"Analyzing Experimentally Concrete Reinforced with Basalt Fibers"

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ABSTRACT:

The ongoing search for new, improved, and more economical materials to produce new goods is very beneficial to the building industry. The manufacture of composite materials has increased noticeably in recent years. Energy efficiency, corrosion risk, and sustainability are important factors to take into account while developing new or modified goods. Basalt fiber (BF), which is made by melting basalt rock at a high temperature, is among the best-performing non-metallic fibers. Strength, excellent fire resistance, and low weight are some of the other characteristics of basalt fiber reinforced concrete (BFRC). In the future, the construction industry will greatly benefit from it. Basalt fiber is widely used in the building, residential, and transportation industries. Most research indicated that varying the amount of BF added to concrete enhanced both the mechanical properties in a positive and negative way. However, the researchers were unable to demonstrate improvements in properties like modulus of elasticity, flexural strength, tensile strength, toughness, early age cracking, compressive strength, etc., despite the fact that these properties are crucial for the desired quality of concrete. To address this, the use of an optimal percentage of BF in concrete will be suggested in conjunction with basalt rebar. In current work, varying percentages of chopped BF are added into M-30 grade concrete. The study plans to cast cubes in order to determine the ideal BF %. Concrete contains BF additions of 0.5%, 1, 1.5%, 2.5%, and 2.5% by volume at intervals of 0.5%. By adding the ideal percentage of BF, 6 cylinders and 12 beams will be cast again with basalt rebars. Compressive, flexural, and split tensile strength tests will be performed on FRC and basalt rebars in order to compare the experimental results. Tables and charts are used to display the results.

KEYWORDS: *Basalt Fiber, Reinforced Concrete, Compressive, Flexural Test, Split Tensile Strength*

1. INTRODUCTION

1.1General

Industry is always trying to find new, better and economical material to manufacture new product, which is very beneficial to the industry. In the recent days, the various fibers develop and used in the construction, industrial and highway engineering. The steel is mainly used in that various application. Also fiber glass polythene fibers, carbon fibers, polyamide fibers are now developed and also used in construction, industrial and infrastructure development. In that list new one fiber is added, called as basalt rock fibers. Today a significant growth is observed in the manufacture of composite material. With this in mind energy conservation, corrosion risk, the sustainability and environment are important when a product is changed or new product is manufactures. Basalt fiber is a high performance nonmetallic fiber made from basalt rock melted at high temperature. Basalt rock can also make basalt rock, chopped basalt fiber, basalt fabrics and continuous filament wire. Basalt fiber originates from volcanic magama and volcanoes, a very hot fluid or semi fluid material under the earth's crust, solidified in the open air. Basalt is a common term used for a variety of volcanic rock, which are gray dark in colour. The molten rock is then extruded through small nozzles to produce continuous filaments of basalt fiber.

1.2Background

Civil engineering buildings in the present era have certain structural and durability criteria. Since each structure has a purpose, typical cement concrete must be modified in order to fulfill it. It has been discovered that adding various types of fibers to concrete at precise percentages enhances the structure's mechanical qualities, serviceability, and longevity. It is well known that fiber-reinforced concrete's (FRC) exceptional resistance to cracking and crack propagation is one of its key characteristics. Fiber-reinforced concrete (FRC) is concrete that has been strengthened structurally by the addition of fiber material. It has randomly oriented, uniformly dispersed short discrete fibers. Concrete can be reinforced with steel, glass, basalt, synthetic, and natural fibers, each of which adds a different set of qualities. Furthermore, combining different fiber materials, geometries, distributions, orientations, and densities alters the properties of fiber-reinforced concrete.

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1.3 Chopped Basalt Fiber and Basalt Rebar

1.3.1 Chopped Basalt Fiber:

Figure 1.1 shows chopped basalt fibers which are manufactured in a single stage process by melting pure basalt rock raw material. Basalt filaments are made by melting crushed volcanic basalt rock of a specific mineral mixture to 1,700 degrees Celsius for 6 hours. The white hot material is drawn through special platinum bushings and then cooled into fibers. The fibers cool into hexagonal chains resulting in a resilient structure substantially stronger than steel or fiber glass. Previous investigations on reinforcing concrete containing basalt fibers with different proportions have confirmed the possibility of enhancing the mechanical properties of concrete significantly. Addition of basalt fibers will have significant effect on the mechanical properties of concrete, as they are capable of resisting the high alkalinity environment of concrete, can bond chemically with cement, are a noncorrosive e material, have high thermal resistance to heat, and also have a high tensile strength. As a result, basalt fibers are considered to be promising material to improve the concrete strength.

1.3.2 Basalt Rebar

There are following some advantages of basalt rebar.

Not harmed by harsh environments: Figure 1.2 shows Basalt rebar having specific advantage that it does not corrode. It was specifically developed for harsh environments such as sea walls and road bridges. One of the major problems the construction industry faces today is corrosion of reinforcing steel, which significantly affects the life and durability of concrete structures. Basalt rebar effectively counters this problem because it is immune to corrosion.

Stronger than steel rebar: Basalt rebar provides high tensile strength. Basalt rebar is about 2.5 times stronger (tensile strength) than series 60 steel rebar of the same diameter.

Stronger than fiber glass rebar: The tensile strength of continuous basalt fibers is about twice that of E-glass fibers and the modulus of elasticity is about 15-30% higher.

High chemical stability: Basalt fibers in an amorphous state exhibit higher chemical stability than glass fibers. When exposed to water at 70 degrees C (158" F), basalt fibers maintain their strength for 1200 hours, whereas the glass fibers do so only for 200 hours.

