EXPERIMENTAL ANALYSIS ON STRENGTH CHARACTERISTICS OF BASALT FIBER CONCRETE

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Abstract:- **The basalt fiber (BF) is made from basalt via the wire drawing technique. BF has the advantages of low price, good tensile strength, thermal stability, high elastic modulus, high heat insulation, etc. Especially, the production process of BF is harmless to health and environment. At present, BF is being promoted actively in many fields such as aeronautics, architecture, automo- tive industry and electronics industry. BF has excellent mechanical properties compared with other natural fibers. However, the research about the effect of BF on the mechanical properties of concrete is inconsistent. Some schol- ars considered that BF can significantly improve the toughness, bending strength and deformation resistance of concrete. While some scholars pointed out that the addition of BF reduced the mechanical properties of concrete. In general, fibers are used in concrete to improve its structural integrity. Now days, among all fibers, Basalt fiber is gaining more importance due to its exceptional properties which include resistance to corrosion and low thermal conductivity. It also improves tensile strength, flexural strength and toughness of concrete. It can be used to extend the life of important concrete structures such as nuclear power plants, highways and bridges. The variable factors considered, in this study were M30 grade of concrete cubes, cylinders and beams are prepared by using cubes of size (150 x 150 x 150) mm. Cylinders of size 150 mm (dia) x 300 mm (depth) and beams of size (500 x 100 x100) mm that were casted and cured in portable water for a period of 28 days. The specimens were then tested for split tensile strength, flexural strength and compression strength of the conventional concrete without using Basalt fiber and concrete with using Basalt fiber material at 7,14,28 days.**

Keywords: Concrete, Basalt fiber, Compressive strength, flexural strength, Split tensile strength.

1. Introduction:

Concrete is a composite material consists of mainly water, coarse aggregate, fine aggregates and cement. The physical properties desired for the finished material can be attained by adding additives and reinforcements to the concrete mixture. A solid mass that can be easily molded into desired shape can be formed by mixing these ingredients in certain proportions. Over the time, a hard matrix formed by cement binds the rest of the ingredients together into a single hard (rigid) durable material with many uses such as buildings, pavements etc., The technology of using concrete was adopted earlier on large-scale by the ancient Romans, and the major part of concrete technology was highly used in the Roman Empire. The colosseum in Rome was built largely of concrete and the dome of the pantheon is the World’s largest unreinforced concrete structure. After the collapse of Roman Empire in the mid-18th century, the technology was re-pioneered as the usage of concrete has become rare. Today, the widely used man made material is concrete in terms of tonnage.

1.1 USING FIBERS AS CONCRETE ADMIXTURES

Admixtures are the materials other than cement, aggregate and water that are added to concrete either before or during its mixing to alter its properties such as workability, curing temperature range, set time or color. Addition of fiber to concrete 2makes it tough and fatigue resistant such type of admixture is used extensively in important engineering projects. Addition of fiber to concrete is a convenient and practical method of improving several properties of the materials for example toughness, impact resistance and flexural strength. It also assists in changing the flow characteristics of the material. The use of new materials and modern techniques is important in construction activities. Proper use of different kinds of materials and the latest technology becomes imperative to improve quality and cut costs. The life and durability of structure also increases.

1.2 BASALT FIBER CONCRETE

Chopped basalt fiber is relatively new in the market, which are recently used in several studies as micro reinforcements for the concrete. The first use of the basalt fibers was reported in the year 1998 in a report published in USA for the highway Innovations Deserving Exploratory Analysis (IDEA) project. It is noted that the basalt fibers easily dispersed within the concrete mix without causing segregation and the fibers lose their shape due to the flexible structure. Basalt fiber is a high strength fiber with high elastic modulus, high thermal stability, chemical stability, good sound insulation, and electrical characteristics.
To date, the maximum fiber volume used to investigate the mechanical properties is 0.5%. this volume percentage is categorized as “low volume fraction (<1%)” which is usually used to reduce shrinkage cracking of the structural members such as slabs and pavements, due to large exposed surface. For the structural application, higher volume fraction that is greater than 2% is recommended to obtain strain hardening behavior of the concrete. The use of 1 to 2% of fiber volume may be beneficial in structural application where there is a requirement of high energy absorption

capability, improved resistance against delamination, spalling and fatigue, modulus of rupture, impact resistance and the fracture toughness of the concrete.

2. PROPERTIES OF BASALT FIBER

1.1.1 Physical Properties

- Color: It is available in golden brown in color.
- Diameter: It is available in different diameter like 5.8 micron.
- Length: Available in 6mm,8mm,12mm etc.
- Density: density of basalt fiber is 2.75 g/cm^3
- Coefficient of friction: The coefficient of friction may be between 0.42 to 0.50.

1.1.2 Chemical Properties

- Basalts are more stable in strong alkalis.
- Weight loss in boiling water, Alkali and acid is also significantly lower.
- Basalt fibers have very good resistance against alkaline environment, with the capability to withstand pH up to 13-14. It also has good acid and salt resistance

3. ENVIRONMENTAL BENEFITS OF BASALT FIBER

The basalt fibers do not contain any other additives in a single producing process, which gives additional advantage in cost. Basalt rock fibers have no toxic reaction with air or water, are noncombustible and explosion proof. When in contact with other chemicals they produce no chemical reaction that may damage health or the environment. So, Basalt fiber is known as green industrial material. Basalt fiber has good hardness and thermal properties.

