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Usage of Chopped Basalt Fibers in Concrete Composites: A Review

Dharmendra Sondarva[1]
[1] PG Student,
Dept. of Civil Engineering,
Marwadi Education Foundation,
Rajkot, India

Ankur C. Bhogayata[2]
[2] Associate Professor & Head,
Civil Engineering Department,
Marwadi Education Foundation,
Rajkot, India

Abstract: **This paper represents the outcomes of some latest trends of research in the field of concrete composites prepared with chopped basalt fibers (CBF) as fillers. The paper summarizes noticeable findings of the experimental studies carried out to demonstrate the advantages and limitations of the addition of CBF in a conventional concrete specifically. The review inspired to conclude that the effect of addition of chopped basalt fibers has been studied by performing tests for the workability of fresh mixes, compressive strength, splitting tensile strength and flexure strength with varying fractions and sizes of CBF. It was noticed that the workability reduced with addition of CBF and the strength properties showed an increment due to the CBF addition. However, lacking the explicit knowledge on the optimum dosage and preferred aspect ratio of CBF from the durability perspectives requires attention. Moreover, a compound usage of CBF with prevailing additives namely polymers, fly ash, silica fumes may be one of the potential areas for the researchers. Therefore, a need of extensive experimental study can be proposed dedicated to a full length experimental program for durability studies on concrete containing CBF can be proposed. The research outcomes indicated that addition of CBF into the concrete may prove advantageous to overcome the durability issues of concrete.**

Keywords: Chopped basalt fiber, Concrete, Workability, Compressive strength, Splitting tensile strength, Flexure strength, Fracture energy, Elastic modulus of concrete.

I. INTRODUCTION:

Concrete is a composite material with a low tensile strength and strain capacity [1–2]. An addition of fiber into the concrete mix can significantly improve the engineering properties of the concrete such as the flexural, tensile, impact and abrasion strength [3-4]. Many natural and synthetic fibers are utilized in concrete obtained from glass, carbon, aramid, polypropylene, and basalt rock. In the past decade, basalt fiber has shown great potential towards its utilization in concrete as a supplementary construction material. [5-6].

A. Historical, Manufacturing and General Properties:

Basalt is naturally obtainable rock acquired from frozen lava, with melting temperature ranging from 1500˚C to 1700˚C [7- 8]. The fiber is developed by the Moscow Research Institute of Glass and Plastic in 1953-1954 and its first industrial production was completed in 1985 at Ukraine Fiber laboratory [9-10].

The manufacturing process of basalt fiber is similar to that of glass fiber, but consumes less energy making them cheaper than the carbon or glass fibers. Basalt fiber is produced by heating a natural volcanic basalt rock in a furnace at 1450(C to 1500(C. In order to generate basalt fibers, molten material needs to pass through a platinum and rhodium crucible bushing to create fibers. This technology is known as continuous spinning. It can offer reinforcing material in the form of continues or chopped fibers [11]. Basalt fiber can provide resistance against corrosion, thermal and alkali reaction on the concrete, making it beneficial to be utilized with the construction materials. The fibers are found to be non hazardous to human health [12].

Physical and chemical compositions of chopped basalt fiber are shown in Table-1 and Table-2.

B. Basalt Fiber

TABLE-1 CHEMICAL COMPOSITION OF CHOPPED BASALT FIBER[13].

Chemical compound	Weight in % of basalt fiber
SiO_2	51.6-59.3
Al_2O_3	14.6-18.3
CaO	5.9-9.4
MgO	3-5.3
$FeO+Fe_2O_3$	9-14
TiO3	0.8-2.25
Na_2O+K_2O	0.8-2.25

TABLE-2 PHYSICAL PROPERTIES OF CHOPPED BASALT FIBER[13].