Thermal expansion coefficient similar to concrete: The thermal expansion coefficient is very close to that of concrete (whereas steel is very different). This avoids concrete cracking.

Completely non-toxic: Basalt rebar is environmentally safe and non-toxic. It is also completely inert. The production process creates no environmental waste and it is non-toxic in use or recycling.

Lighter in weight than steel: Basalt rebar is about a third of the weight of steel and given that it is 2.5 times stronger than steel, then its strength to weight ratio is 7.5 times better. This makes it far easier to use and less expensive to ship.

Used in thermal breaks: Basalt rebars are used in thermally isolated balconies. It is observed that basalt rebar allows the balconies to be structurally attached without heat loss from the internal building structure.

Does not conduct electrically and Safe in house fires: The basalt fibers have good insulating characteristics. It does not loose strength in a house fire situation (it can stand 600 degrees C quite happily). The basalt fibers have high heat stability.

UV resistance: Basalt is naturally resistant to UV exposure (although the epoxy resin can be harmed by UV).

1.4 Properties of Chopped Basalt Fiber

1.4.1 Physical Properties

1. Color: It is available in golden brown in color.
2. Diameter: It is available in different diameter like 5.8 micron.
3. Length: Available in6mm, 8mm, 12mm etc.
4. Density: density of basalt fiber is 2650 kg/m^3
5. Coefficient of friction: 0.42 to 0.50.

Table No. 1.1Physical Properties of Chopped Basalt Fiber

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

1.4.2 Chemical Properties

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

1.4.3 Thermal Properties

With a thermal range of –260 ◦C to 982 ◦C and melt point of 1450◦C as well as low thermal conductivity 0.031 – 0.038w/mk, the basalt fibers are ideal for fire protection and insulation applications. Basalt fibers are most cost effective than the other high-temper Materials including E-glass, silica, ceramics, stainless steel and carbon by preventing rapid overheating and improving brake life. Offer three times the thermal efficiency of asbestos with no heat hazards.

Table No. 1.3 Thermal properties of chopped Basalt fiber

Thermal properties	Basalt	E-glass
Maximum operating temperatures	980℃	650℃
Sustained operating temperatures	700℃	480℃
Minimum operating temperatures	-2.60℃	-60℃
Thermal conductivity	0.031-0.038 W/m K	0.034-0.04 W/m K
Melting temperature	1,280℃	1,120℃
Thermal expansion coefficient	8.0 ppm/℃	5.4 ppm/℃

1.4.4 Corrosion and fungi resistance

Basalt fiber has better corrosion resistance. It does not undergo any toxic reaction with water and air or gases also. Moisture regain and moisture content of basalt fibers exist in the range of less than 1%. Basalt materials have strong resistance against the action of fungi and microorganisms.

1.4.5 Abrasion property

Basalt material is extremely hard and has hardness values between 5 to 9 on Mohr’s scale, which results in better abrasion property. Even continuous abrasion of the basalt fiber-woven fabrics over the propeller type abraders do not result in the splitting of fiber by fracture and results only in breaking of individual fibers from woven structure which eliminates possibility of causing hazards.

1.5 Effects on properties of concrete by adding BF

The principle effects of basalt fibers on the mechanical properties of concrete are they can react chemically with the cement, producing more calcium silicate hydration which is required to increase the concrete strength. To promote bonding between the fibers and cement it was initially intended to use a cross-linking agent and coat the fibers. Calcium-Silicate-Hydrate (C-S-H) reaction outputs have been notoriously difficult to predict and model. They are capable of reducing crack propagation, thus enhancing the tensile strength of concrete. And they also have high thermal and alkaline resistance, which improves the durability of concrete. Therefore, the effects on the mechanical properties of concrete by using BF of different lengths and proportions are as presented below.

1.5.1 Workability

Workability is the ease with which a fresh mix of concrete or mortar can be handled and placed. It is also defined as the ability of the concrete mix to fill in the shape of a form/mould with the desired work, and without reducing the concrete quality. Several factors affect the workability of fresh concrete: water content, aggregate shape, mix proportions, grading of aggregates, and the use of fibers. Workability of concrete is measured using a slump test; the addition of fibers can change the water cement ratio and, as a result, reduce its slump. The influence of pre-soaked basalt fiber on the mechanical properties of concrete, found that the slump of concrete reinforced with basalt fiber is reduced with an increase in the content and length of the basalt fiber. Different basalt fiber lengths of 10mm, 20mm and 30mm were used with different dosages of 3, 5 and 7kg/m3. The decrease in slump occurred for two main reasons: the increase of the coefficient of friction between fibers and cement during mixing; and the absorption of certain moisture by the basalt fiber, causing the slump to reduce. And the influence for workability of reinforcing concrete with different basalt fiber contents (0%, 0.5%, 1%, 1.5%, 2%, and 2.5%). The results showed that increasing the percentage volume of fibers leads to a decrease in slump. This is because basalt fibers affect the flow ability of fresh concrete, which results in a decrease in workability.

1.5.2 Compressive Strength

The compressive strength of concrete is the most common performance measure used by civil engineers in designing buildings. Compressive strength is defined as the capacity of materials to withstand load that reduces its size. In general, concrete is strong in compression and can exhibit high strength. However adding different basalt fiber lengths and content has an effect on the compressive strength of concrete. The concrete using cubic and cylindrical tests to determine the average compressive strength of three samples, mixed with and without basalt fibers, at 28 days. The results showed that the average compressive strength for the basalt fiber concrete samples was higher than the compressive strength of the normal concrete samples at 28 days at particular percentage of BF content. The variation of concrete compressive strength mixed with different basalt fibers content has been presented. The compressive strength of concrete increases with increasing basalt fiber content up to specific percentages depending on the length and properties of BF used for investigations after this, the concrete compressive strength tends to decrease gradually by 12%. This is due to the cohesive decrease between the cement paste and the aggregate that plays a significant role in the compressive strength of concrete. The basalt fiber length that was used was 24.3 mm, with a diameter of 13 μm.

