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INVESTIGATING THE STRUCTURAL PROPERTIES OF BASALT FIBER REINFORCED CONCRETE

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Abstract*:* This project aimed to investigate the mechanical properties of basalt fiber-reinforced concrete (BFRC) and assess its potential for various construction applications. BFRC is a relatively new type of fiber-reinforced concrete that has shown favorable mechanical performance. Basalt fibers possess exceptional mechanical characteristics, including high strength, stiffness, and resistance to heat and chemicals. In this study, different proportions of basalt fibers were incorporated into the concrete mix to create BFRC specimens. Compression, flexural, and split tensile strength tests were conducted to evaluate the mechanical properties of the BFRC. The findings indicated that the inclusion of basalt fibers in the concrete mix resulted in improved mechanical properties, particularly in terms of flexural strength. Additionally, the compressive strength of the BFRC showed enhancement, albeit to a lesser extent compared to flexural and split tensile strength. The presence of basalt fibers in the concrete contributed to enhanced toughness and ductility, thereby enhancing the overall performance of the material. The study also examined the durability of the BFRC by subjecting specimens to freeze-thaw cycles and chemical exposure, demonstrating that the basalt fibers bolstered the concrete's resistance to cracking and deterioration under harsh environmental conditions. These results confirm the potential of basalt fiber-reinforced concrete as a viable alternative to conventional concrete in applications requiring superior strength, improved crack resistance, and extended service life. Future research could focus on optimizing fiber content and distribution within the concrete mix to achieve an optimal balance of mechanical properties. Furthermore, investigating the long-term behavior of BFRC in real-world scenarios would provide valuable insights into its performance and further validate its use as a sustainable and resilient construction material.

Keywords: basalt fiber-reinforced concrete, BFRC, mechanical properties, construction applications, basalt fibers, high strength, stiffness, heat resistance, chemical resistance, compression strength, flexural strength, split tensile strength, toughness, ductility, durability, crack resistance, freeze-thaw cycles, optimization, fiber content, distribution, long-term behaviour, sustainable construction material

I INTRODUCTION

Basalt fiber is a lightweight material produced from fine basalt fibres through a melting and spinning process. It possesses comparable strength to fiberglass but with a higher melting point and reduced weight. Basalt fiber finds applications in various industries, including construction, automotive, aerospace, marine, and sports equipment. It is a non-toxic, non-flammable, and non-carcinogenic material that offers versatility and performance

In the construction industry, basalt fiber is gaining prominence as a reinforcement material due to its exceptional tensile strength, corrosion resistance, and durability. It is often used as a substitute for traditional reinforcement materials like steel, fiberglass, and carbon fiber. Incorporating basalt fiber in concrete enhances its strength and longevity. Moreover, it can replace steel rebar in structures such as bridges, tunnels, and buildings, offering advantages such as lighter weight, ease of handling, and resistance to corrosion and high temperatures.

Basalt fiber also finds utility in the production of composite materials such as laminates and panels. These composites exhibit excellent resistance to impacts, vibrations, and thermal shocks, making them suitable for high-performance applications like wind turbine blades, marine vessels, and aerospace components. Beyond its mechanical properties, basalt fiber is environmentally friendly, as it originates from a renewable and abundant natural resource, is recyclable, and poses no toxicity concerns. Consequently, it is increasingly chosen for green building projects.

Overall, basalt fibber's exceptional properties and environmental benefits make it a promising material for diverse applications in multiple industries. Its superior strength, corrosion resistance, and durability position it as a viable alternative to conventional reinforcement materials, fostering advancements in construction and promoting sustainable practices.

II. LITERATURE REVIEW

The inclusion of basalt fibers in cementitious composites has been investigated in several studies. Meyyappan et al. [16] explored the use of basalt fibers to enhance the tensile strength of concrete, which is typically limited. Basalt fibers offer advantages such as high elastic modulus, thermal stability, chemical resistance, sound insulation, and electrical properties. The study incorporated basalt fibers at different volume fractions (0.5%, 1%, 1.5%, 2%, 2.5%, and 3%) into M30 grade concrete. The results showed that adding 1% basalt fibers yielded the best enhancement in strength properties, while further increasing the fiber volume led to diminishing returns. The 7-day compressive strength of basalt fiber-reinforced concrete ranged from 55% to 64% of the 28-day compressive strength, with a maximum split tensile strength improvement of 18.24% compared to ordinary concrete.