4. BASALT FIBER

Basalt fiber is known as green industrial material which is colloquially known as the “21st- century nonpolluting green material”. Basalt is a natural material that is found in volcanic rocks originated from frozen lava, with a melting temperature comprised between 1500^{0}C and 1700^{0}C. Basalt fibers are 100% natural and inert. They have been tested and proven to be noncarcinogenic and nontoxic. Basalt fiber can be classified as a sustainable material because basalt fibers are made of natural material and during its production no chemical additives as well as any solvents, pigments or other hazardous materials are added. Specific gravity of basalt fiber is 2.7.

Fig.1 Basalt fiber sample

Chemical components	Basalt weight %
SiO_2 (silica)	57.5
Al_2O_3 (alumina)	16.9
Fe_2O_3 (ferric oxide)	9.5
CaO	7.8
MgO	3.7
Na_2O	2.5

Table 1: chemical composition of Basalt fiber

5. CONCRETE MIX DESIGN (AS PER IS:10262-2019)

5.1 MIX DESIGN FOR M30 GRADE CONCRETE:

[According to investigations done on FA, CA, cement]

5.2 DESIGN STIPULATIONS DATA:

1.	Grade designation	:	M30
2.	Type of cement	:	OPC 53 grade
3.	Maximum nominal size of aggregate	:	20 mm
4.	Minimum cement content	:	320 kg/m^3
5.	Maximum water-cement ratio	:	0.45
6.	Degree of supervision	:	Good
7.	Type of aggregate	:	Crushed angular
8.	Exposure condition	:	Severe

5.3 TEST DATA FOR MATERIALS:

1. Type of cement	:	OPC 53 grade conforming to IS:
2. Specific gravity of cement	:	3.18
3. Specific gravity of		
a) Fine aggregates	:	2.63
b) Coarse aggregates	:	2.77
4. Water absorption of		
a) Fine aggregates	:	1%
b) Coarse aggregates	:	0.15%

5.4 TARGET MEAN STRENGTH:

[According to IS 10262-2019, clause 4.2]

$$f^{l}ck=fck+1.65(S.D)$$

$$f^{l}ck=30+1.65(5)$$

[here S.D is standard deviation from table 2, clause 4.2.1.3]

$$f^{l}ck=38.25\ N/mm^2$$

5.5 SELECTION OF WATER CEMENT RATIO:

[According to IS 456-2000, table 10.26] (i)

W/C=0.45

(ii) W/C=0.45

W/C=0.45

5.6 SELECTION OF WATER CONTENT:

[According to IS 10262-2019, table 4, clause 5.3]

The required water content for 20 mm aggregates with 50 mm slump is 186 kg, also the required water content may be increased by about 3 percent for each increase of 25 mm slump.

By assuming 100 mm true slump,

Water content=186+(6 % of 186)

=197.16 kg

Adopting a water content of 197.16 kg.

5.7 CALCULATION OF CEMENT CONTENT:

We have, W/C=0.45

Cement content=197.16/0.45

=438.13 kg

From IS 456-2000, the minimum cement content is 320 kg for severe exposure. Hence, ok.

ESTIMATION OF COARSE AGGREGATE PROPORTION:

[According to IS 10262-2019, table 5, clause 5.5] Vol proportions of CA= 0.62
Entrapped air= 1%
= 0.01
Vol proportion of CA= 0.62-0.01
= 0.61
We have, vol proportion of CA+ vol proportion of FA= 1
Vol proportion of FA= 1-0.61
= 0.39

MIX CALCULATIONS:

(a) Total volume = 1 m^3
(b) vol of cement = (mass of cement/ specific gravity of cement) * (1/1000)
= (438.13/3.18) * (1/1000)
= 0.137 m^3
(c) vol of water = (mass of cement/ specific gravity of cement) * (1/1000)
= (197.16/1) * (1/1000)
=0.197 m^3
(d) vol of all in aggregates = [a- (b+ c)]
= [1- (0.137+ 0.197)] = 0.666 m^3
(e) mass of CA = 0.666 * (vol of CA) * (specific gravity of CA) * 1000
= 0.666 * 0.61 * 2.77 * 1000

=1125.34 kg
(f) mass of FA = 0.666 * (vol of FA) * (specific gravity of FA) * 1000
= 0.666 * 0.39 * 2.63 * 1000

= 683.1162 kg

FINAL MIXPROPORTIONS:

C	:	FA	:	CA	:	W
438.13	:	683.11	:	1125.34	:	197.16
1	:	1.56	:	2.56	:	0.45

MIX PROPORTIONS:

For 0.1%, 0.2%, 0.3%, 0.4% of Basalt fiber

C	:	FA	:	CA	:	W
438.13	:	682.09	:	1123.65	:	197.16
1	:	1.57	:	2.57	:	0.45

6. Experimentation:

6.1 WORKABILITY:

The property of fresh concrete, which is indicated by the amount of useful internal work, required to fully compact the concrete without bleeding or segregation in the finished product. Workability is one of the physical parameters of concrete, which affects the strength and durability, as well as the cost of labor and appearance of the finished product. Concrete is said to be workable when it is easily placed and compacted homogeneously i.e. without bleeding or Segregation. Unworkable concrete needs more work or effort to be compacted in place, also honeycombs &/or pockets may also be visible in finished concrete.

6.2 DIFFERENT TEST METHODS FOR WORKABILITY MEASUREMENT:

Depending upon the water cement ratio in the concrete mix, the workability may be determined by the following

Three methods.