1.5.3 Tensile strength

Although concrete is weak in tension, the knowledge of concrete tensile strength is essential to determine the load under which cracks will develop. This load has an influence on the formation of cracks and their propagation to the tension side of the concrete and other concrete members. Reinforcing concrete with basalt fibers reduces the crack width, thus improving concrete strength and durability. The tensile strength of concrete reinforced with basalt fibers increases with the age of curing. Concrete tensile tests were carried out on concrete samples reinforced with and without basalt fibers. The specimens were kept in water for curing for 7 days, 14 days and 28 days, and on removal were tested by spraying water on the concrete. The tensile strength of concrete increases as the length of the pre-soaked basalt fibers increases. The effect of using different basalt fiber lengths of 10mm, 20mm and 30mmon the tensile strength of concrete. Using 30mm basalt fiber achieved the highest tensile strength. Using 12mm basalt fiber with 1-2% content results in achieving Higher concrete tensile strength in addition, reinforcing concrete with basalt fiber 24mm and50mm in length, with 1-3% content, increases the tensile strength significantly by 1.79 times. Although most fiber lengths achieved higher tensile strength, there was no a significant difference when using 24mm and 50mm fiber lengths.

1.5.4 Flexural strength

In the construction and engineering field, knowing some terms such as the flexural strength of the material is essential in order to make sure that the material is strong enough to be used in structures. The flexural strength is defined as the material's ability to resist deformation under load. The flexural concrete strength tests using prisms for different samples, the results showed that the flexural strength of concrete increases for all concrete mix proportions with age. This shows that the contribution made by mixing basalt fibers with concrete increases its flexural strength.

1.6 Aim and Objective

The aim of the experimental investigation is to analyse the properties of concrete by adding the most suitable combination of basalt fiber percentage and use of basalt rebars into the concrete. This optimum percentage basalt fiber quantity is considered for further investigation. Comparison of results with normal concrete is carried out.

1. To determine the optimum percentage of Basalt Fiber quantity into the concrete.
2. To use basalt rebar with optimum percentage of Basalt Fiber into the concrete.
3. To check the behaviour of BFRC under compression, tension and flexural strength
4. To check the deflections in FRC beams by using basalt rebars.

2. LITERATURE REVIEW

2.1 General

As we know that from last few decades the construction field has seen a growing interest in the advantages by using fiber reinforced concrete structures. Between the different types of fibers available, basalt fiber is considered a promising new material to use. It has extremely good strength characteristics and thermal resistance, high resistance to an alkaline environment, and is cheap product, making it an excellent material to reinforce concrete. In view of the significance of basalt fibers for concrete, and because different lengths and proportions of basalt fibers have an effect on the mechanical properties of concrete, it is proposed to review the effect of using different hybrid fibers with basalt fibers lengths and content on the mechanical properties of concrete.

2.2 Review of literature

1. Dr. K. Ramadevi - Basalt fiber is a relatively newcomer to fiber reinforced polymers (FRPs) and structural composites. It has a similar chemical composition as glass fiber but has better strength characteristics and unlike most glass fibers is highly resistant to alkaline, acidic and salt attack making it to perform well for water retaining structures. This paper presents an experimental investigation that was carried out to evaluate the performance characteristics of basalt fiber reinforced concrete beams. The variation of mechanical properties with the fiber length and optimum dosage of fiber content is found out experimentally. It was observed that higher fiber length showed increase in compressive strength, split tensile strength and flexural strength compared to plain concrete control specimen an attempt is made to predict the impact of basalt fiber in the properties of M40 grade concrete. The influence of fiber length in the mechanical properties and the optimum range of fiber are also studied.

2. Abhijeet B. Revade - Basalt fiber is easy to disperse when mixed with cement concrete. Fresh concrete with basalt fibers has important characteristics like good workability, good stability, excellent thermal resistance, anti-seepage, crack resistance and impact resistance. The study it was proposed that, the usage of Basalt fibers in low cost composites for civil infrastructure applications gives good mechanical properties like strength and lower cost predicted for basalt fibers. Basalt fiber has used as a cost effectively replace to fiber glass, steel fiber, polypropylene, polyethylene, polyester, aramid and carbon fiber products in many applications. A coir fiber, glass, steel, polypropylene, polyester fibers are used in concrete to gain strength to the concrete. In this study, the compressive and splitting tensile strength was studied after introducing chopped basalt fibers.

3. Julita Krassowska - Fiber reinforced concrete beams were not destroyed rapidly. Failure mode of beams varied in dependence on the amount of shear reinforcement and fiber content in concrete. Larger number of diagonal cracks with a smaller width were observed in fiber reinforced concrete beams. Failure of beams of concrete without fibers was rapid with a characteristic brittle cracking. Basalt fibers revealed the ability to transfer significant shear stress after cracking in comparison to plain concrete. The main purpose of the fibers in concrete is to provide control of cracking and to increase the fracture toughness of the brittle matrix through bridging action during both micro and macro cracking of the matrix. Analyzing the shear stresses on the central support of two-span beams, it can be concluded that in the case of basalt fiber series, the higher the fiber content in concrete, the higher the stresses at failure. As a result of the investigation carried out, a significant effect of basalt fibers on the cracking resistance was found. The moment of first crack appearance in the fiber reinforced beams occurred later than in the beam without fibers and it was related to their content. The increase in the amount of dispersed reinforcement caused the increase in value of cracking moment.