Adeyemi Adesina [10] provided an overview of basalt fiber reinforcement in cementitious composites, focusing on mechanical and durability aspects. The review highlighted the positive impact of basalt fibers on parameters like flexural strength and split tensile strength. However, further research is needed to fully understand their effect on compressive strength and durability performance. It was also noted that the addition of basalt fibers decreased the slump of cementitious composite mixtures compared to non-fiber mixtures.

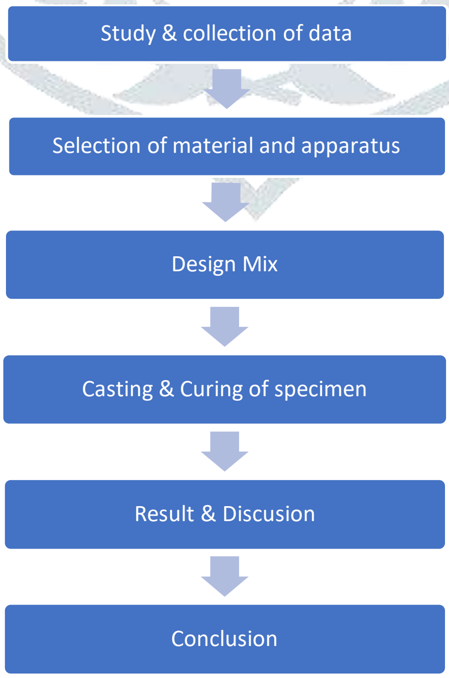
An experimental study [2] examined the effect of incorporating basalt fibers in an ultra-high-performance concrete (UHPC) T-beam. Results were compared to a similar T-beam reinforced with steel fibers. The study investigated two parameters: fiber volume fraction and shear span to effective depth ratio. Steel fibers contributed to a more ductile failure behavior, while basalt fibers improved compressive strength to a greater extent. The shear capacity of the compression zone in the T-beam was enhanced by the presence of basalt fibers. Basalt fibers also delayed the onset of diagonal cracking, with 0.5%, 1.0%, and 1.5% fiber content increasing cracking shear load by 160% compared to non-fibrous concrete.

The utilization of basalt fiber in self-compacting concrete (SCC) was explored in a study [8]. Different volumes (0%, 0.1%, 0.3%, and 0.5%) of basalt fibers with lengths of 3, 6, 12, and 24 mm were incorporated into SCC mixtures. The mechanical properties and durability of the hardened SCC were evaluated through tests for compressive strength, flexural strength, splitting tensile strength, rapid chloride permeability, and water penetration. The study found that the addition of basalt fibers reduced the workability of SCC but enhanced its mechanical characteristics. Optimal results for flexural and splitting tensile strength were achieved with 0.5% fiber content and a fiber length of 24 mm. Compressive strength was highest with 0.1% fiber content and fiber lengths of 12 mm and 24 mm. Based on strength and durability criteria, the study determined that a volume percentage of 0.49% and fiber length of 21.12 mm were optimal for basalt fiber in SCC. The compressive strength of these samples was about 9.5% higher than the control sample.

In summary, the literature review showcases the potential of basalt fiber reinforcement in cementitious composites, highlighting improvements in mechanical properties such as flexural strength, split tensile strength, and compressive strength. However, further research is needed to explore the full impact of basalt fibers on durability aspects and optimize their inclusion in concrete mixtures.

