EXPERIMENTAL STUDY ON MECHANICAL PROPERTIES OF HIGH PERFORMANCE CONCRETE REINFORCED WITH BASALT FIBER AND POLYPROPYLENE FIBER

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Abstract - *High-performance concrete is typically used for high towers, long-span bridges, mega-structures, as well as the rehabilitation of historic kinds of structures. For a strong and long-lasting structure, HPC appears to be a better option. To solve the world's existing material cost issue, researchers are looking for new low-cost materials that work better in concrete. HPC cannot be accomplished solely by the use of OPC or solely through the reduction of W/c ratio through the use of admixtures, but also through the replacing cement with minerals admixture. The use of Silica Fume and Fly Ash as additional cementing materials and super plasticizers in concrete results in the development of high-performance, long-lasting concrete. As fibres are added to high-performance concrete, the structure is transformed from brittle to ductile, improving the engineering properties of the material. In this study Silica Fume and Fly ash are replacing cement in 5% and 15% and Basalt Fiber and Polypropylene fiber Addition with (0.1%, 0.15%, and 0.2%) and (0.5%, 1% and 1.5%) and design M70 grade of concrete mix design Based on IS Code 10262:2019 and find the mechanical and durability property of concrete with basalt and polypropylene fiber.*

***Key Words*: High-performance concrete, Basalt fiber, Polypropylene fiber, Silica fume, Fly ash, Compressive Strength test, Split Tensile Strength test, Flexural strength test, Durability test, Workability test.**

1. INTRODUCTION

Concrete has played a crucial role in the evolution of human civilization. With the advancement of human civilization, it is well understood that concrete will continue to be a prevalent construction material in the future. As opposed to conventional concrete, High Performance Concrete (HPC) is a combination of concrete that has a higher consistency and strength. High Performance Concrete is described as any concrete that meets certain criteria for overcoming conventional concrete limitations. The water - cement ratio in high-performance concrete is much lower than in conventional concrete, and it can contain mineral admixtures that alter the fresh and hardening properties of the concrete.

Improvements in reliability, such as placing and compacting without segregation in extreme conditions, long-term mechanical properties, and early-age strength or service life, are all required by the standards.

To assess mechanical properties of HPC such as compressive strength test, flexural strength test, Split tensile strength test, and slump test, detailed laboratory investigations were carried out with various proportions and combinations of admixtures and fibres.

1.1 Cement

Ordinary Portland Cement (OPC) 53 grade is the cement form that was chosen based on the specific specifications of the current analysis. Cement was tested according to IS: 12269-1987:

1.2 Fine Aggregate

Aggregates have structure of the proportions that make up the majority of concrete. Since concrete needs 35 percent fine aggregates, the use of good quality aggregates in high-strength concrete is particularly critical for the desired characteristics. Fine aggregates are in high demand due to the worldwide rise in building activities.

Fine aggregate is described as aggregate that passes through a 4.75 mm IS Sieve and is retained on a 150 micron IS Sieve.

1.3 Coarse Aggregate

The greatest and least porous material for concrete is considered to be CA. It should also be a material that is extremely stable. The crushed granite, 20 mm and 12.5 mm down, available locally, is used for the present work as a C.A.

1.4 Silica Fume

Silica fume was a thin pozzolanic powder that was mixed with cement. It improves the concrete's strength as well as its longevity. Water permeability and cement quantity are also reduced as silica fume is added to concrete. It was used in any situation where high-strength concrete was needed. The addition of silica fumes to cement makes it sulphate and chloride resistant, as well as reducing slump, segregation, and shrinkage cracks. It has anti-carbonation qualities.

1.5 Fly Ash

In the manufacture of Portland cement concrete, fly ash was used as a supplemental cementitious substance (SCM). When used in combination with Portland cement, a supplementary cementitious substance adds to the properties of the hardened concrete by hydraulic or pozzolanic action, or both.