4. Zhong-Xian Li - The contributions of different types of fibers to the mechanical properties of HFRC were also investigated. The observations from the tests offer a practical guidance to concrete composites designers on the shear strength and shear deformation ability of different structures, especially for use in constructing the shear keys of an immersed tunnel. The optimized unit weight of the hybrid fibers was obtained through the parametric studies on the improvements of different fiber contents on the mechanical properties of the HFRC, especially the shear strength and toughness. Additionally, the influences of incorporating hybrid fibers on flexure, direct shear toughness and residual load were also studied. The direct shear strength, shear toughness and residual shear load significantly increased due to the addition of steel fibers and basalt fibers.

5.Marek Urbanski - was to clarify the effect of basalt flexural reinforcement on ductility, deformability, ultimate stresses and damage mechanisms of structures reinforced with BFRP compared to traditional structures, reinforced with steel bars. Particular attention was paid to studies examining the impact of slip phenomenon, which may occur at the interface between the BFRP bars and the surrounding concrete. That in contrast to the bilinear stress-strain dependence for a steel reinforcement, basalt reinforcement has a linear dependence until the entire the beam section load capacity has been exhausted. It was noted that critical load for tested beams reinforced with BFRP bars was much greater than the carrying capacity of beams with conventional steel reinforcement, which arose from the different degrees of mechanical reinforcement in both types of beams.

6. Duaa Fadil - Experimental of fibers and hybrid fiber concrete mixtures and RC beams. The flexural and mechanical behavior of concrete reinforced with fibers are compared. The crack pattern for all beams was failed in the flexural zone where the number of cracks increased. When Vertical cracks appeared during the initial load until the beams failed. Fibers are capable of avoiding a sudden and brittle concrete crushing owing to their capability of improving concrete toughness in compression.

7. Rajvi T. Desai - is to compare the flexure behavior of beam casted by using conventional steel reinforcement and BFRP (Basalt Fiber Reinforced Polymer) rebar. As structural behavior of any element is also influenced by bond strength between reinforcement and concrete, an attempt is also made to study bond strength for conventional steel and BFRP rebar. Of behavior of beam reinforced with basalt fiber reinforced polymer bars. As steel reinforcement are susceptible to corrosion in aggressive environment. An attempt is intent to use a new type of fiber reinforced polymer rebar in beam instead of steel bar as flexural reinforcement. To study bond strength 10 mm and 12 mm size of BFRP bars were used to perform pull out test. For flexural behavior 10 mm and 12 mm size BFRP bars were provided in flexural zone and compared with convention RCC beam were tested and analyzed. The potential to significantly contribute towards providing a reference for the application of concrete.

8. YihongGuo - The simultaneous effect of basalt fiber (BF) and mineral admixtures (fly ash and silica fume) on the resistance of concrete to chloride penetration at different curing ages. Fifteen mixtures with five BF volume contents and three types of cementations materials were fabricated and cured for 28 or 56 days. The apparent density, compressive strength, charge passed and chloride diffusion coefficient reinforced with basalt fiber in salty and other severely corrosive environments. However, further research, particularly the effect of fiber length and length-to- diameter ratio on the properties of concrete is needed to facilitate the design and production of such concrete.

9. L I Khudyakova - It is shown that they can be applied in building material production. Adding magnesium-silicate rocks into binding compositions allows enhancing their physical and mechanical parameters. Using them as coarse or fine aggregate, as well as a reinforcing component, enhances performance characteristics of concretes. Adding batch to the composition allows optimizing process parameters for obtaining ceramic materials and improving their quality. Practically all magnesium-silicate rocks are located in overburden dumps. Their involvement into production cycle will allow for not only solving environmental problems but also expand the list of raw materials applicable in construction industry. The goal of this paper is to provide a review of application of magnesium-silicate rocks (serpentines, basalts) in building material production, as well as describe the perspective of using other rocks, namely unites, in this industry.

3. PROBLEM STATEMENT AND METHODOLOGY

3.1 General

Now a day's construction has been increased so fast that it needs a lot of resources for its execution. A lot of construction needs a lot of concrete. During the process of selecting an appropriate material to improve the properties of concrete by adding challenging materials like basalt fiber and basalt rebars into the concrete is the new trend and technology. For construction industry, the mechanical properties of material are considered to play a major role in this selection, which depends strongly upon understanding the material microstructure and components. In this context, it's important for engineers to possess a deep understanding of how the microstructure is formed, and how the addition of new materials can influence the engineering properties. Hence there is so much demand for study and apply the basalt fibers and basalt rebars into the concrete construction. As per the demand, various optimum percentages of addition of basalt fibers into the concrete have been needed to study.

3.2 Problem statement

One of the major problems faced in reinforced concrete construction is the corrosion of reinforcing steel, which significantly affects the life and durability of concrete structures. Due to the corrosion of steel bars, structural members cannot take deflections under loads. Basalt rebars can effectively eliminate the problem of corrosion as they are immune to corrosion. In addition to high tensile strength, light weight, and good chemical resistance basalt fibers also possess high thermal resistance and they do not conduct electricity. However, it has only been a limited number of researches found in open literature concerning chopped basalt fiber reinforced concrete. However, no previous research was conducted using basalt bundled fibers and chopped basalt fibers. Hence, this study was developed to investigate the effect of using chopped basalt fibers and its rebars into the concrete to check the mechanical properties by conducting tests like flexural, compressive, and split tensile strength on concrete specimens.