III .MIX DESIGN AND METHODOLOGY

Fig. 2: Flowchart of methodology



3.1 Chopped Basalt Fiber:

- Length 12mm
- Density 2.6gm/cubcm
- Tensile Strength 3200-3850MPa
- Filament Diameter 13-20 micron

- Elastic Modulus 93GPa
- Elongation At Break 3.15%
- Sizing Content 0.4%
- Moisture Content 0.1-12%
- Sustained Operating Temperature +680 ºC
- Minimum Operating Temperature -260 ºC
- Melting Temperature 1450 ºC

3.2 Mix Design :

- **Specimens**
  I) 6 cubes (15cm X 15cm X 15cm)
  II) 1cylinder (15cm X 30cm)
  III) 1 beam (15cm X 15cm X 75cm)
- **M35 Concrete Proportion Mix**
  I) Cement = 350kg/m^3
  II) Crush Sand = 955 kg/m^3
  III) Aggregate = 1190kg/m^3
  IV) Water cement ratio = 0.38
  V) Add mixture = 4.6 kg/m^3

Basalt Fiber % = (0,0.5,1.0,1.5)% of weight of cement

Table 1: Mix with basalt fiber Cement

Mix=>	0.0%	0.5%	1.0%	1.5%
Cement (kg)	16.90	16.90	16.90	16.90
Crush Sand (kg)	46.10	46.10	46.10	46.10
Aggregate (kg)	57.50	57.50	57.50	57.50
Water (kg)	6.50	6.50	6.50	6.50
Admixture (kg)	222.00	222.00	222.00	222.00
Basalt Fiber (gm)	0.00	84.50	169.00	235.50

3.3 MATERIALS:

Cement: The cement utilized in this research is ordinary Portland cement sourced from a local supplier. It is classified as 53-grade cement according to IS 11269. The specific gravity of the cement is 3.15, and its fineness, as per IS:4031-PART 1-1996, is less than 5%. Additionally, it possesses a commendable specific surface area of over 600 m2/kg. To ensure its quality, the cement is stored in a sealed environment, preventing moisture infiltration and avoiding the formation of lumps.

Fine aggregate: The fine aggregate employed in this research is sourced from a nearby location. It consists of clean river sand that adheres to the specifications outlined in IS:383 and is categorized as Zone-II. The specific gravity of the fine aggregate is 2.68, and it is free from any foreign particles. To maintain its quality, the sand is stored in large containers, preventing moisture infiltration. It is carefully managed to ensure cleanliness and dryness, enabling effective control of water content in the mix design.

Coarse aggregate: The coarse aggregate utilized in this study is obtained from a nearby crusher unit, derived from basalt rock. It possesses a non-flaky structure with well-defined edges. The aggregates are sieved on the crusher end to achieve a nominal size of 20 mm, adhering strictly to the standards set by IS 383. The coarse aggregate exhibits a specific gravity of 2.65 and an abrasion value of less than 6%. Furthermore, it demonstrates a commendable impact crushing strength of less than 3%, indicating its suitability for highway applications. To maintain its quality, the material is stored in a concrete tank with shelter, preventing water infiltration. Throughout the study, only clean and dried aggregate is used.

Water: The water employed in the entire process is tap water, characterized by a density of 1000 kg/m3. It has a pH value of 6.2 and a total dissolved solids (TDS) measurement of less than 500 ppm. The water is clear, devoid of any color or impurities

Admixture: For this project, the admixture used is Master Rebuild 8051. This admixture is suitable for concrete grades up to M40 and is particularly effective in enhancing the bond between fine particles, resulting in strong connections.

Basalt fiber : Basalt fiber is derived from basalt rock, a volcanic rock abundant in many regions worldwide. To produce basalt fibers, the rock is melted at high temperatures and extruded through fine nozzles. These fibers possess remarkable strength, stiffness, and exceptional resistance to heat and chemicals. The construction industry is increasingly embracing basalt fiber due to its ability to enhance the mechanical properties and durability of concrete. When incorporated into concrete mixes, basalt fibers bolster the strength and toughness of the resulting composite. Moreover, basalt fibers exhibit low thermal conductivity, making them ideal for applications requiring insulation properties. The versatility of basalt fiber extends to industries such as construction, aerospace, automotive, and sports equipment. Studying the mechanical properties of basalt fiber is crucial for comprehending its potential applications and optimizing its utilization across various sectors.

Fig 1) Basalt Fiber, Length 12mm

IV TESTING

The compressive strength test of concrete cubes serves as a comprehensive indicator of various concrete characteristics. This single test enables an assessment of the adequacy of the concrete placement. Typically conducted after 7, 14, or 28 days of curing, the concrete cube or cylinder test is employed to evaluate the strength of the concrete. Additionally, the split tensile strength and flexural strength of cylinders and beams were determined after 28 days of curing. These tests further contribute to a comprehensive understanding of the concrete's strength properties.