1.6 Basalt fiber

Basalt fibre was a composite constructed from basalt fibres that were incredibly fine. Basalt fibre was a modern kind of eco-friendly, green, and high-performance fibre that performed well and was commonly used in a variety of applications. Acid and alkali tolerance are two important properties of basalt fibres. It's also resistant to cracks and corrosion. Basalt fibre can help cement matrix composites increase their flexural strength, hardness, and fracture energy.

1.7 Polypropylene fibre

Polypropylene fiber, also known as polypropene or PP, is a synthetic fiber, transformed from 85% propylene, and used in a variety of applications.

polypropylene (PP) fibers on various properties of concrete in fresh and hardened state such as compressive strength, tensile strength, flexural strength, workability, bond strength, fracture properties, creep strain, impact and chloride penetration.

1.8 Super-plasticizer

CONFLOW-CP is an admixture of a new generation based on modified Polycarboxylic ether. The product has been primarily developer for application in high performance concrete where the highest durability and performance is required.

CONFLOW-CP is free of chloride and low alkali, it is compatible with all type of cement.

2. MIX PROPORTION

- According to IS 10262: 2019 Concrete Mix Proportioning
- Concrete grade M70
- w/c ratio adopted = 0.264
- Admixture = 1% (Polycarboxylate based advance super plasticizers)

TABLE 1: MIX PROPORTION

The Mix Proportion then becomes (By Wt. kg) (Consumption per m3)						
Water	Cement	Silica fume	Fly ash	FA	CA	Total
141	428	26.75	80.25	589	1219	2484
0.329	1.00	0.0625	0.188	1.38	2.85	5.81

TABLE 2: FIBER CONSUMPTION PER M^3

Polypropylene fiber (PF%) volume fraction	Consumption per cubic meter (kg)	Basalt fiber (BF%) volume fraction	Consumption per cubic meter (kg)
0.5	4.6	0.1	2.65
1.0	9.2	0.15	3.97
1.5	13.8	0.2	5.30

TABLE 3: FIBER MIX PROPORTION

Mix Designation	Polypropylene fiber (PF%) volume fraction	Basalt fiber (BF%) volume fraction
M0	0	0
M1	0.1	0
M2	0.15	0
M3	0.2	0
M4	0	0.5
M5	0	1.0
M6	0	1.5
M7	0.1	0.5
M8	0.1	1.0
M9	0.1	1.5
M10	0.15	0.5
M11	0.15	1.0

M12	0.15	1.5
M13	0.2	0.5
M14	0.2	1.0
M15	0.2	1.5

3. EXPERIMENTAL INVESTIGATION

Fresh concrete tests are used to determine the workability of the concrete, while hardened concrete tests are used to determine the consistency of the concrete.

1. SLUMP TEST

The workability of High-Performance Concrete is generally good at low slumps, and it is also typically pumpable, thanks to the high volume of cementitious materials and the addition of chemical admixtures. High Performance Concrete has been successfully pumped up to 20 storeys. Workable concretes can fill heavily reinforced sections without division or voids of significant scale. The rate of flow is a critical element in deciding the rate of output and the placement plan for workable concrete. It may also be used to evaluate the consistency of the mixture.

TABLE 4: SLUMP TEST RESULT

MIX	Polypropylene fiber (PF%) volume fraction	Basalt fiber (BF%) volume fraction	Slump Value M70 (mm)
M0	0	0	74
M1	0.1	0	75
M2	0.15	0	73
M3	0.2	0	75
M4	0	0.5	76
M5	0	1.0	72
M6	0	1.5	77
M7	0.1	0.5	78
M8	0.1	1.0	75
M9	0.1	1.5	76
M10	0.15	0.5	74
M11	0.15	1.0	79
M12	0.15	1.5	72
M13	0.2	0.5	75
M14	0.2	1.0	74
M15	0.2	1.5	76