3.3 Methodology

The experimental study was carried out in three phases. The first phase is to prepare a mix design of concrete as per the properties obtained and gradation of materials. The Second phase of the experimental investigation is to find the optimum percentage of BF mixed into the concrete under compression test. Addition of different percentage of BF For a mix designed concrete is scheduled, from which optimum percentage of BF available for experimental investigation was to be found out. The third phase includes preparing a concrete for cylinder and beam specimens by adding optimum percentage of BF. Casting of 6 cylinders is carried out and further by using basalt rebars with same (Optimum Percentage) BF casting of 12 beams will be carried out. A comparison of experimental results with normal concrete specimens will be carried out using FRC and basalt rebars by conducting split tensile and flexural strength tests into the laboratory.

1. A mix design for M-30 grade of concrete is adopted for trial. Cubes were casted for curing period of 28 days. These cubes were tested for compression strength.
2. A total 18 number of cubes were casted with addition of BF percentage into the concrete by volume, such as 0%, 0.5, 1, 1.5, 2 and 2.5% at an increment of 0.5%.
3. By adding different percentage of BF into the concrete, optimum percentage of BF will be obtained.
4. Further, by using optimum percentage of basalt fibers into the concrete, 6 cylinders were allowed to cast and comparison the split tensile strength results with normal concrete cylinders is proposed.
5. Further beam specimens were proposed to cast by using optimum percentage basalt fibers and basalt rebar instead of steel bars as a Basalt Fiber Reinforced Concrete (BFRC).A total number of 12 beams were casted for flexural strength test. After the test, load-deflection data and flexural strength of different beams specimens was compared with normal concrete specimens.

4. MATERIALS AND MIX DESIGN

4.1 Mix Design

Mainly the concrete mix design is done to check the compressive strength of the concrete. The cost of concrete is totally dependent over the cost of materials which we are going to add in it. Also it depends on the plant and labour charges. The variation in the cost of concrete mainly comes from the fact is that the cement is much costlier than that of aggregates. Thus the main motive of the mix design is to produce a concrete with not more than required the quantity of cement. Also higher quantity of cement causes shrinkage and cracking in the structure.

The Bureau of Indian Standards (BIS) has given us a recommended guideline specified for concrete mix design which was published in IS 10262:1982 for the proportioning of concrete mixes. It is then revised in the year 2009. During the experimental study of this project, the concrete mix design is adopted from Indian Standards of concrete mix proportioning - guidelines first revision (IS 10262:2009) for the M30 grade of concrete.

1.1.1 Data required

Data required for the concrete mix design is as follows:

Table 4.1 Data required

SN	Description	Values
1	Grade designation	M-30
2	Type of Cement	OPC (53 grade)
3	Max nominal size of aggregates	20 mm
4	Water-cement ratio	0.45
5	Workability	75mm (slump)
6	Exposure condition	Mild
7	Type of aggregates	Crushed angular aggregates
8	Sp. Gravity of cement	3.15
9	Sp. Gravity of C.A.	10mm (2.68) 20mm (3.02)
10	Sp. Gravity of River Sand	2.688
11	Fine aggregate zone	Grade zone I

1.1.2 Target strength of mix proportioning

The target compressive strength of the mix design can be calculated by using following formula:

$$f_{ck}' = f_{ck} + 1.65\, s \qquad (4.1)$$

From **Table 1** of IS 10262:2009, Standard deviation,

s = 5 N/mm^2 Therefore,

Target compressive strength = 30 + 1.65 × 5

= 38.25 N/mm^2 (Table 1)

1.1.3 Selection of water cement ratio
According to IS 10262:2009 from **Table 5**
The maximum water cement ratio for mild exposure RCC = 0.55 For trials, take water cement ratio as 0.45

1.1.4 Selection of water content
From IS 10262:2009, **Table 2**, the water content for 20mm size of aggregate is 186kg for 25 to 50mm slump. Water content for 75 mm slump is,
Consider 186 kg, as water absorption of river sand, 20mm and 10mm is 2.21, 1.2 and 1.29 respectively.
As the F. A. (River Sand) confirms sieve analysis limit (60-95) on 2.36mm IS sieve, considering zone I grading from Table 4 of IS: 383
Consider w/c Ration 0.45 Table 5 of IS: 456
Hence Max Water Content= 186 liter or kg

1.1.5 Calculation of cement content

$$\text{Cement content} = \frac{\text{Water content}}{\text{w/c ratio}} = \frac{186}{0.45} = 400\ kg/m^3 > 320\ kg/m^3$$

(Min cement content) hence ok

1.1.6 Volume of C. A. and F. A.
According to IS 10262:2009,
from
Table 3 volume of coarse aggregate per unit volume of total aggregate for 20mm aggregate and grade zone II is given by:
Volume proportion if C.A. = 0.60
Volume proportion of F.A. = 1 – 0.60 = 0.40

