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Enhancement of Concrete Strength Using Basalt Fiber Reinforcement

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Abstract: Concrete is the most widely used construction material; however, its inherent limitations such as low tensile strength, brittleness, and susceptibility to cracking restrict its structural performance. To address these issues, the incorporation of fibers has emerged as an effective method to enhance the mechanical properties of concrete. This study investigates the influence of basalt fiber reinforcement on the strength characteristics of M25 grade concrete.Basalt fibers were added in varying proportions of 0%, 0.15%, 0.30%, and 0.45% by volume of concrete, and a total of 72 specimens (cubes and cylinders) were prepared and tested. The specimens were evaluated for compressive strength and split tensile strength at curing periods of 7, 14, and 28 days.The experimental results indicate that the inclusion of basalt fibers significantly improves both compressive and tensile strength of concrete. The maximum enhancement was observed at 0.45% fiber content, demonstrating superior performance compared to conventional concrete. The improvement is attributed to the crack-bridging ability of fibers, which delays crack propagation and enhances ductility.The study concludes that basalt fiber is an effective, durable, and environmentally sustainable reinforcement material that enhances the overall performance and longevity of concrete structures, making it suitable for modern construction applications [1], [5].

Keywords: Basalt Fiber Reinforced Concrete, Compressive Strength, Split Tensile Strength, Fiber Reinforced Concrete, Crack Resistance, Sustainable Construction

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I. INTRODUCTION

Concrete is one of the most extensively used construction materials due to its high compressive strength, durability, and cost-effectiveness. However, conventional concrete exhibits several inherent limitations, including **low tensile strength, brittle behavior, and susceptibility to cracking**, which adversely affect its structural performance and long-term durability. Micro-cracks are formed within the concrete matrix during hydration and under applied loads, leading to crack propagation and eventual failure of structural elements [3], [5].

To overcome these limitations, the concept of **fiber-reinforced concrete (FRC)** has been widely adopted. In FRC, discrete fibers are uniformly distributed within the concrete matrix to improve its mechanical properties. These fibers act as crack arresters by bridging micro-cracks, thereby enhancing tensile strength, ductility, and resistance to crack propagation [1], [2]. The addition of fibers also improves impact resistance and reduces the chances of sudden brittle failure.

Among the various types of fibers, **basalt fiber** has emerged as a promising reinforcement material in recent years due to its superior mechanical and chemical properties. Basalt fiber is produced from naturally occurring volcanic rock through a controlled melting and extrusion process. It possesses high tensile strength, excellent resistance to corrosion and alkali attack, and good thermal stability. Additionally, basalt fiber is non-toxic, recyclable, and environmentally friendly, making it a sustainable alternative for modern construction applications [2], [6].

Previous studies have demonstrated that the inclusion of basalt fibers significantly enhances the mechanical properties of concrete, including compressive strength, split tensile strength, and flexural strength. The improvement is primarily attributed to the ability of fibers to control crack initiation and propagation within the concrete matrix [1], [5]. However, the effectiveness of basalt fiber depends on its dosage, length, and distribution within the mix.

This study focuses on evaluating the effect of varying basalt fiber content (0%, 0.15%, 0.30%, and 0.45%) on the mechanical properties of M25 grade concrete. The primary objective is to determine the optimum fiber content that provides maximum strength enhancement while maintaining adequate workability. The findings of this study contribute to the development of **high-**

performance, durable, and sustainable concrete materials for modern infrastructure.

II.LITERATURE REVIEW

The use of fibers in concrete has gained significant attention in recent years due to their ability to enhance mechanical properties and durability. Among various fibers, basalt fiber has emerged as a promising material owing to its high strength, chemical resistance, and eco-friendly characteristics.

Prabhakar et al. [1] conducted an experimental study on basalt fiber reinforced concrete with varying fiber content ranging from 0% to 3%. Their results indicated that the inclusion of basalt fibers significantly improved compressive strength, split tensile strength, and flexural strength, with optimum performance observed at around 1.5% fiber content.

Ramadevi et al. [2] investigated the effect of basalt fiber length and content on the strength properties of concrete. The study revealed that increasing fiber length and dosage enhanced compressive and tensile strength. The fibers effectively controlled crack propagation, leading to improved structural performance.

Umadevi et al. [3] studied the mechanical behavior of basalt fiber reinforced concrete and reported considerable improvement in tensile strength and durability. The study highlighted that basalt fiber, being an inorganic material derived from volcanic rock, provides excellent resistance to chemical attack and environmental degradation.

Mohan Kumar et al. [4] explored the combined use of basalt fiber and manufactured sand in concrete. Their findings showed that the addition of basalt fibers improved compressive, tensile, and flexural strength while also contributing to cost-effective and sustainable construction practices.