V RESULT

Table 2: Compressive strength of cubes

Days Of Testing	Name	Curing (Days)	Weight (kg)	Load (kN)	Compression Load on Cured Cubes (N/mm^2)
7	P1-1-7	6	8.395	254.300	11.302
	P1-2-7	6	8.500	357.000	15.867
	P2-1-7	6	8.420	257.900	11.462
	P2-2-7	6	8.420	358.100	15.916
	P3-1-7	6	8.780	383.300	17.036
	P3-2-7	6	8.795	360.900	16.040
14	P1-1-14	13	8.190	305.800	13.591
	P1-2-14	13	8.715	327.000	14.533
	P2-1-14	13	8.425	463.300	20.591
	P2-2-14	13	8.615	453.700	20.164
	P3-1-14	13	8.755	663.700	29.498
	P3-2-14	13	8.790	590.800	26.258
28	P1-1-28	27	8.725	492.400	21.884
	P1-2-24	27	8.720	449.100	19.960
	P2-1-24	27	8.665	545.400	24.240
	P2-2-24	27	8.815	404.500	17.978
	P3-1-24	27	8.635	779.300	34.636
	P3-2-24	27	8.445	664.300	29.525

FIg. 3: Compressive Strength of Cubes on 7th day

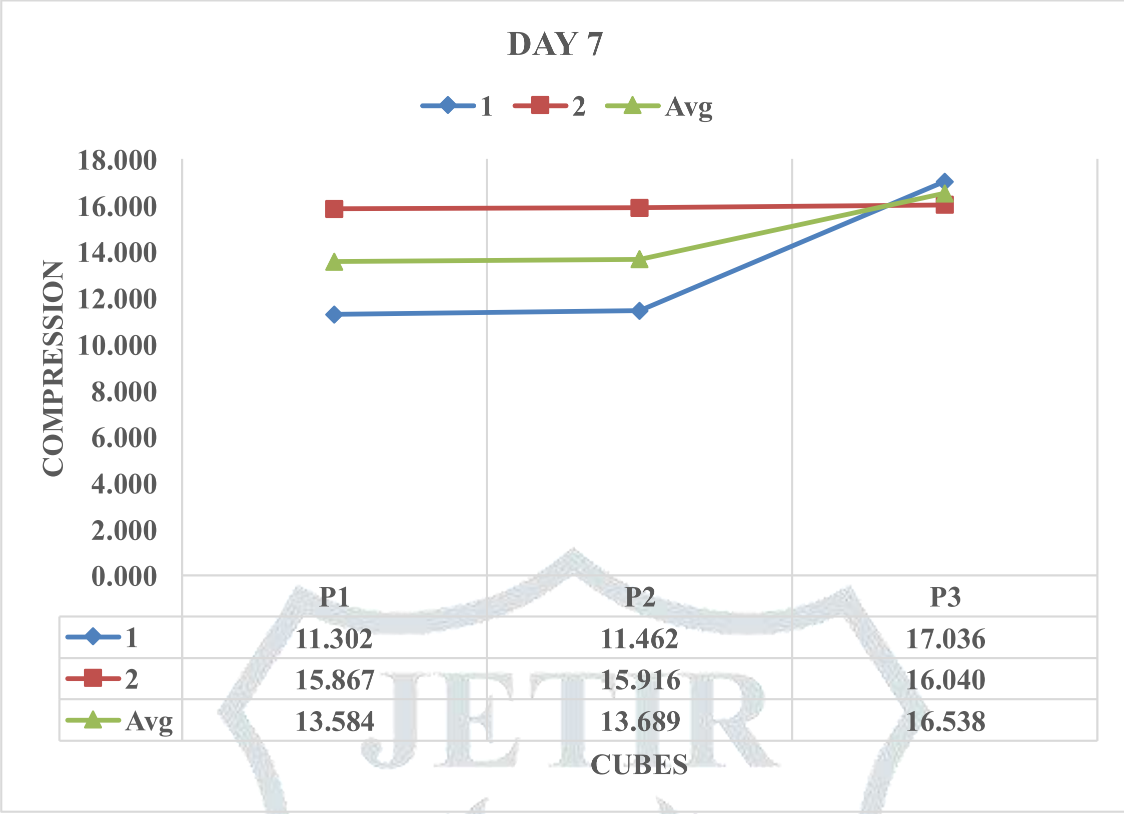