1.1.7 Mix calculation per m^3 of concrete
a. Volume of concrete = 1 m^3

Volume of cement= 396.6

$$\text{b. Volume of water} = \frac{\text{Mass of water}}{\text{Sp. gravity of water}} \times \frac{1}{1000} = \frac{186}{1} \times \frac{1}{1000} = 0.180\ m^3 \quad (5.3)$$

c. Volume of all in aggregates = [a – (b + c)] = [1 – (0.126 + 0.180)] = 0.694m^3

d. Mass of C.A. = d x Volume of C.A. x Sp. Gravity of C.A. x 1000

= 0.694 x 0.6 x 3.03x 1000 = 1261.692 kg/m^3

e. Mass of F.A. = d x Volume of F.A. x Sp. Gravity of F.A. x 1000

= 0.694 x 0.4 x 2.68 x 1000 = 743.968 kg/m^3

1.1.8 Final mix proportion for M 30 grade of concrete is 1:1.87:3.18

The mix proportion calculated above can be stated as given in

Table 4.2 Mix proportion

Description	Cement	Fine Aggregate	Coarse Aggregate	Water
Mix proportion (by weight)	1	1.87	3.18	0.45
Quantities of materials (in kg/m^3)	396.9	743.968	1261.692	186

5. EXPERIMENTAL PROGRAM

5.1 General

The experimental program has been designed to carry out casting and testing of 18cubes by varying fiber content, 12 beams specimens using Basalt rebars of varying diameters and 6 cylinders using chopped BF. Comparisons of results are investigated. M-30 grade of concrete is used.

5.2 Experimental program

Basalt fiber contents are varied in percentage such as 0%, 0.5, 1, 1.5, 2 and 2.5% by volume of concrete for cube specimens. Further we found optimum percentage of BF by conducting compression test. According to the results 0.5% is the optimum percentage of BF. Further 6 cylinders were casted to investigate split tensile test. The results are tabulated in comparison of normal concrete. Further 12 beams are casted. For first 3 beams using steel reinforcement, 2 bars of 8 mm diameter at bottom and 2 bars of 6 mm diameter at topto hold stirrups are provided as a control beams specimen. In this investigation remaining beams are casted by using 8mm, 10mm and 12mm basalt rebar as main reinforcement for flexural strength instead of normal steel bars. A comparison of load-deflection data and flexural strength with control beams specimens is carried out in this experimental investigation. Minimum shear reinforcement of 2-legged 6 mm diameter stirrups is provided. In the present study an attempt has been made to study the performance of concrete at normal curing to enhance the practical application of basalt fiber mixed concrete. Normal curing for a period of 28 days is carried throughout the experimental program.

5.2.1 Compressive test

Compressive strength of cubes are determined at 28 days using compression testing machine (CTM) of capacity 2000 kN or universal testing machine (UTM) of capacity 1000 kN. The tests are performed at SP Construction, Pune.

5.2.2 Flexural test on beam specimen

After 28 days of water curing, the beam specimens are stickled with aluminium scale on both side of beam to observe the deflection with the help of strain gauges and crack development during testing. The beams are tested up to failure under gradually increasing load using universal testing machine of capacity 1000 kN. Two dial gauges are placed on both side of beam to measure the mid-span deflection

6. RESULTS AND DISCUSSION

6.1 General

Results and discussions include the test results which were carried out during the experiment. In this experiment cube specimen, cylinder specimen and beam specimen were prepared for the testing of compression, split tensile and flexure test respectively. In this chapter, test results were shown in Table as well as in Graphical format.

6.2 Compression test

At first compression test was conducted on the cubes of BF mixed into the concrete by proportion of 0%, 0.5%, 1.0%, 1.5%, 2.0% and2.5% in each set of three cubes. The compression tests on cubes carried out at age of 28 days for normal as well as for different percentages. For each variation three specimens were prepared and the average of three test results is stated as below. The maximum compressive stress is for the 0.5% BF which is optimum percentage required mixed in concrete for next investigation. Hence to check further, specimens were casted for split tension test in cylinder specimens and flexural test in beam specimens.

Table 6.1: Difference in Percentage and Average Cube compressive strength With Normal Concrete

Sr. No.	Set of Cube designation Size 150 mm^3	% Basalt Fiber content	Average Compressive Strength(MPa)	Compressive strength difference between normal concrete(MPa)	% difference (%)
1	C-1	0	37.32	-------	-------
2	C-2	0.5	42.93	5.61	15.03
3	C-3	1.0	30.66	- 6.66	- 17.84
4	C-4	1.5	25.53	-11.79	- 31.59
5	C-5	2.0	23.05	-14.27	- 38.23
6	C-6	2.5	21.94	-15.38	- 42.21

Average Compressive Strength of basalt fibers added specimens by volume of concrete at 0.5% addition is 42.93 MPa (increased by 5.61 MPa by normal specimens) that is by 15.03% more than normal specimens the average compressive strengths for different variations of BF percentage .

6.3 Split Tensile test

Split tensile test was carried out for the variation of 0% and 0.5% of basalt fiber. For each variation 3 cylindrical concrete specimens were casted. The test was carried out for the age of 28 days. The test was carried over UTM machine. The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine and the load is applied until failure of the cylinder, along the vertical diameter.

Table 6.2: Test results of split tensile Strength

Sr. No.	Cylinder Specification	Load in (kN)	Split Tensile Strength=2P/πld (MPa)	Average Split Tensile Strength (MPa)	Remark
1	CS-1	198.9	2.81	2.69	C+B
2	CS-1	161.1	2.28		D+B
3	CS-1	211.5	2.99		C+B
4	CBF-2	229.3	3.24	3.91	D+C+B
5	CBF-2	380.7	5.39		D+B
6	CBF-2	219.9	3.11		C+B

C: Cracked B: Breaked D: Slightly deformed

Split Tensile Strength of basalt fiber cylinders increased by 1.22 MPa that is by 45.35% more than normal specimens.

