mater., 211 (2019), pp. 349-362

[3]. Manu P.P. and Eldhose C.(2019) Flexural Behavior of Hybrid Steel Basalt Fibre Reinforced Concrete Int. Research J. of Engineering and Tech. 6 (5) pp. 760–764 (2019)

[4]. S. Pourfalah (2018) "Behaviour of engineered cementitious composites and hybrid engineered cementitious composites at high temperatures" Constr. Build. Mater., 158 (2018), pp. 921-937

[5]. Kumar M.V., Niveditha K., Anusha B. and Sudhakar B. (2017) "Comparison Study of Basalt Fiber and Steel Fiber as Additives to Concrete", Int. J. for Research in Applied Sc. & Engineering Tech. 5 (VIII), pp. 6–14 (2017)

[6]. J. Branston, S. Das, S.Y. Kenno, C. Taylor (2016) "Mechanical behaviour of basalt fibre reinforced concrete" Constr. Build. Mater., 124 (2016), pp. 878-886

[7]. V. Fiore, T. Scalici, G. Di Bella, A. Valenza (2015) "A review on basalt fibre and its composites" Compos. B Eng., 74 (2015), pp. 74-94

[8]. F. Qi, M. Qinyong, Z. Ying (2015), "Experiment and analysis on compressive and tensile performance of steel slag powder concrete with basalt fiber" Science Technology and Engineering, 15 (33) (2015), pp. 224-227

[9]. V. Dhand, G. Mittal, K.Y. Rhee, S.-J. Park, D. Hui (2015) "A short review on basalt fiber reinforced polymer composites" Compos. B Eng., 73 (2015), pp. 166-180

[10]. Ye, J. Xu, L. Nie (2015) "Splitting tensile strength of early strength concrete with different volume fractions of basalt fiber" Bulletin of Chinese Ceramic Society, 34 (6) (2015), pp. 1700-1704

[11]. C.G. Li, C.Q. Dong, Q.J. Qin, L.L. Xiang, L. Ma, X.Y. Huo, Z.Y. Xing (2015), "Experimental research on mechanical properties of nano-SiO2 hybrid fiber concrete" Materials Review, 29 (25) (2015), pp. 48-52

[12]. C.H. Jiang, K. Fan, F. Wu, D. Chen (2014), " Experimental study on the mechanical properties and microstructure of chopped basalt fiber reinforced concrete" Materials and Design, 58 (2014), pp. 187-193

[13]. J.Q. Dong, Y.T. Du, B.L. Wen, L.X. Sun, J.Q. Wang (2011) "Research on mechanical properties and toughening mechanism of basalt fiber reinforced concrete" Industrial Construction, 4 (2011), pp. 638-641

[14]. C.H. Jiang, T.J. McCarthy, D. Chen, Q.Q. Dong, (2010) "Influence of basalt fiber on performance of cement mortar",in: Key Eng. Mater., 2010.

[15]. https://doi.org/10.4028/www.scientific.net/KEM.426-427.93.

[16]. Z.Y. Jin, S. Gao, B.R. Hou, T.J. Zhao, J.Y. Jiang (2010) , "Mechanics and crack resistance capacity of basalt fiber reinforced concrete pavements" Journal of Southeast University (Natural Science Edition), 40 (2010), pp. 160-164

[17]. H. Pan (2009), "Experimental study on mechanical property of basalt fiber reinforced concrete" Bulletin of Chinese Ceramic Society, 28 (5) (2009), pp. 955-958

[18]. J. Sim, C. Park, D.Y. Moon (2005) "Characteristics of basalt fiber as a strengthening material for concrete structures" Compos. B Eng., 36 (6-7) (2005), pp. 504-512