1. Slump Test
2. Compaction Factor Test
3. Vee-bee consistometer test

SLUMP CONE TEST: The test was conducted for fresh concrete prepared before the moulding process. A total of 4 concrete mixes are prepared at different times. Workability Results obtained from slump cone test for M30 grade of concrete is shown in below table.

S. No	Basalt fiber %	Workability(mm)
		Slump value
1	0	100
2	0.1	92
3	0.2	85
4	0.3	74
5	0.4	65

Table-2: Test results from slump cone test for workability in mm

The workability from the slump cone test is in increasing manner as the mix proportion increasing. The workability range of concrete increasing as mentioned while being inmedium range overall.

6.3 COMPRESSIVE STRENGTH TEST:

A total of 45 cubes of size 150 x 150 x 150mm were casted and tested for 7 days, 14 days and 28 days after conducting the workability tests. The results are tabulated below:

S. No	Basalt fiber %	Compressive strength of M30 grade in N/mm^2		
		7 days	14 days	28 days
1	0	25.02	31.2	35.24
2	0.1	26.24	32.4	37.2
3	0.2	27.43	32.92	37.9
4	0.3	27.92	33.08	38.42
5	0.4	27.78	32.89	37.78

Table-3: Compressive strength results of M30 grade of concrete for 7, 24 and 28 days

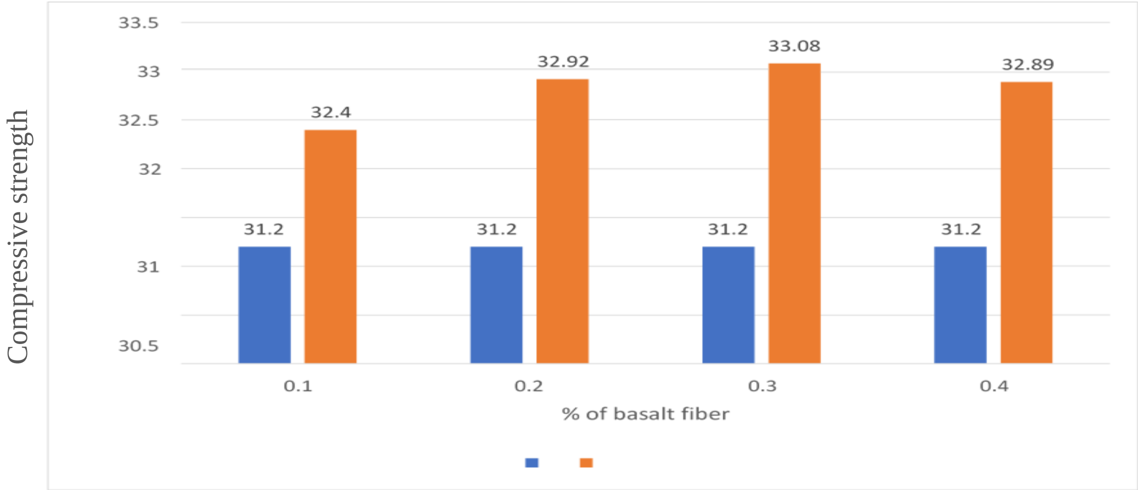

Figure 2: Comparison of Compressive strength of M30 at 14 days

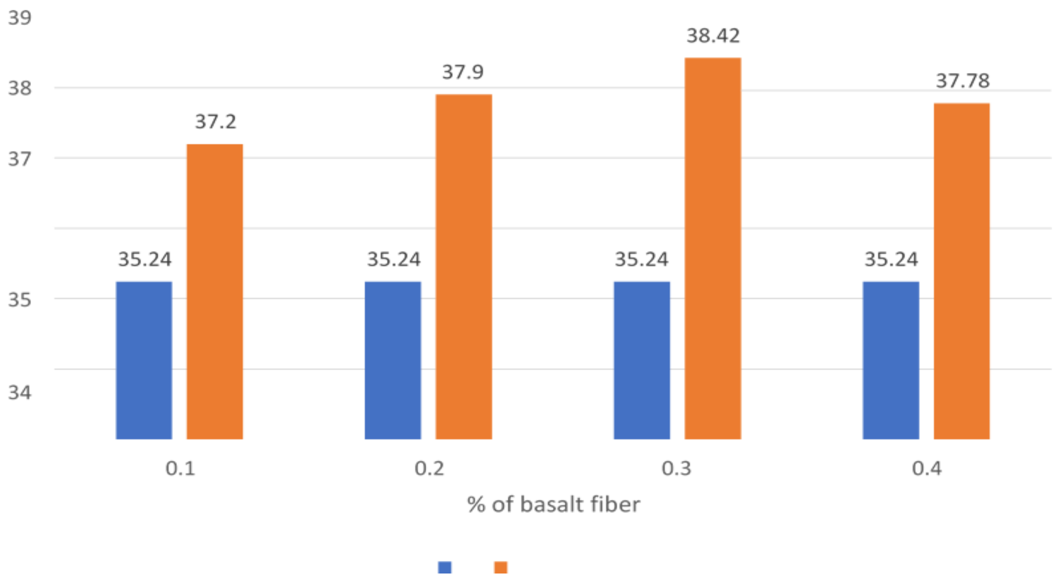

Figure 3: Comparison of Compressive strength of M30 at 28 days

The results obtained from compression testing gives comprehensive outcome of the project as the addition of basalt fiber produces a concrete with suitable properties as conventional.