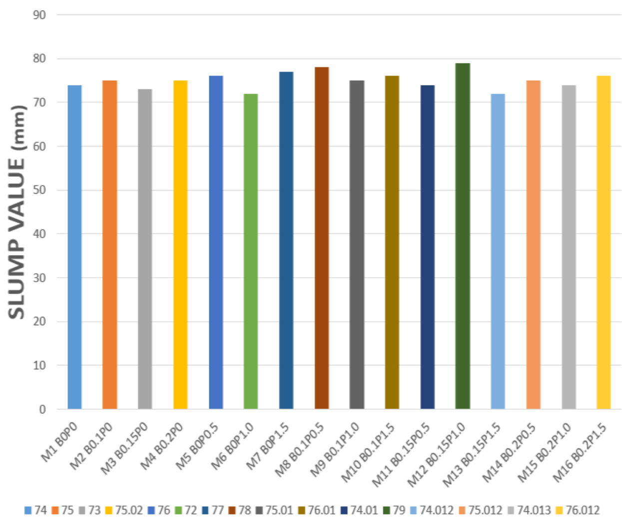

FIGURE 1: SLUMP TEST

2. COMPRESSIVE STRENGTH

Compressive strength test is shown on 7the compression testing machine. Size of cube is 150 mm * 150 mm * 150 mm. Compressive Strength was determined after 28 days and 56 days of curing respectively.

2.1 COMPRESSIVE STRENGTH AFTER 7 DAYS.

Cast cube specimens with dimensions 150 mm x 150 mm for M 70 Grade with concrete were used for the compressive strength test.

TABLE 5: COMPRESSIVE STRENGTH AT 7 DAYS

MIX	Polypropylene fiber (PF%) volume fraction	Basalt fiber (BF%) volume fraction	7 days Average compressive strength (N/mm^2)
M0	0	0	52.8
M1	0.1	0	52.3
M2	0.15	0	53.3
M3	0.2	0	56.6
M4	0	0.5	50.1
M5	0	1.0	54
M6	0	1.5	55.4
M7	0.1	0.5	51.8
M8	0.1	1.0	49
M9	0.1	1.5	47.7
M10	0.15	0.5	53.7
M11	0.15	1.0	60.3
M12	0.15	1.5	54.9
M13	0.2	0.5	53.32

M14	0.2	1.0	51.7
M15	0.2	1.5	48.4

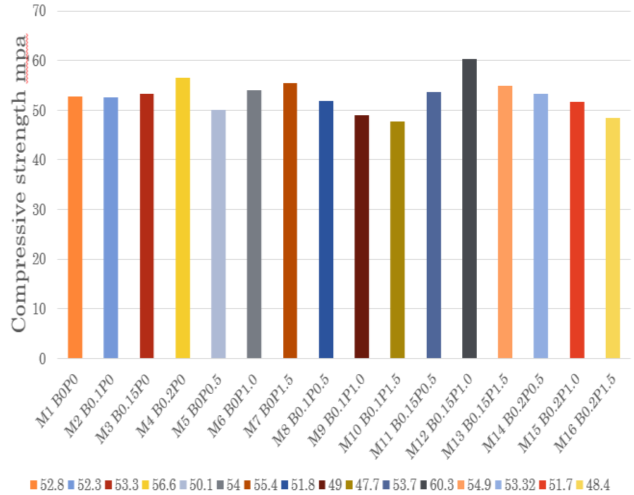

FIGURE 2: COMPRESSIVE STRENGTH AT 7 DAYS

2.2 COMPRESSIVE STRENGTH AFTER 7 DAYS.

TABLE 6: COMPRESSIVE STRENGTH AT 28 DAYS

MIX	Polypropylene fiber (PF%) volume fraction	Basalt fiber (BF%) volume fraction	7 days Average compressive strength (N/mm²)
M0	0	0	80
M1	0.1	0	79.3
M2	0.15	0	80.8
M3	0.2	0	85.7
M4	0	0.5	75.9
M5	0	1.0	81.8
M6	0	1.5	83.9
M7	0.1	0.5	78.5
M8	0.1	1.0	74.3
M9	0.1	1.5	72.2
M10	0.15	0.5	81.4
M11	0.15	1.0	91.3
M12	0.15	1.5	83.2
M13	0.2	0.5	80.8
M14	0.2	1.0	78.3
M15	0.2	1.5	73.3