Fig. 4: Compressive Strength of Cubes on 14th day

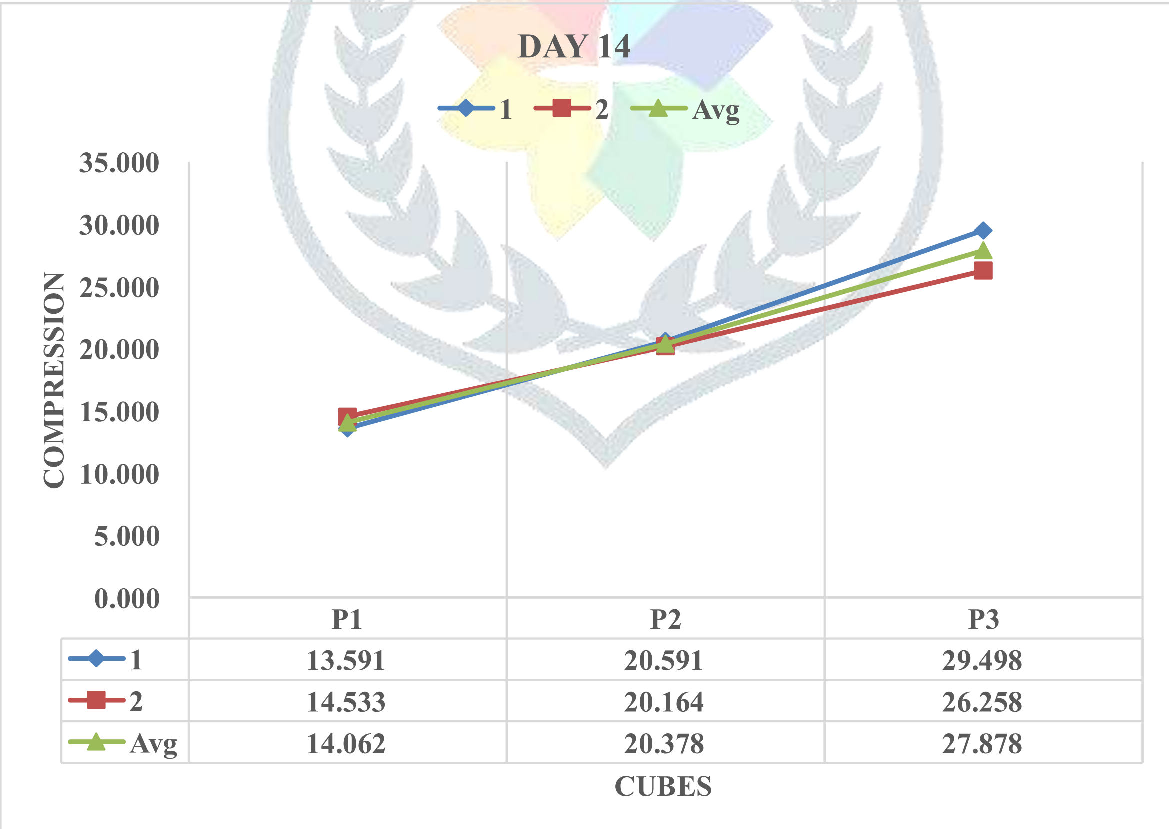


Fig. 5: Compressive Strength of Cubes on 28th day

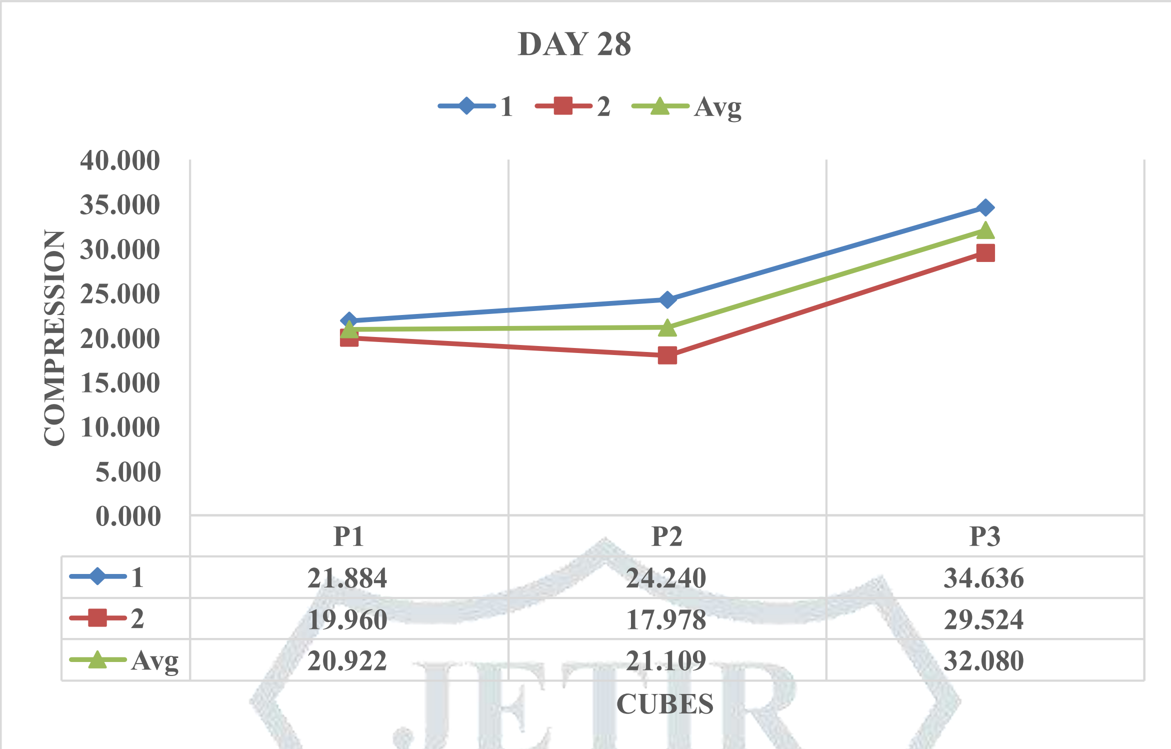


Table 3: Split Tensile Strength of Cylinder

Specimen	Name	Results on th Day		Split Tensile Strength (N/mm2)
		Weight (kg)	Load (kN)	
Cylinder	P1	13.485	140.8	1.9929
	P2	13.46	143.6	2.0326
	P3	13.825	215.5	3.0502