6.4 SPLIT TENSILE STRENGTH TEST:

A total of 30 cylinders of size 300 x 150 mm were casted and tested for 7 days, 14 days and 28 days after conducting the workability tests. The results are tabulated below:

S. No	Basalt fiber %	Split Tensile Strength of M30 grade in N/mm^2		
		7 days	14 days	28 days
1	0	2.54	3.19	4.2
2	0.1	2.72	3.34	4.31
3	0.2	2.94	3.91	4.45
4	0.3	3.052	4.02	4,71
5	0.4	3.013	3.92	4.68

Table 4: Split tensile strength results for M30 grade of concrete

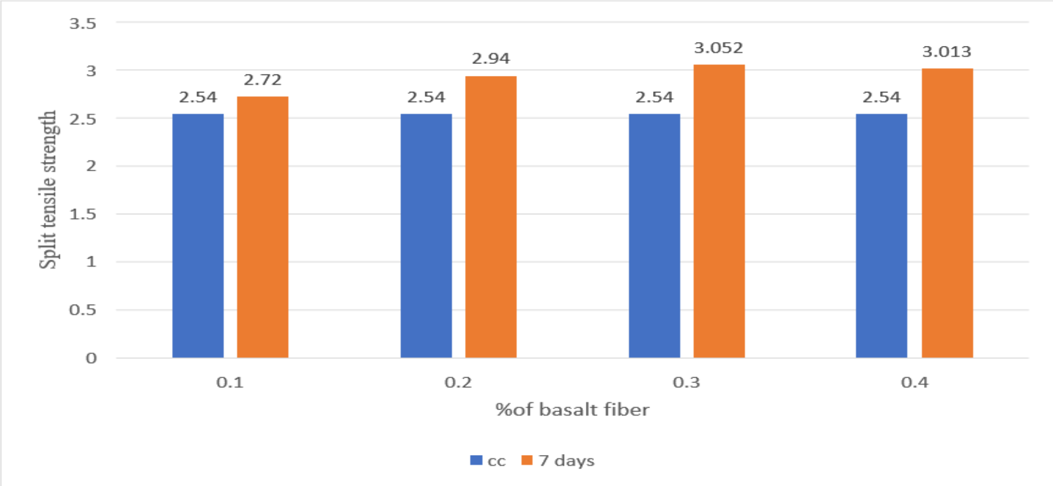

Figure 4: Comparison of Split tensile strength of M30 at 7days

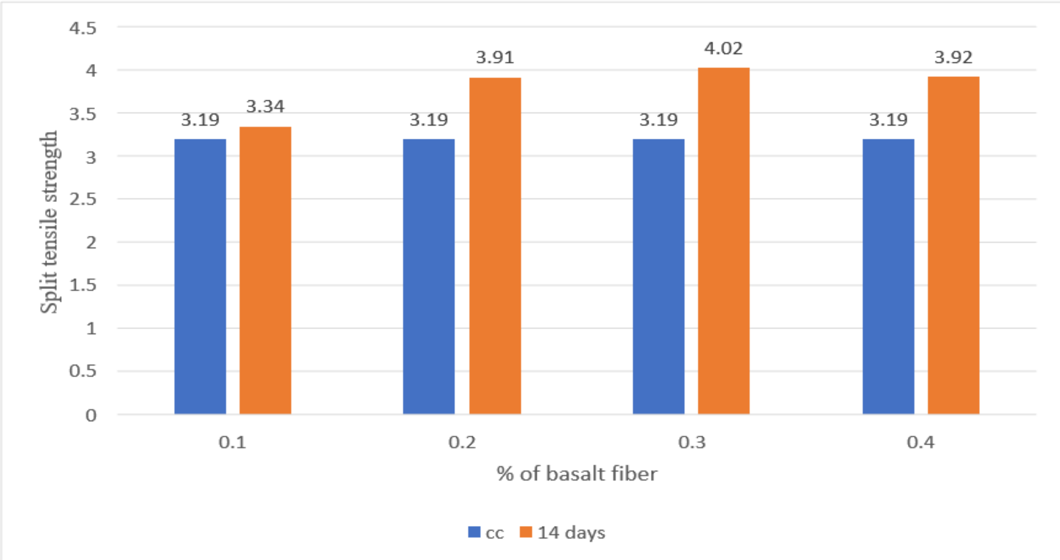

Figure 5: Comparison of Split tensile strength of M30 at 14days

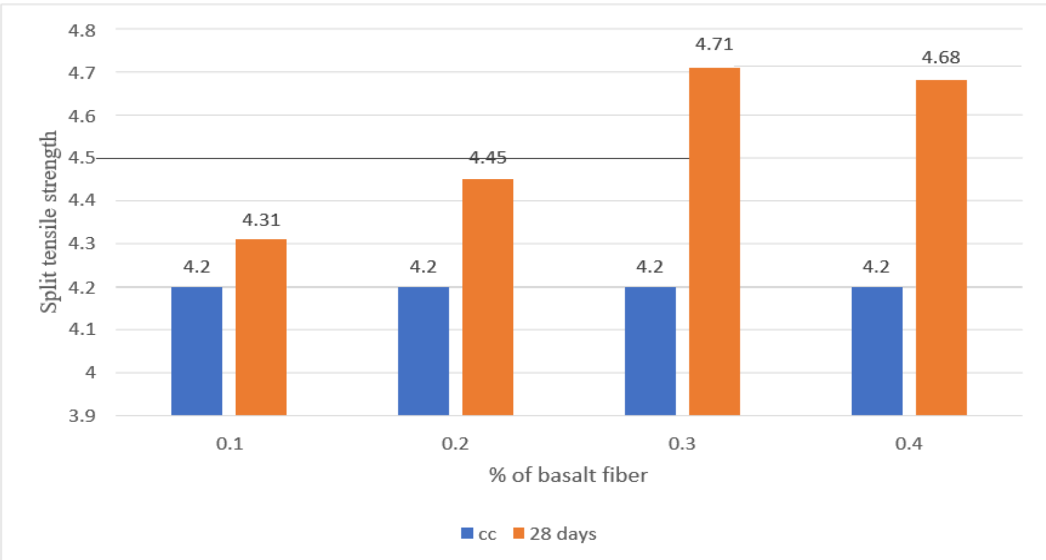

Figure 6: Comparison of Split tensile strength of M30 at 28days

The strength i.e., the tensile strength, from the results is clearly in an increment way compared to the conventional concrete at all the curing ages of 7days, 14 days and 28 days. The addition of basalt fiber by various proportions has positive effect on the strength of the concrete.

6.5 FLEXURAL STRENGTH TEST:

A total of 15 beams of size 500 x 100 mm were casted and tested for 7 days, 14 days and 28 days after conducting the workability tests. The results are tabulated below:

S. No	Basalt fiber %	Flexural Strength of M30 grade in N/mm^2		
		7 days	14 days	28 days
1	0	5.64	6.94	8.36
2	0.1	6.12	7.281	9.34
3	0.2	6.541	7.892	10.3242
4	0.3	6.9125	8.12	11.42
5	0.4	6.8012	8.052	10.95