Tarkesh Vhale et al. [5] analyzed the effect of low percentages of basalt fiber on concrete strength. The results demonstrated that even small additions of basalt fiber significantly improved compressive and tensile strength, indicating its efficiency as a reinforcement material.

Nawale et al. [6] conducted an experimental investigation on basalt fiber reinforced concrete and reported substantial increases in compressive, tensile, and flexural strength. The study also emphasized the hydrophilic and amorphous nature of basalt fiber, which contributes to better bonding with the cement matrix.

From the reviewed literature, it is evident that basalt fiber enhances the mechanical properties and durability of concrete. However, the optimal fiber content varies depending on mix design and application. Therefore, further investigation is required to determine the most effective dosage for specific concrete grades, such as M25, which is addressed in the present study.

III. MATERIALS AND METHODS

This section describes the materials used, mix proportions, specimen preparation, and testing procedures adopted to evaluate the mechanical properties of basalt fiber reinforced concrete.

3.1 Materials

The following materials were used in the preparation of concrete:

Cement:
Ordinary Portland Cement (OPC) of 43 grade conforming to IS 269:2015 was used. The cement had a specific gravity of 3.15, normal consistency of 30%, initial setting time of 30 minutes, and final setting time of 580 minutes.

Fine Aggregate:
Natural river sand conforming to IS 383:2016 (Zone II) was used as fine aggregate. It had a specific gravity of 2.65, water absorption of 1.01%, and fineness modulus of 2.699.

Coarse Aggregate:
Crushed angular aggregates of 20 mm maximum size were used. The aggregates had a specific gravity of 2.68 and water absorption of 0.8%.

Water:
Clean potable water conforming to IS 456:2000 was used for mixing and curing purposes.

Basalt Fiber:
Basalt fibers of 12 mm length were used as reinforcement. The fibers possess high tensile strength, good chemical resistance, and excellent thermal stability. The density of basalt fiber is approximately 2.75 g/cm³.

3.2 Mix Proportion

Concrete of grade M25 was designed as per standard guidelines. The mix proportion used in the study is given below:

Material	**Quantity (kg/m³)**
Water	192
Cement	400
Fine Aggregate	782
Coarse Aggregate	1007

Water-cement ratio: **0.48**
Mix ratio: **1 : 1.96 : 2.52**

3.3 Fiber Content

Basalt fibers were added to the concrete mix in the following proportions (by volume of concrete):

- 0% (Control mix)
- 0.15%
- 0.30%
- 0.45%

3.4 Specimen Preparation

A total of **72 specimens** were prepared for experimental analysis:

- **36 cubes** (150 mm × 150 mm × 150 mm) for compressive strength

- **36 cylinders** (150 mm diameter × 300 mm height) for split tensile strength

Concrete was mixed thoroughly to ensure uniform distribution of fibers. The specimens were cast in moulds in three layers, with each layer compacted using a tamping rod or vibrator. After casting, specimens were kept undisturbed for 24 hours, then demoulded and cured in water for **7, 14, and 28 days**.

3.5 Testing Procedures

3.5.1 Compressive Strength Test

The compressive strength of concrete cubes was determined using a **Compression Testing Machine (CTM)** as per standard procedures. The load was applied gradually until failure.

fc=PAf_c = \frac{P}{A}fc =AP

Where:
fcf_cfc = Compressive strength (N/mm²)
PPP = Ultimate load (N)
AAA = Area of specimen (mm²)

3.5.2 Split Tensile Strength Test

The split tensile strength of cylindrical specimens was determined using a CTM. The load was applied along the diameter until failure occurred.

ft=2PπDLf_t = \frac{2P}{\pi D L}ft =πDL2P

Where:
ftf_tft = Split tensile strength (N/mm²)
PPP = Maximum applied load (N)
DDD = Diameter of cylinder (mm)
LLL = Length of cylinder (mm)

IV. EXPERIMENTAL PROCEDURE

The experimental procedure was carried out to evaluate the effect of basalt fiber reinforcement on the mechanical properties of M25 grade concrete. The methodology includes batching, mixing, casting, curing, and testing of specimens under controlled laboratory conditions.

4.1 Batching and Mixing

The materials were batched according to the designed mix proportion. Cement, fine aggregate, and coarse aggregate were first mixed in dry condition to achieve uniform distribution. Basalt fibers were then added gradually to ensure proper dispersion and to avoid fiber clustering (balling effect).

After dry mixing, water was added slowly, and the entire mixture was thoroughly mixed until a homogeneous concrete mix was obtained.

4.2 Casting of Specimens

Concrete specimens were cast in standard moulds:

- Cubes of size **150 mm × 150 mm × 150 mm** for compressive strength
- Cylinders of size **150 mm diameter × 300 mm height** for split tensile strength

The concrete was placed in moulds in three equal layers. Each layer was compacted using a **tamping rod (25 blows per layer)** or a mechanical vibrator to eliminate air voids and ensure proper compaction.