Fig. 6: Split Tensile Strength of Cylinder

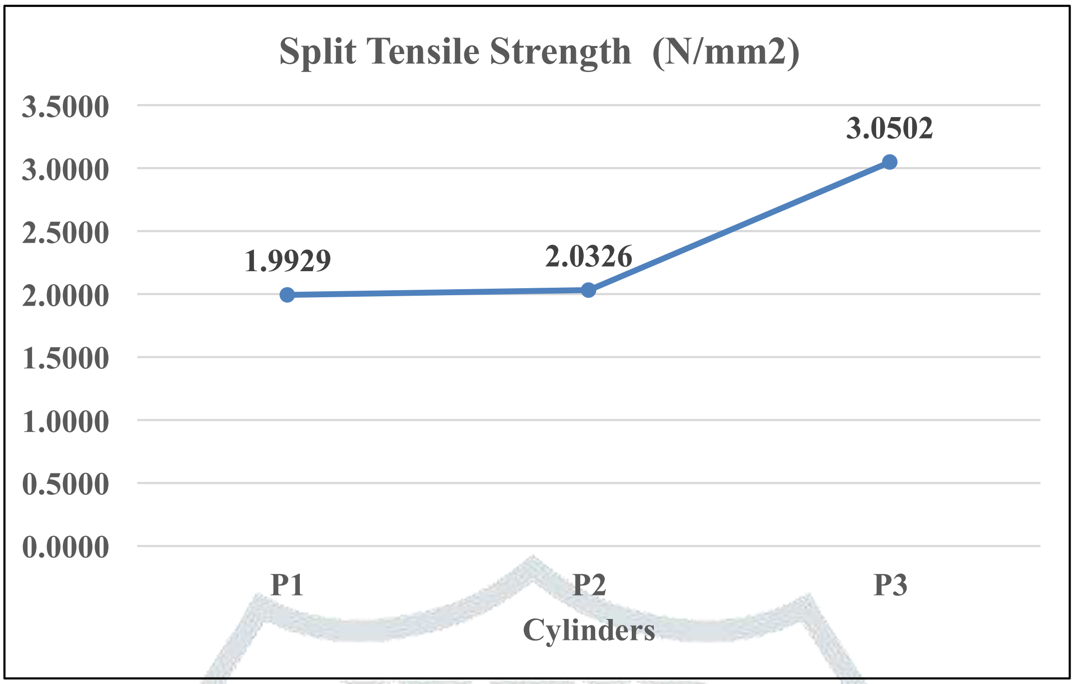
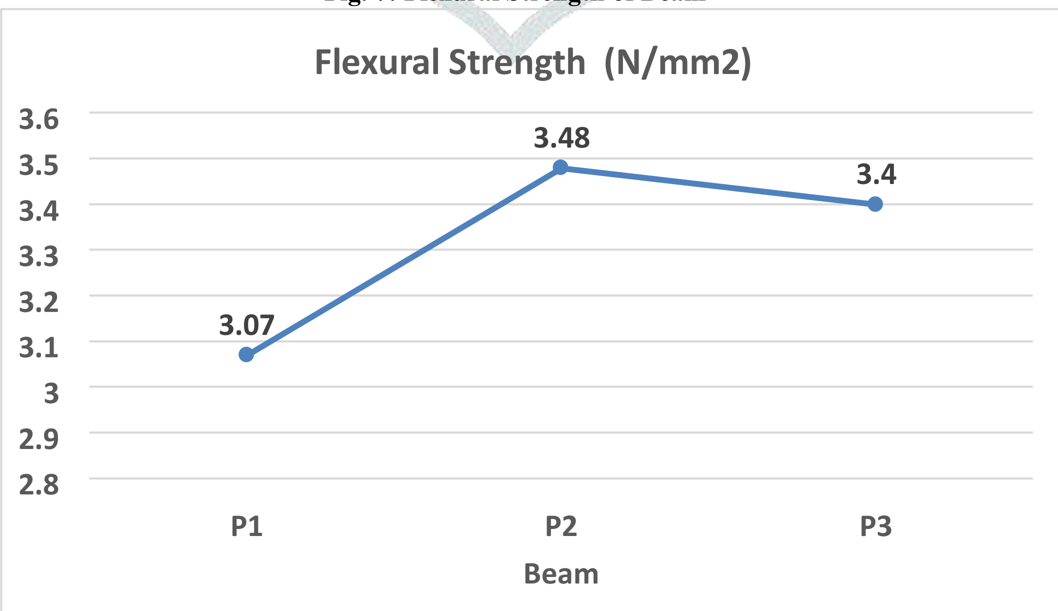


Table 4: Split Tensile Strength of Cylinder

Specimen	Name	Results on 28th Day		Flexural Strength (N/mm2)
		Weight(kg)	Load (kN)	
Beam	P1	40.410	11.50	3.07
	P2	39.820	13.05	3.48
	P3	40.350	12.75	3.40

Fig. 7: Flexural Strength of Beam



VI CONCLUSION-

I) The conclusions drawn from the aforementioned tests are as follows:

II) The compressive strength of the concrete cubes exhibited an increase in percentage as the amount of basalt fiber increased.

III) Similarly, the split tensile strength also showed an increase with a higher percentage of basalt fiber.

IV) Regarding flexural strength, mix P2 with 1% basalt fiber demonstrated a higher value compared to other mixes.

V) According to Meyyappan et al. [16], the optimal volume fraction is 1%. In this study, 1% of the cement weight was added to mix P2, resulting in a higher flexural strength.

VI) These findings support the notion that the inclusion of basalt fiber, particularly at the optimal dosage, can enhance the compressive strength, split tensile strength, and flexural strength of concrete.

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