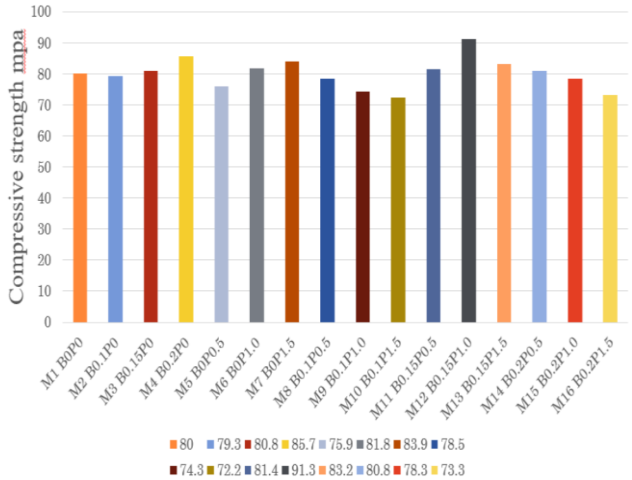

FIGURE 3: COMPRESSIVE STRENGTH AT 28 DAYS

3. SPLIT TENSILE STRENGTH

Cylinder specimens of 150 mm x 300 mm in diameter and height are casted for M70 grade concrete for split tensile testing.

3.1 Split Tensile Strength After 28 Days

TABLE 7: SPLIT TENSILE STRENGTH AT 28 DAYS

MIX	Polypropylene fiber (PF%) volume fraction	Basalt fiber (BF%) volume fraction	28 days Average Split Tensile strength (N/mm²)
M0	0	0	6.45
M1	0.1	0	7.15
M2	0.15	0	7.41
M3	0.2	0	7.90
M4	0	0.5	7.21
M5	0	1.0	7.40
M6	0	1.5	7.51
M7	0.1	0.5	7.39
M8	0.1	1.0	7.60
M9	0.1	1.5	7.27
M10	0.15	0.5	8.39
M11	0.15	1.0	8.16
M12	0.15	1.5	7.62
M13	0.2	0.5	7.96
M14	0.2	1.0	7.82
M15	0.2	1.5	7.73

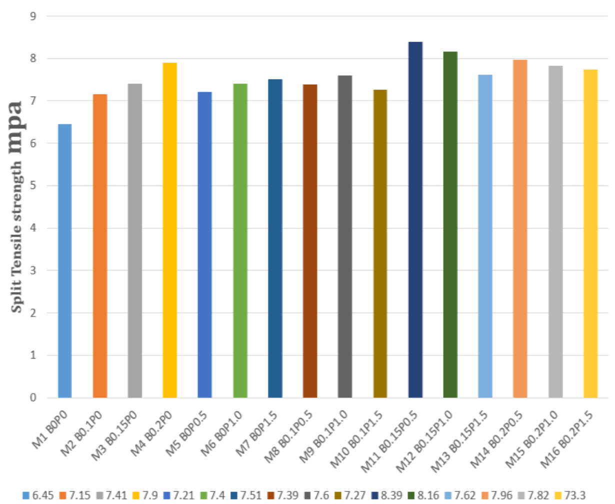

FIGURE 4: SPLIT TENSILE STRENGTH AT 28 DAYS

4. FLEXURAL STRENGTH

Beam specimens of dimensions 150 mm x 150 mm x 700 were casted for M 70 Grade of concrete for flexural strength testing.