The top surface of the specimens was leveled and finished smoothly. Each specimen was properly labeled to indicate mix designation and fiber content.

4.3 Curing of Specimens

After casting, the specimens were kept at room temperature for **24 hours**. They were then demoulded carefully and immersed in a curing tank filled with clean water.

The specimens were cured for **7, 14, and 28 days** to evaluate the strength development over time.

4.4 Compressive Strength Testing

The compressive strength of cube specimens was determined using a **Compression Testing Machine (CTM)** of suitable capacity. The specimens were removed from water, wiped dry, and placed centrally on the testing platform.

Load was applied gradually and uniformly until failure occurred. The maximum load was recorded, and compressive strength was calculated using:

fc=PAf_c = \frac{P}{A}fc =AP

4.5 Split Tensile Strength Testing

The split tensile strength of cylindrical specimens was determined using the CTM. The specimen was placed horizontally between the loading platens, and load was applied along the diameter until failure.

The maximum load at failure was recorded, and tensile strength was calculated using:

ft=2PπDLf_t = \frac{2P}{\pi D L}ft =πDL2P

4.6 Data Recording and Analysis

For each mix, three specimens were tested, and the **average value** was calculated to ensure accuracy and consistency of results. The results obtained were compared with conventional concrete to evaluate the effect of basalt fiber content.

V.RESULT

The experimental investigation was carried out to evaluate the effect of basalt fiber content on the mechanical properties of M25 grade concrete.

The results obtained from compressive strength and split tensile strength tests at curing periods of **7, 14, and 28 days** are presented below.

5.1 Compressive Strength Results

The average compressive strength values of concrete with different percentages of basalt fiber are summarized in Table 1.

Table 1: Compressive Strength of Basalt Fiber Reinforced Concrete (N/mm²)

Fiber Content (%)	7 Days	14 Days	28 Days
0 (Control)	21.57	27.91	35.21
0.15	22.65	29.66	36.81
0.30	24.06	31.68	38.85
0.45	26.07	33.44	40.49

Observation:
The compressive strength of concrete increases with the addition of basalt fiber. The maximum compressive strength is observed at **0.45% fiber content**, showing a significant improvement compared to conventional concrete.

5.2 Split Tensile Strength Results

The average split tensile strength values for different fiber contents are presented in Table 2.

Table 2: Split Tensile Strength of Basalt Fiber Reinforced Concrete (N/mm²)

Fiber Content (%)	7 Days	14 Days	28 Days
0 (Control)	2.29	3.24	4.43
0.15	2.51	3.51	4.74
0.30	2.76	3.82	5.05
0.45	3.00	4.09	5.32

Observation:
The split tensile strength also increases with the addition of basalt fiber. The highest tensile strength is recorded at **0.45% fiber content**, indicating improved crack resistance and ductility.

5.3 Graphical Representation

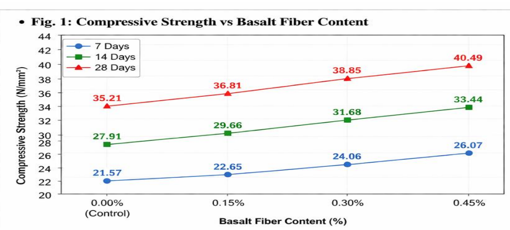

Fig. 1. Variation of compressive strength of concrete with basalt fiber content at different curing ages.

Fig. 1 illustrates the variation in compressive strength of concrete with increasing basalt fiber content. It is observed that the compressive strength increases progressively as the fiber percentage increases from 0% to 0.45%. The maximum strength is achieved at **0.45% basalt fiber content**, indicating improved load-carrying capacity and structural performance.

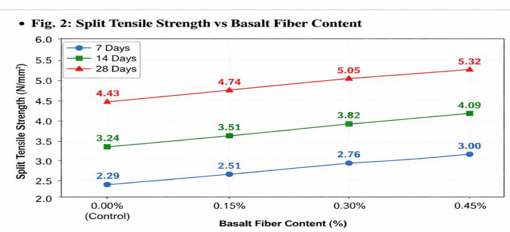

Fig. 2. Variation of split tensile strength of concrete with basalt fiber content at different curing ages.

Fig. 2 illustrates the variation in split tensile strength of concrete with increasing basalt fiber content. It is observed that tensile strength increases significantly as the fiber percentage increases from 0% to 0.45%. The highest tensile strength is achieved at **0.45% basalt fiber content**, indicating improved crack resistance and ductility of the concrete.