Table 5: flexural strength results for M30 grade of concrete

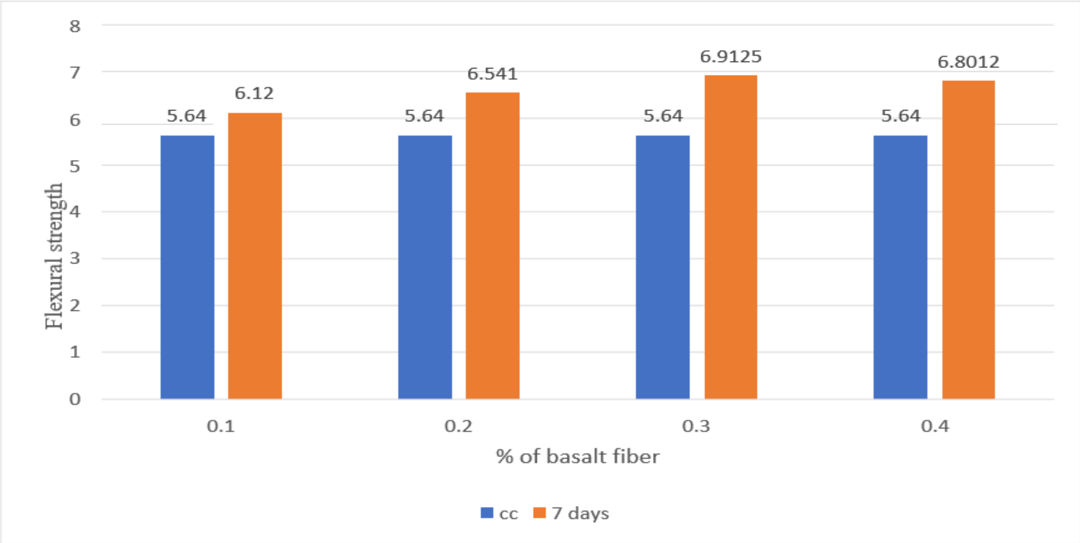

Figure 7: Comparison of flexural strength of M30 concrete at 7days

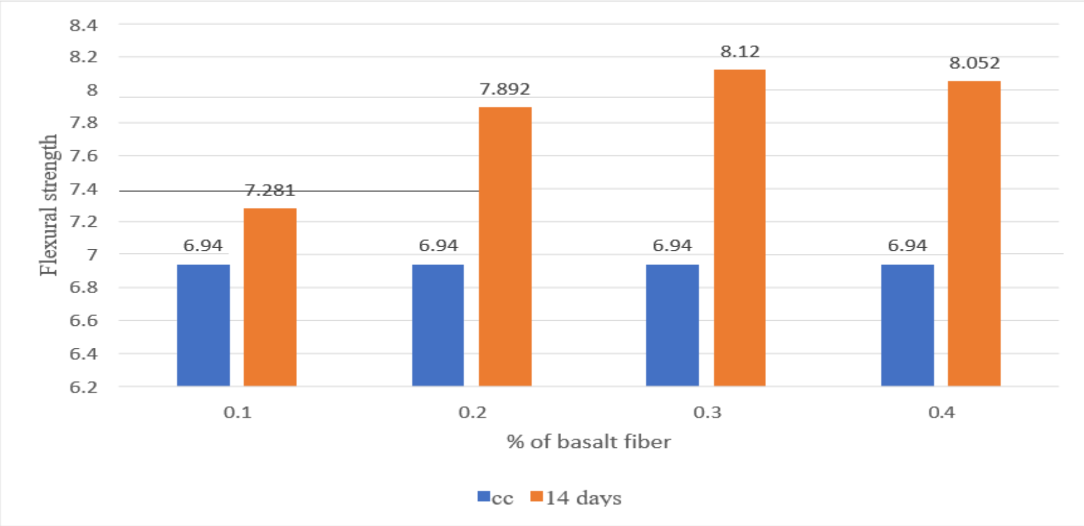

Figure 8: Comparison of flexural strength of M30 concrete at 14days

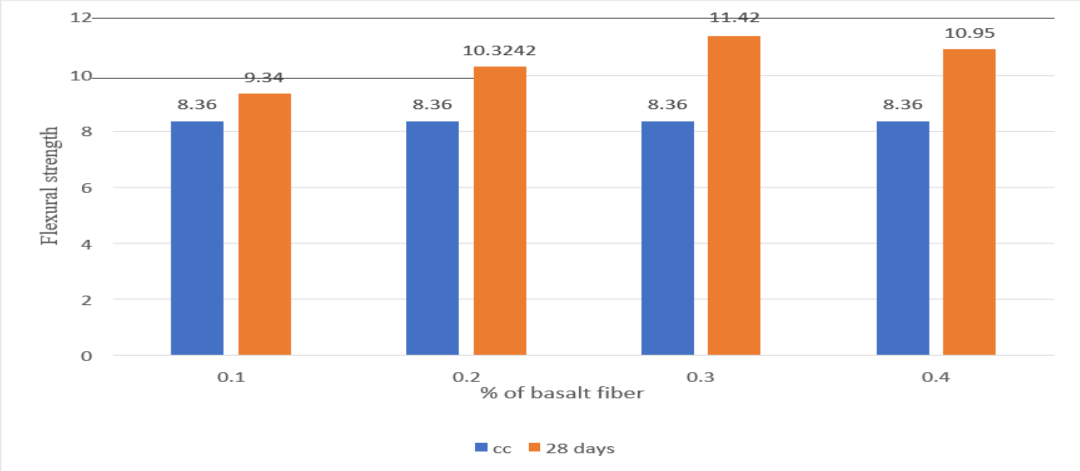

Figure 9: Comparison of flexural strength of M30 concrete at 28days

The strength i.e., the flexural strength, from the results is clearly in an increment way compared to the conventional concrete at all the curing ages of 7days, 14 days