6.4 Flexure test

The experimental setup is based on the four-points bending test on Universal testing machine. The specimen is then placed in the machine in such a manner that the load is applied to the uppermost surface as cast in the mould, along two lines spaced 20 cm apart. The axis of the specimen is carefully aligned with the axis of the loading device. The load is increased until the specimen fails, and the maximum load applied to the specimen during the test is recorded. The deflection at the centre of beam is measured by using dial gauge. In this setup 3 basalt rebars of 8mm, 10mm, and 12mm diameter are used.

Table 6.3: Test results of flexure test

Sr. No	Beam specification	Ultimate load (KN)	Average deflection (mm)	Flexure Strength =Pl/bd^2(MPa)	Average Flexure Strength (MPa)	Mode of Failure
1	CB-1	102.6	2.14	21.20	21.92	Shear
2	CB-2	110.3	3.62	22.90		Shear + Flexure
3	CB-3	104.2	2.34	21.61		Flexure
4	BR-8	134.3	5.80	27.85	26.50	Shear
5	BR-8	128.9	4.35	26.73		Shear + Flexure
6	BR-8	120.1	3.95	24.91		Flexure
7	BR-10	119.3	4.45	24.74	27.07	Shear + Flexure
8	BR-10	138.2	5.75	28.70		Shear + Flexure
9	BR-10	134.1	4.80	27.81		Flexure
10	BR-12	135.8	5.95	28.17	27.81	Shear
11	BR-12	139.2	6.30	28.87		Shear + Flexure
12	BR-12	127.3	5.10	26.40		Shear + Flexure

Flexural strength increased by 4.58 MPa, 5.15 MPa, and 5.89 MPa that is 20.89%, 23.49%, 26.87% more than normal specimens.

From these results we can say that the maximum load is taken by the beam with optimum percentage of BF as basalt rebars diameter increases. The graphical representation of test results is shown in **Figure 6.6.** The graph shows the average test results for each of the variations in concrete.

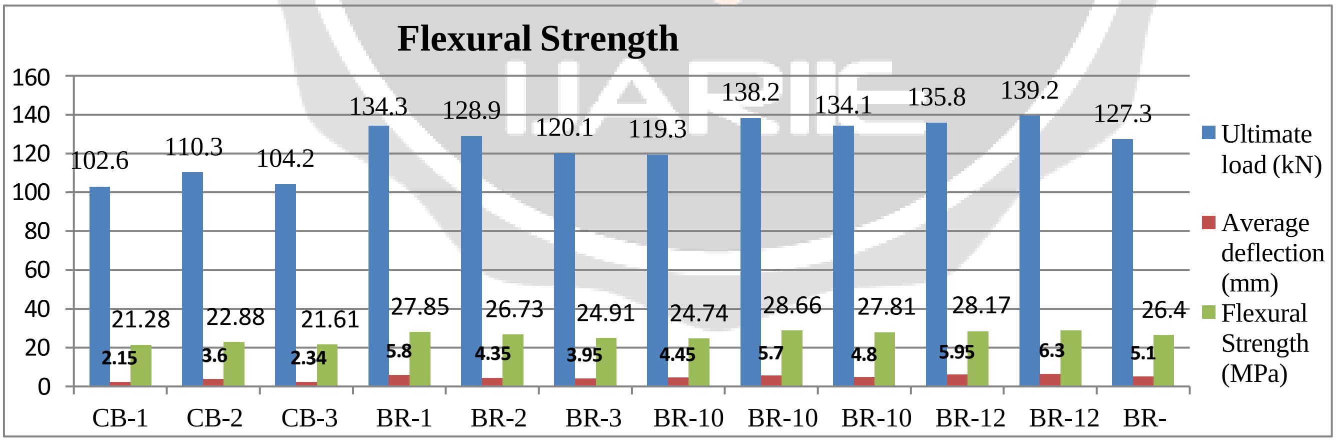

Fig: 6.1 Graphical representation of flexure test results

Flexural strength increased by 4.58 MPa, 5.15 MPa, and 5.89 MPa that is 20.89%, 23.49%, 26.87% more than normal specimens.

Deflection increased by 2 mm, 2.28 mm, 3.08 mm that is 74.07%, 84.44% and 114.07% more than normal beam specimens deflection.

6.4 Discussions

The variations in results under compression test of different BF percentage content of cube specimens are stated below with its optimum BF content required to mix in concrete. By using this optimum percentage of BF the results of the split tensile test and flexural test are also justified by the statements below. The variations of basalt rebars diameter in BFRC show different variations in results for all tests specimens. The increase and decrease in strength as well as the load carrying capacity for different beams and their deflections are stated below.

6.4.1 Strength of specimens

1. For the compression test, it has been observed that the maximum increase in the percentage of compressive stress with the control specimen is of 15.03% for 0.5% addition of BF into the concrete. The decrease in the percentage of compressive stress with control specimen is found to be 17.84% for 1.0% BF addition and 31.84%, 38.23%, 42.21% for 1.5%, 2.0%, 2.5% of BF addition in concrete respectively.
2. For split tensile test, using this optimum percentage of BF into the concrete the maximum increase in tensile strength was found out to be 45.35% more than control cylinder specimens.
3. In case of flexure test, average flexural strength of control beams is 21.92MPa,

a) The increase in flexure strength with the control beam is 20.89% for 8 mm diameter basalt rebar that is 26.50 MPa
b) The increase in flexure strength with the control beam is 23.49% for 10mm diameter basalt rebar that is 27.07 MPa
c) The increase in flexure strength with the control beam is 26.87% for 12mm diameter basalt rebar that is 27.81MPa

6.4.2 Deflection

The average deflection for control beam was found out to be 2.70 mm.

a) The average deflection of beam with basalt rebar 8mm diameter is 4.70mm which is 74.07% more than control beam specimen.
b) The average deflection of beam with basalt rebar 10mm diameter is 4.98mm which is 84.44% more than control beam specimen.
c) The average deflection of beam with basalt rebar 12mm diameter is 5.78mm which is 114.07% more than control beam specimen.