Property	Value
Density	2.63-2.8 g/cm^3
Elastic modulus	90-110GPa
Tensile strength (MPa)	4100-4800
Elongation at break (%)	3.1–3.2

II. FRESH CONCRETE PROPERTIES:

Different authors declared the workability of fresh concrete decreases with the addition of the basalt fibers. Chaohua jiang and their fellows [14] observed influence for the workability of concrete containing basalt fiber with different aspect ratio(12mm and 22mm) and different proportion (0.05%,0.1%,0.3% and 0.5%) by total volume of concrete. The result showed that slump decrease with increasing the percentage volume of basalt fiber. Padmanabhan lyer and their fellows [15] conclude that slump of concrete containing basalt fiber fall down with increase the length and proportion of basalt fiber. In this experimental work they were used 12mm,36mm

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and 50mm different length basalt fiber with different dosage of 4,8 and 12kg/m^3.Nihat Kabay [16] investigated the properties of fresh concrete with different length 12mm and 24 mm basalt fiber with different dosage of 2 and 4kg/m^3. Mr. Navnath Raut and their fellows [17] examined that use of 18mm basalt fiber in proportion of (0.1,0.2,0.3,0.4,0.5%) gives a decrease in result of slump 13.68, 24.21, 40, 51.57, 55.78% respectively. Fatima Irine I. A [18] conclude that the decrease of slump value when basalt fiber added in concrete. In this experiment they use 1,2,4 kg/m3 of chopped basalt fiber gives slump value -10, -14.16, -19.16 respectively. The result indicated that the slump of concrete with basalt fiber lower as the fiber dosage increases. The main reason of reduction in workability of concrete containing basalt fiber is large amount and large surface area of fiber which control mixture from flow and segregation.

III. HARDENED CONCRETE PROPERTIES:

A. *Compressive strength:*

Several authors revealed that there is significant variation in compressive strength of concrete with use of fiber as ingredient. A. B. Kizilkanata and their fellows [19] investigated the strength and durability properties of concrete containing 12mm basalt fiber and different dosage (0.25%, 0.50%, 0.75% and 1.0%) by total volume of concrete. the result showed that highest compressive strength occurred at 0.5% dosage of basalt fiber. the increase in strength for BF specimen at 0.5% dosage is 5.1% compared to the reference specimen. Chaohua jiang and their fellows[14] examined mechanical properties of concrete containing basalt fiber with different length (12mm and 22mm) and different content (0.05%,0.1%,0.3% and 0.5%) by total volume. they observed that compressive strength of basalt fiber reinforced concrete (BFRC) increase up to 10% compared to normal concrete at 0.1% dosage of 22mm basalt fiber. Padmanabhan lyer and their fellows [15] investigated the comparative study of properties of hardened concrete containing different length (12mm, 36mm and 50mm) basalt fiber with different dosage of 4, 8 and 12kg/m^3. They conclude that the compressive strength of BFRC increase up to 10% compared to normal concrete at 12kg/m^{3}dosage of 50mm basalt fiber. Nihat Kabay [16] studied the influence of using different length (12mm and 24mm) and different content (2 and 4 kg/m^3) of basalt fiber on compressive strength of concrete. the result indicated that compressive strength decrease up to 8% and 18% at 2 and 4 kg/m^{3}dosage of basalt fiber. Mehmet Emin Arslan [20] examined the mechanical properties of concrete containing different dosage (0.5, 1, 2, 3kg/m^3) of basalt fiber with 24mm length. They found that maximum compressive strength occurred at 3kg/m^{3}dosage of basalt fiber. The increase in strength of BF specimen at 3kg/m^{3}dosage is 7% compared to the reference specimen. Variation in compressive strength is observed by several authors for their research work. Abhijeet B. Revade and their fellows [21] examined that adding basalt fiber of 12mm length of 2% to 1% will give increase compressive strength of 10 to 13%. Mr. Navnath Raut and their fellows [17] conclude that adding 18mm basalt fiber in concrete results increase in compressive strength. Fatima Irine I. A [18] conclude that adding basalt fiber of 1,2,4 kg/m3 gives an increase in compressive strength 3.10, 8.47, 13.55% respectively. F.U.A. Shaikh and their fellows [22] from their research conclude that adding 0.5% basalt fiber of 25.4mm length will result in a 10 % decrease in compressive strength. Maria Wlodarczyk and their fellows [23] conclude for basalt fiber of 43mm length and 8kg/m3 basalt fiber results in a 22 % decrease in compressive strength, while 10-12% addition of basalt fiber results in an increase of strength. Hai Cao [24] examined that use of basalt fiber of 12mm length and 1.5kg/m3 gives increase in 9.9% of the compressive strength of concrete. Wang Xinzhong and their fellows [25] studied from their research by adding basalt fiber of 12mm and 24mm conclude that compressive strength is more increased in 12mm than 24mm. Er. M.A Faseela Nasar and their fellows [26] added basalt fiber of 12mm length in HFRC will increase the length. Chaohua Jiang and their fellows [14] conclude that adding basalt fiber of 12mm length will give increase in compressive strength up to 4.68%, while basalt fiber of 22mm will increase in compressive strength up to 5.72%. Tehmina Ayub and their fellows [27] conclude that adding of basalt fiber in HSC 25mm length gives an increase of 5 to 9% compressive strength. Tehmina Ayub and their fellows [28] done research by adding basalt fiber of 25mm by 1% will increase in the compressive strength of plain concrete while for the same for silica fume and metakaolin will increase the compressive strength. Paul Archbold and their fellows [29] adding basalt fiber of 12.7mm length from 0.1 to 0.7% will give max compressive strength at 0.3%. Hasan Katkhuda and their fellows [30] conclude that increase in compressive strength while adding basalt fiber of 18mm length in concrete, but while replacing aggregate with recycled & treated recycled concrete aggregate it gives an increase in compressive strength when adding 0.5 & 1%, while decreases when adding basalt fiber 0.1 & 1.5%. Shruti Jalasutram and their fellows [31] examined that 12.7mm length and 0.5,1,1.5,2% of basalt fiber added in concrete it gives decrease in compressive strength 0, 2.6, 2.08, 2.86% respectively. Wang Jun and their fellows [32] added 0.1 & 0.15% and 30mm length basalt fiber gives an increase in compressive strength of 11.33 & 6.07%, respectively, while 0.2, 0.25, 0.3, 0.35% added basalt fiber deceases compressive strength of 2.22, 5.26, 10.72, 8.09% respectively. Abhijeet B. Revade and their fellows [33] added 0.5, 1.0, 1.5% basalt fiber of 12mm length results increase in compressive strength 13.27, 11.15, 7.06% respectively. Anil Ronald and their fellows [34] conclude that using basalt fiber in geopolymer will increase the compressive strength up to 67.88%. S. Sai Charan and their fellows [35] gives a result of replacing of cement with GGBS it decreases in compressive strength while added 1, 1.5, 2, 2.5% of basalt fiber of 20-60mm length.