and 28 days. The addition of basalt fiber by various proportions has positive effect on the strength of the concrete.

7. Results & Discussions:

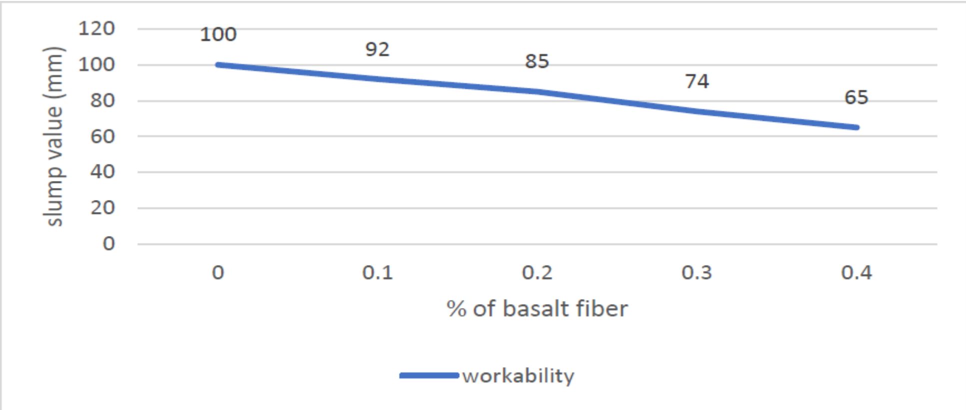

Figure 10: Comparison of workability for different mixes of M30 Grade

From the results it is observed that the workability is decreases with an increase of basalt fiber content over conventional M30 concrete grade

7.1 Compressive strength

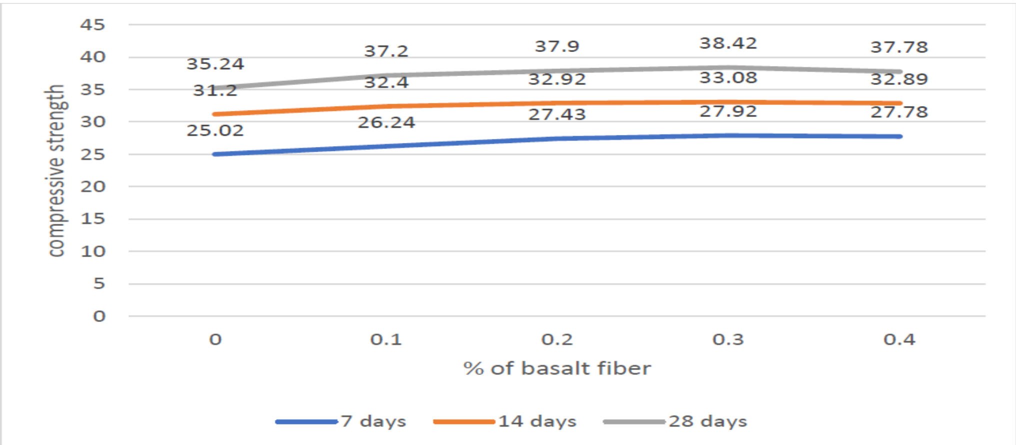

Figure 11: Graph of Compressive Strength comparison at 7, 14 and 28 days for M30 concrete