4.1 Flexural strength After 28 Days

TABLE 8: FLEXURAL STRENGTH AT 28 DAYS

MIX	Polypropylene fiber (PF%) volume fraction	Basalt fiber (BF%) volume fraction	28 days Average Flexural strength (N/mm^2)
M0	0	0	6.29
M1	0.1	0	7.52
M2	0.15	0	7.56
M3	0.2	0	7.83
M4	0	0.5	6.36
M5	0	1.0	7.10
M6	0	1.5	7.25
M7	0.1	0.5	7.38
M8	0.1	1.0	7.50
M9	0.1	1.5	7.59
M10	0.15	0.5	7.93
M11	0.15	1.0	7.72
M12	0.15	1.5	7.22
M13	0.2	0.5	6.67
M14	0.2	1.0	6.60
M15	0.2	1.5	6.31

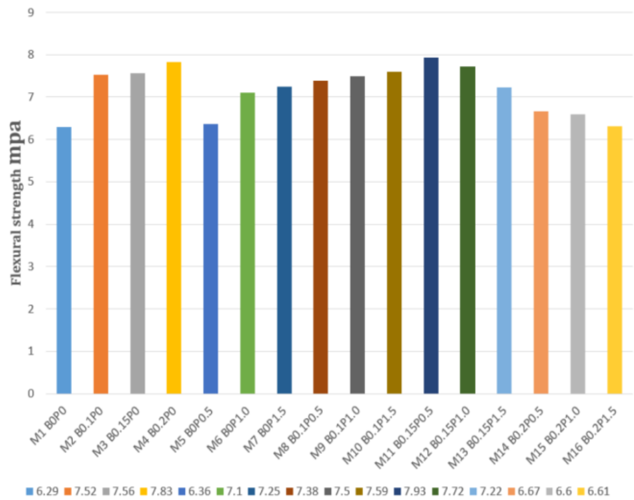

FIGURE 5: FLEXURAL STRENGTH AT 28 DAYS

5 DURABILITY TEST

After 28 days of curing, the cubes are removed from the water and cleaned, as well as the weight of the cubes. After the weight cubes have been immersed in H2SO4 and NaCl for the next 28 days, the strength of the cubes will be assessed.

5.1 Acid attack

The lack of compressive strength after 56 days or the difference of compressive strength of concrete cubes after 28 days and 28 days submerged in Sulphuric acid can be used to determine the susceptibility of concrete to acid attack (H2SO4). The concrete cubes with dimensions of 150mm X 150mm will be soaked in 5% sulphuric acid for 28 days, followed by 28 days of curing in natural water. The concrete cubes will be removed after a 28-day immersion time in acidic water to be observed for corrosion and cleaned in tap water before being weighed in a digital balance and checked for compressive strength. Changes in weight and compressive strength can be noted, as well as the percentage reduction in compressive strength.

TABLE 9: ACID ATTACK TEST AT 56 DAYS

MIX	Avg. Comp. Strength at 28 days (N/mm^2)	Avg. Comp. Strength at 56 days Acid attack (H2SO) (N/mm^2)	Loss in Comp Strength (%) @56 days
M0	80	74.55	6.81
M1	79.3	74.00	6.69
M2	80.8	75.77	6.22
M3	85.7	80.57	5.98
M4	75.9	70.15	5.75

M5	81.8	77.38	5.40
M6	83.9	78.01	5.89
M7	78.5	73.86	5.91
M8	74.3	70.07	5.69
M9	72.2	68.23	5.50
M10	81.4	77.00	5.41
M11	91.3	86.63	5.12
M12	83.2	79.18	4.83
M13	80.8	76.72	5.05
M14	78.3	74.13	5.33
M15	73.3	69.49	5.20

5.2 Sulphate attack

The loss of compressive strength or compressive strength of a concrete cube immersed in 5% sodium chloride (5%), and water-free sulphates was measured to determine concrete resistance to sulphate pressure. During 28 days of hydration hardening, a 150 mm x 150 mm concrete cube was immersed in 5 percent Na2SO4 and 5 percent MgSO4 for 28 days. The sulphate concentration was kept constant during this period. The concrete cubes were taken out of the sulphate bath after 28 days and rubbed off the water and soil from the cube surface before being checked for compressive strength according to the protocol stated in IS: 516-1959. This form of fin acceleration test dings out the lack of compressive strength for measuring concrete's sulphate resistance.