B. *Splitting tensile strength:*

Several researchers revealed that there is significant improvement in tensile strength of concrete with addition of fiber because fiber reduces the cracks propagation. A. B. Kizilkanata and their fellows [5] examined mechanical properties of concrete containing 12mm basalt fiber and different content (0.25%, 0.50% , 0.75% and 1.0%) by total volume. they observed that tensile strength of BFRC increase up to 40% compared to normal concrete at 1% dosage of basalt fiber. Chaohua jiang and their fellows [14] investigated the strength and durability properties of concrete containing basalt fiber with different length (12mm and 22mm) and different content (0.05%, 0.1%, 0.3% and 0.5%) by total volume. The

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result showed that highest tensile strength occurred at 0.5% dosage of basalt fiber. the increase in strength for BF specimen at 0.5% dosage is 24% compared to the reference specimen. Mehmet Emin Arslan [20] investigated the comparative study of properties of hardened concrete containing different length (12mm and 24mm) basalt fiber with different dosage (0.5, 1, 2, 3 kg/m^3). They conclude that the tensile strength of BFRC increase up to 10% compared to normal concrete at 2 kg/m^3dosage of 24mm basalt fiber and decrease at 3 kg/m^3 dosage of 24mm basalt fiber. Abhijeet B. Revade and their fellows [21] determine that adding of 12mm basalt fiber in concrete will increase in tensile strength up to 20%. Mr. Navnath Raut and their fellows [17] examined that adding 0.2% basalt fiber of 18mm length gives increase 8.08% of tensile strength. Fatima Irine I. A [18] achieve 61.77% tensile strength by adding 4% of basalt fiber in concrete. Maria Wlodarczyk and their fellows [23] concluded that there will be no change in tensile strength when added 8 & 12% basalt fiber of 43mm in concrete. Hai Cao [24] researched that by adding basalt fiber 0.5 to 2.5% in order of 0.5% increase all time it will result in an increase in tensile strength. Wang Xinzhong and their fellows [25] derived that use of 12mm and 24mm basalt fiber in concrete increases tensile strength 13% and 15% respectively. Chaohua Jiang and their fellows [14] conclude that there will be no major changes in tensile strength while added 12 & 22mm of basalt fiber in concrete. Tehmina Ayub and their fellows [27] observed that adding 2% basalt fiber of 25mm length will decrease 3.74% tensile strength of concrete. Tehmina Ayub and their fellows [28] perceived that adding basalt fiber of 25mm length in plain, silica fume and metakaolin concrete, it will result increase in maximum tensile strength 16, 54, 39% respectively. Hasan Katkhuda and their fellows [30] examined that adding of 18mm basalt fiber in plain concrete will increase in tensile strength while same will decrease in recycled and treated recycled concrete aggregate when added 0.1% basalt fiber. Shruti Jalasutram and their fellows [31] determine that adding 0.5 & 1% basalt fiber of 12.7mm length will give min and max tensile strength of 3.4 & 13.7% respectively. Wang Jun and their fellows [32] researched that adding 0.2% of 30mm length basalt fiber will decrease in tensile strength of 2.5%, but for same length 3% of basalt fiber will give an increase in tensile strength of 22.5%. Abhijeet B. Revade and their fellows [33] resulting that adding 12mm basalt fiber 1, 1.5, 2% will increase in tensile strength of concrete by 11, 17, 20% respectively. S. Sai Charan and their fellows [35] concluded that adding about 20-60mm basalt fiber in concrete, which is partially replaced with GGBS will increase in tensile strength by 69% max in plain concrete and 50% marks in GGBS concrete.