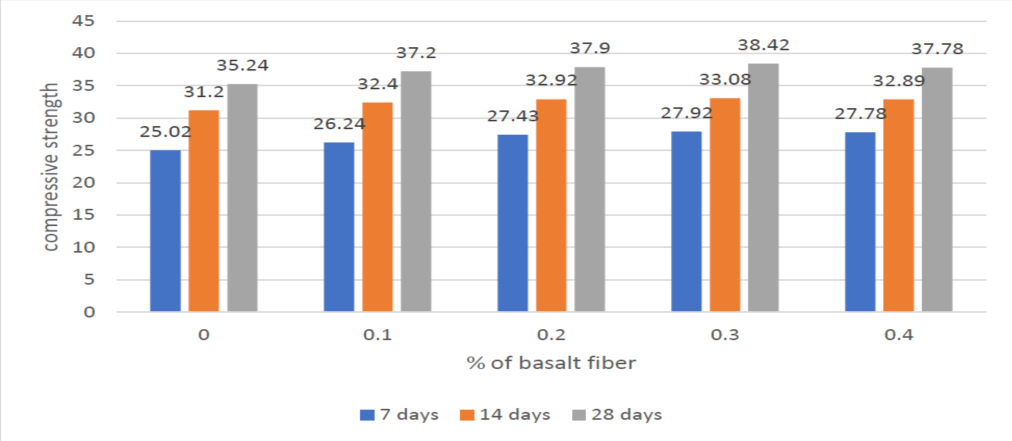

Figure 12: Compressive Strength comparison at 7, 14 and 28 days for M30 concrete

- The Compressive strength of concrete varies as 4.8%, 9.6%, 11.5%,11.1%for M1, M2, M3 and M4 compared with the conventional concrete after 7days of curing.
- The Compressive strength of concrete varies as 3.8%, 5.5%, 6.1%, 5.4% for M1, M2, M3 and M4 compared with the conventional concrete after 14days of curing.
- The Compressive strength of concrete varies as 5.6%, 7.6% ,9.1%,7.2% For M1, M2, M3 and M4 compared with the conventional concrete after 28days of curing.

7.2 Split tensile strength:

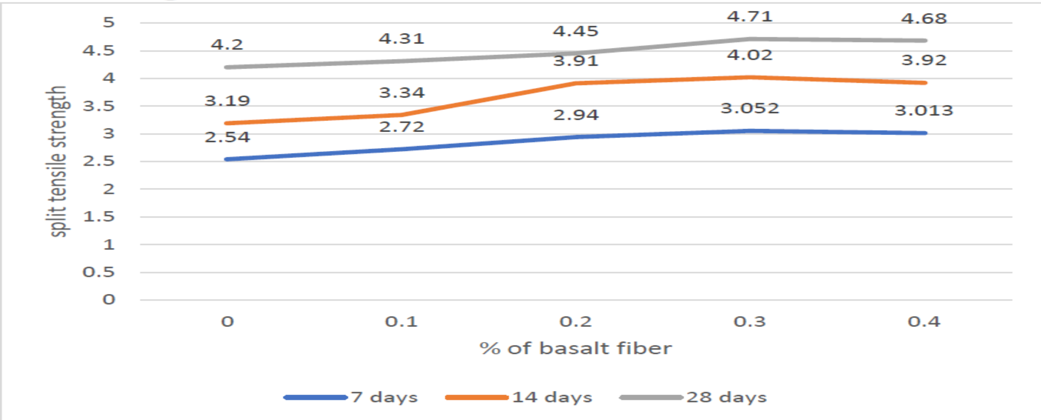

Figure 13: Graph of split tensile Strength comparison at 7, 14 and 28 days for M30 concrete

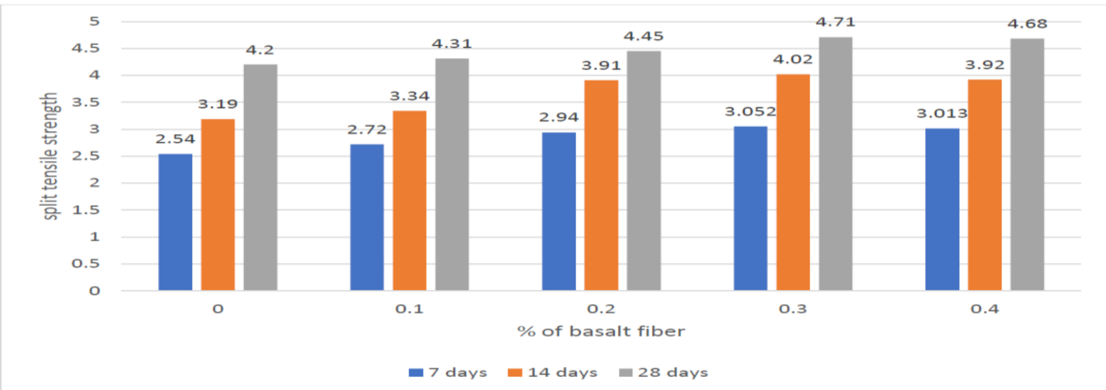

Figure 14: Split tensile Strength comparison at 7, 14 and 28 days for M30 concrete

- The split tensile strength of concrete varies as 7.1%, 15.7%, 20.2%, 18.6% for M1, M2, M3 and M4 compared with the conventional concrete after 7days of curing.

- The split tensile strength of concrete varies as 4.7%, 22.6%, 26.1%, 22.9% for M1, M2, M3 and M4 compared with the conventional concrete after 14days of curing.