6.4.3 Testing methodology

A testing machine of capacity 100 tonnes was used for testing the compressive strengths of cube specimens at 28 days from casting as well as split tensile strengths of cylindrical Specimens at 28 days. Beams were tested as per IS: 516- 1989 specifications, on a displacement Controlled testing machine at a rate of 0.05 mm/Min. The net deflections at the centre were recorded on to as train gauges connected through a System. The load versus displacement curve for each Specimen was obtained and the various flexural parameters (flexural strength, average deflections, and average flexural strength) were calculated as perIS:516-1989 method. A sample load–deflection plot. It can be seen from this figure that because of the optimum percentage of BF fractions of fibers used, none of the concretes exhibited a true strain hardening behaviour, which is typical of fiber reinforced concrete when the fiber content is high.

6.4.4. Compressive split tensile and flexural strength

The variations in results under compression test of different BF percentage content of cube specimens are stated below with its optimum BF content required to mix in concrete. By using this optimum percentage of BF the results of the split tensile test and flexural test are also justified by the statements below. The variations of basalt rebars diameter in BFRC show different variations in results for all tests specimens. The increase and decrease in strength as well as the load carrying capacity for different beams and their deflections are stated below.

6.4.5 Strength of specimens

1. For the compression test, it has been observed that the maximum increase in the percentage of compressive stress with the control specimen is of 15.03% for 0.5% addition of BF into the concrete. The decrease in the percentage of compressive stress with control specimen is found to be 17.84% for 1.0% BF addition and 31.84%, 38.23%, 42.21% for 1.5%, 2.0%, 2.5% of BF addition in concrete respectively.
2. For split tensile test, using this optimum percentage of BF into the concrete the maximum increase in tensile strength was found out to be 45.35% more than control cylinder specimens.
3. In case of flexure test, average flexural strength of control beams is 21.92MPa,

a) The increase in flexure strength with the control beam is 20.89% for 8 mm diameter basalt rebar that is 26.50 MPa
b) The increase in flexure strength with the control beam is 23.49% for 10mm diameter basalt rebar that is 27.07 MPa
c) The increase in flexure strength with the control beam is 26.87% for 12mm diameter basalt rebar that is 27.81MPa

6.4.6 Deflection

It was discovered that the control beam's average deflection was 2.70 mm.
A beam with an 8mm diameter of basalt rebar has an average deflection of 4.70mm, which is 74.07% greater than that of the control beam specimen. A beam with a 10 mm diameter of basalt rebar has an average deflection of 4.98 mm, which is

84.44% greater than that of the control beam specimen. A beam with a 12 mm diameter of basalt rebar has an average deflection of 5.78 mm, which is 114.07% greater than that of the control beam specimen.
To obtain a consistent distribution throughout the concrete, chopped basalt fibers were manually added to the slurry and stirred for a total of five minutes. The specimens listed below were made:
(i) Cubes of 150 mm in size (for compressive strength according to IS516-1999 [21])
(ii) Cylinders with a diameter of 150 mm and a length of 300 mm (for split tensile strength according to IS 5816-1999 [22])
(iii) 700 x 150 x 150 mm (l x b x d) beam specimens (for IS 516-1999 [21] flexural tests)

7. CONCLUSIONS

7.1General

The purpose of this experimental study was to determine how concrete behaved under compression, tension, and flexure. Using 0%, 0.5%, 1.0%, 1.5%, 2.0%, and 2.5% by volume of concrete, the ideal proportion of BF in the concrete can be determined by varying the percentage of BF quantity. Using this ideal amount of BF in the concrete, a total of 18 cubes, 6 cylinders, and 12 beams are cast. Three specimens were cast for every variation. The following conclusions were drawn from the test findings.

7.2Conclusions

1. The ideal proportion of BF available for this inquiry is determined to be 0.5% of the concrete's BF content, which yields the maximum compression strength.
2. In the compression test, it was shown that adding 0.5% BF to the concrete increased the percentage of compressive stress by a maximum of 15.03% when compared to the control specimen. After that, it was discovered that when the percentage of BF in the concrete increased, the percentage of compressive stress with the control specimen decreased.
3. In the split tensile test, the highest increase in split tensile strength was determined to be 3.91MPa, or 45.35% more than control cylinder specimens with split tensile strength 2.69, employing this ideal proportion of BF into the concrete.
1. In case of flexure test,

The average flexural strength of control beams was 21.92 MPa.
a) The increase in flexure strength with the control beam is 20.89% for 8 mm diameter basalt rebar that is 26.50 MPa
b) The increase in flexure strength with the control beam is 23.49% for 10mm diameter basalt rebar that is 27.07 MPa
c) The increase in flexure strength with the control beam is 26.87% for 12mm diameter basalt rebar that is 27.81MPa

The average deflection for control beam was 2.70 mm.
a) A beam with 8 mm of basalt rebar has an average deflection of 4.70 mm, which is 74.07% greater than that of the control beam specimen.
b) A beam with a 10 mm diameter of basalt rebar has an average deflection of 4.98 mm, which is 84.44% greater than that of the control beam specimen.
c) A beam with a 12 mm diameter of basalt rebar has an average deflection of 5.78 mm, which is 114.07% greater than that of a control beam specimen.

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