C. Flexural strength:

The capability of concrete beam to with stand against frailer in bending which measures by flexural test. Three-point loading and four-point loading are generally utilized in the flexural tests. A. B. Kizilkanata and their fellows [5] investigated the comparative study of properties of hardened concrete containing 12mm basalt fiber and different content (0.25%, 0.50% , 0.75% and 1.0%) by total volume. they conclude that the flexural strength of BFRC increase up to 34% compared to normal concrete at 1%dosage of basalt fiber. Chaohua jiang and their fellows[14] examined the mechanical properties of concrete containing basalt fiber with different length (12mm and 22mm) and different content (0.05%,0.1%,0.3% and 0.5%) by total volume. they found that maximum flexural strength occurred at 0.5%dosage of 22mm basalt fiber. the increase in flexural strength of BF specimen at 0.5% dosage is 21% compared to the reference specimen. Padmanabhan lyer and their fellows [15] investigated the strength and durability properties of concrete containing different length (12mm, 36mm and 50mm) basalt fiber with different dosage of 4, 8 and 12kg/m^3. The result indicated that flexural strength increase up to 22% at 8 kg/m^3dosage of 36mm basalt fiber. Nihat Kabay [16] studied the influence of using different length (12mm and 24mm) and different content (2 and 4 kg/m^3)of basalt fiber on compressive strength of concrete. they observed that flexural strength of BFRC increase up to 9% compared to normal concrete at 4kg/m^3dosage of 12mm basalt fiber Nasir Shafiq, Tehmina Ayub and Sadaqat Ullah Khan [13] examined the mechanical properties of concrete containing 25mm basalt fiber and different content (1%,2%, and 3%) by total volume. they conclude that the flexural strength of BFRC increase up to 23.02% compared to normal concrete at 3%dosage of basalt fiber. Mehmet Emin Arslan [20] investigated the strength and durability properties of concrete containing different dosage (0.5, 1, 2, 3kg/m^3) of 24mm basalt fiber. They conclude that the highest flexural strength occurred at 2kg/m^3dosage of 24mm basalt fiber and decrease at 3kg/m^3 dosage of 24mm basalt fiber. Mr. Navnath Raut and their fellows [17] discovered that the use of 0.1, 0.2, 0.3, 0.4, 0.5% basalt fiber of 18mm length will give an increase in flexural strength 22.40, 43.57, 57.10, 52.45, 49.72% respectively. Fatima Irine I. A [18] examined that 4kg/m3 of basalt fiber give a max increase in flexural strength of 53.84%. Hai Cao [24] conclude that adding 0.5, 1, 1.5, 2, 2.5% basalt fiber in concrete significantly increases the flexural strength of concrete. Wang Xinzhong and their fellows [25] derived that use of 12mm and 24mm basalt fiber in concrete at 0.1% of the total concrete volume will give max flexural strength. Chaohua Jiang and their fellows [14] conclude that adding 12mm and 22mm length basalt fiber in concrete will increase the flexural strength of concrete. Tehmina Ayub and their fellows [28] researched that using 25mm length and 1, 2, 3% basalt fiber in concrete will gives maximum flexural strength of 49.2% by adding 2% basalt fiber, while gives min 19.8% by adding 3% basalt fiber in concrete, but same in metakaolin concrete it will increase flexural strength up to 74.6% which is quite more than silica fume concrete with basalt fiber. Paul Archbold and their fellows [29] conclude that adding 0.3, 0.5, 0.7% basalt fiber of 12.7mm length will give increase flexural strength of 9.36% all the time. Hasan Katkhuda and their fellows [30] examined that adding of 18mm basalt fiber in plain concrete will increase in flexural strength while same will give max increase of flexural strength in recycled and treated recycled concrete aggregate by adding 1.5% basalt fiber. Shruti Jalasutram and their fellows [31] revealed that adding 12.7mm and 2% basalt fiber in concrete will increase max 75% of flexural strength of concrete. Wang Jun and their fellows [32] conclude that adding 30mm and 0.25% basalt fiber in concrete will give a min increase of 0.53% flexural strength. Abhijeet B. Revade and their fellows [33] derived that adding 12mm and 1, 1.5, 2% basalt fiber in concrete will increase in flexural strength of 11, 26, 35% respectively. Nasir Shafiq and their fellows [13]