- The split tensile strength of concrete varies as 2.6%, 5.9%, 12.1%, 11.4% for M1, M2, M3 and M4 compared with the conventional concrete after 28days of curing

7.3 Flexural strength:

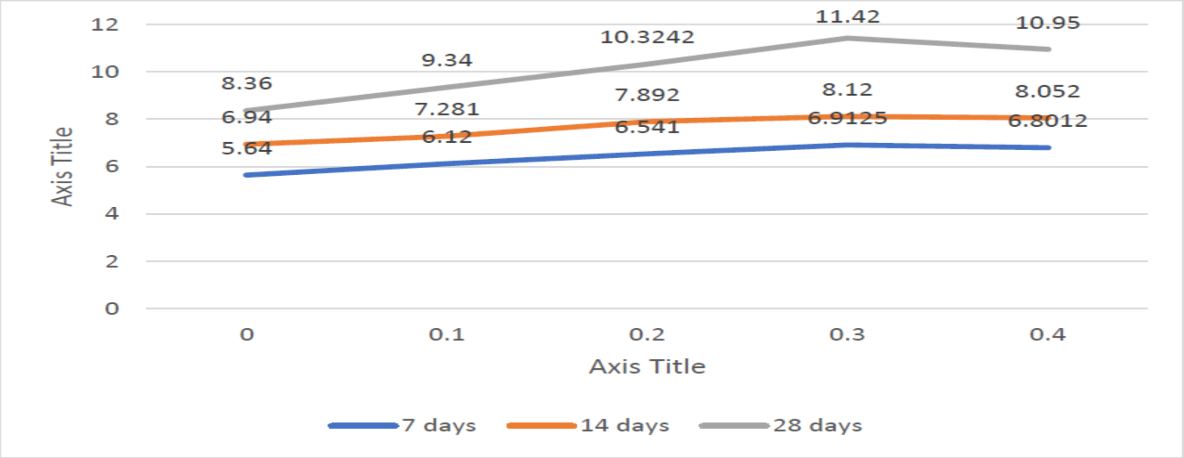

Figure 15: Graph of flexural Strength comparison at 7, 14 and 28 days for M30 concrete

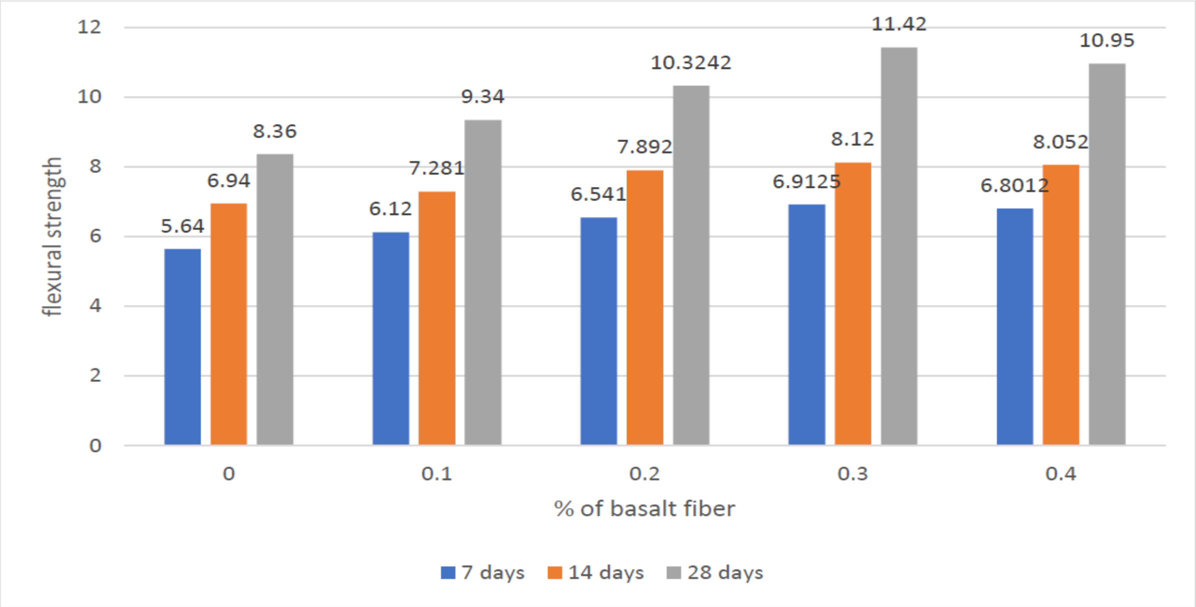

Figure 16: Flexural Strength comparison at 7, 14 and 28 days for M30 concrete

- The split tensile strength of concrete varies as 8.5%, 15.9%, 22.6%, 20.6% for M1, M2, M3 and M4 compared with the conventional concrete after 7days of curing.

- The split tensile strength of concrete varies as 4.9%, 13.7%, 17%, 16% for M1, M2, M3 and M4 compared with the conventional concrete after 14days of curing.

- The split tensile strength of concrete varies as 11.7%, 23.5%, 36.6%, 31% for M1, M2, M3 and M4 compared with the conventional concrete after 28days of curing.

8. CONCLUSION:

Basalt fiber concrete increases the compressive strength, flexural strength and tensile strength as compared with the conventional concrete. As the percentage of the basalt fiber in concrete increases workability of concrete decreases. From strength point of view, conventional concrete by using basalt fiber shows the positive results. 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 basalt fiber concrete. Basalt fiber increases the mechanical properties of concrete. Basalt fibre was found to be amorphous in nature. It is possible to use basalt fiber in the field of reinforced cement and concrete. The addition of basalt fiber had a greater compressive and flexural strength at early stages.

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