5.4 Key Findings

- Strength increases progressively with fiber content
- Maximum improvement observed at **0.45% fiber content**
- Tensile strength shows higher percentage improvement compared to compressive strength
- Fiber inclusion enhances crack resistance and load-carrying capacity

VI.DISCUSSION

The experimental results clearly demonstrate that the incorporation of basalt fibers significantly enhances the mechanical properties of concrete. Both compressive strength and split tensile strength show a consistent increase with the rise in fiber content from 0% to 0.45%.

6.1 Effect on Compressive Strength

The increase in compressive strength with basalt fiber addition can be attributed to the improved internal structure of concrete. The fibers act as micro-reinforcement within the matrix, reducing the formation and propagation of cracks.

As observed in Fig. 1, the compressive strength increases progressively with fiber content, reaching its maximum at **0.45% fiber dosage**. This improvement is due to the ability of fibers to enhance load distribution and delay crack development under compressive loading [1], [5].

6.2 Effect on Split Tensile Strength

The improvement in split tensile strength is more significant compared to compressive strength. This is because fibers directly contribute to tensile resistance by bridging cracks and transferring stress across crack surfaces.

As shown in Fig. 2, the tensile strength increases steadily with fiber content, with the highest value observed at **0.45% fiber content**. The fibers prevent sudden brittle failure and improve ductility of concrete [2], [6].

6.3 Crack Resistance and Ductility

Basalt fibers play a crucial role in controlling crack propagation. They act as crack arresters and distribute stresses more uniformly within the concrete matrix. This results in improved ductility and toughness, reducing the chances of sudden structural failure.

The enhanced crack resistance makes basalt fiber reinforced concrete suitable for applications subjected to dynamic or impact loading conditions.

6.4 Effect on Workability

Although the addition of basalt fibers improves strength, it slightly reduces the workability of concrete. Higher fiber content leads to increased internal friction and reduced flowability. Therefore, proper mix design and compaction techniques are required to maintain workability.

6.5 Comparison with Previous Studies

The results obtained in this study are consistent with previous research findings. Similar improvements in compressive and tensile strength have been reported by Prabhakar et al. [1] and Vhale et al. [5]. The enhanced tensile performance observed in this study also aligns with the findings of Ramadevi et al. [2] and Nawale et al. [6].

This confirms that basalt fiber is an effective reinforcement material for improving concrete performance.

VI.CONCLUSION

This study investigated the effect of **basalt fiber reinforcement** on the mechanical properties of M25 grade concrete. Based on the experimental results and analysis, the following conclusions can be drawn:

- The incorporation of basalt fibers significantly improves both **compressive strength and split tensile strength** of concrete.
- The strength of concrete increases progressively with an increase in fiber content from **0% to 0.45%**.
- The maximum improvement in both compressive and tensile strength is observed at **0.45% basalt fiber content**, indicating it as the optimum dosage for the given mix.
- The enhancement in strength is primarily due to the **crack-bridging mechanism** of fibers, which delays crack initiation and propagation within the concrete matrix.
- Basalt fibers improve the **ductility and toughness** of concrete, reducing brittle failure and enhancing structural performance.
- Although strength properties improve, a slight reduction in workability is observed with increasing fiber content, which should be considered in practical applications.

Overall, basalt fiber reinforced concrete proves to be an **effective, durable, and sustainable material** for improving the performance of concrete structures. It is particularly suitable for applications requiring enhanced strength, crack resistance, and long-term durability.

VIII.FUTURE SCOPE

The present study demonstrates the effectiveness of basalt fiber in improving the mechanical properties of concrete. However, further research can be carried out to expand its applications and optimize performance under different conditions:

- **Higher Strength Concrete Grades:**
  Investigate the effect of basalt fiber in higher grade concretes (M40, M60, and above) to evaluate its performance in high-strength structural applications.
- **Hybrid Fiber Reinforcement:**
  Study the combined use of basalt fiber with other fibers such as steel, glass, or polypropylene to develop **hybrid fiber reinforced concrete** with enhanced mechanical and durability properties.
- **Durability Studies:**
  Analyze long-term durability aspects such as resistance to chemical attack, freeze-thaw cycles, corrosion, and permeability to assess performance in aggressive environmental conditions.
- **Workability Improvement:**
  Explore the use of superplasticizers and admixtures to overcome the reduction in workability caused by higher fiber content.
- **Structural Applications:**
  Evaluate the behavior of basalt fiber reinforced concrete in structural elements such as beams, columns, slabs, and pavements under real loading conditions.
- **Seismic and Impact Resistance:**
  Study the performance of basalt fiber reinforced concrete under dynamic loading, impact loads, and earthquake conditions to assess its suitability for disaster-resistant structures.
- **Sustainability and Cost Analysis:**
  Conduct life-cycle assessment and economic analysis to evaluate the environmental benefits and cost-effectiveness of using basalt fiber in construction.

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