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examined on silica fume concrete and metakaolin concrete by adding basalt fiber will give an increase in flexural strength. Anil Ronald and their fellows [34] conclude that using basalt fiber in geopolymer will increase flexural strength by 67.88%. S. Sai Charan and their fellows [35] concluded that by replacing of cement with GGBS it will increases the flexural strength of concrete.

D. Fracture energy:

A. B. Kizilkanata and their fellows [5] investigated the strength and durability properties of concrete containing 12mm basalt fiber and different dosage (0.25%, 0.50% , 0.75% and 1.0%) by total volume. the result showed that fracture energy increase with increasing the content of basalt fiber. the fracture energy of BFRC at 1% basalt fiber dosage 51% higher than normal concrete. Nihat Kabay[16] examined the mechanical properties of concrete containing basalt fiber with different length (12mm and 24mm) and different dosage (2 and 4 kg/m^3).the concluded that that the fracture energy of BFRC 126% higher than normal concrete 4kg/m^3dosage of 24mm basalt fiber. Mehmet Emin Arslan[20] investigated the comparative study of properties of hardened concrete different dosage(0.5, 1, 2, 3kg/m^3) of 24mm basalt fiber. the result indicated that the fracture energy of BFRC 35% higher than normal concrete at 1kg/m^3dosage of basalt fiber and the fracture energy of BFRC decrease at 2 and 3kg/m^3dosage of fiber.

E. Elastic modulus:

A. B. Kizilkanata and their fellows [5] investigated the strength and durability properties of concrete containing 12mm basalt fiber and different dosage (0.25%, 0.50% , 0.75% and 1.0%) by total volume of concrete. they found that the modulus of elasticity of BFRC slightly reduce with increasing the dosage of basalt fiber. Mehmet Emin Arslan [20] investigated the strength and durability properties of concrete containing different dosage (0.5, 1, 2, 3kg/m^3) of 24mm basalt fiber. The result showed that there is no significant of fiber content on modulus of elasticity of BFRC.

F. Abrasion resistance:

Nihat Kabay [16] examined the strength and durability properties of concrete containing basalt fiber with different length (12mm and 24mm) and different dosage (2 and 4 kg/m^3). The result showed that basalt fiber produced reduction between 2% to 4% in abrasive wear of concrete.

CONCLUSION

Based on the reviews, following concluding remarks are obtained

- The fresh properties of concrete are influenced by aspect ratio and fractions of basalt fibers. The slump decreases as the proportion of basalt fibers increases.
- The strength of concrete in compression reduces beyond 0.5% addition of basalt fibers.
- The preferred length of basalt fiber is observed to be in the range of 12mm to 22mm.
- Tensile resistance is noticeably improved due to the addition of basalt fibers in concrete. It is observed that longer the basalt fibers used in the mixture, the higher the tensile strength achieved.
- The review reflected that increasing the parameters namely an aspect ratio and the fractions of basalt fibers in concrete increases the flexural strength, fracture energy and abrasion resistance of concrete.
- However all authors noted that basalt fiber reinforced concrete has higher strength properties compare to the normal concrete But, Very few research work has been done on a durability aspect of concrete containing basalt fiber therefore generation experimental database may be one of the factors affecting the future research work.

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