TABLE 10: SULPHATE ATTACK TEST AT 56 DAYS

MIX	Avg. Comp. Strength at 28 days (N/mm²)	Avg. Comp. Strength at 56 days Sulphate attack (Nacl) (N/mm²)	Loss in Comp Strength (%) @56 days
M0	80	74.00	7.5
M1	79.3	73.50	7.32
M2	80.8	75.23	6.89
M3	85.7	79.87	6.80
M4	75.9	70.75	6.78
M5	81.8	76.48	6.50
M6	83.9	77.67	6.23
M7	78.5	72.93	7.1
M8	74.3	69.26	6.79
M9	72.2	67.57	6.41
M10	81.4	75.94	6.70
M11	91.3	85.47	6.39
M12	83.2	78.28	5.91
M13	80.8	75.57	6.47
M14	78.3	73.05	6.70
M15	73.3	68.15	7.02

5.3 Carbonation testing

The moment concrete is released to the sunlight, it starts to react with carbon dioxide. Concrete is very alkaline (high pH). This high alkalinity interacts with the bare steel on reinforced steel to form a passivation coat, which is an oxide film that forms around the steel. The steel is protected from corrosion by this sheet. Concrete's pH is reduced as a result of the reaction with carbon dioxide. This procedure begins on the pavement and progresses into the concrete. Cracks in the concrete surface will speed up the reaction. Concrete's reaction with carbon dioxide does not always weaken the concrete's efficiency. As an auditor, I'm concerned that if the reaction reaches the reinforced steel, the pH will decrease to the point where the oxide layer around the steel will be affected. When this happens, the steel becomes susceptible to corrosion due to the electrochemical process. Carbonation inspection allows the investigator to assess the amount of carbon dioxide that has gotten into the concrete. The procedure is similar to chloride ion testing in that a sample is extracted by coring or drilling, and the sample is then analyzed with a revealer. Phenolphthalein is a widely used revealer.

As phenolphthalein is mixed with concrete with a high pH (greater than 10) the result is a bright pink solution. As the solvent comes into contact with a low pH (less than 10) it does not change color, indicating that the concrete is carbonated.

TABLE 11: CARBONATION TESTING AT 56 DAYS

MIX	Polypropylene fiber (PF%) volume fraction	Basalt fiber (BF%) volume fraction	Carbonated or non-carbonated
M0	0	0	non-carbonated
M1	0.1	0	non-carbonated
M2	0.15	0	non-carbonated
M3	0.2	0	non-carbonated
M4	0	0.5	non-carbonated

M5	0	1.0	non-carbonated
M6	0	1.5	non-carbonated
M7	0.1	0.5	non-carbonated
M8	0.1	1.0	non-carbonated
M9	0.1	1.5	non-carbonated
M10	0.15	0.5	non-carbonated
M11	0.15	1.0	non-carbonated
M12	0.15	1.5	non-carbonated
M13	0.2	0.5	non-carbonated
M14	0.2	1.0	non-carbonated
M15	0.2	1.5	non-carbonated

6. CONCLUSIONS

- The strength of HPC concrete are increases with fibers.
- All the HPC concrete mix gets good slump nearly 75 mm.
- The splitting tensile strength of HPC reinforced with a single fibre was increased by 22.48%, and the flexural strength of HPC reinforced with a single fibre was increased by 24.48%.
- There are both positive and negative synergy results as the two kinds of fibres are combined. The synergy effect of hybrid fibres was highest when the volume fraction of basalt fibre was 0.15% and the polypropylene fibre was 1.0%.
- As compared to HPC without fibre, compressive strength, flexural strength, and splitting strength are all improved by 14.13%, 22.73%, and 26.41% respectively.
- Due to addition of Basalt fiber and polypropylene in concrete, we can minimize the pores in concrete and give good resistant to acid attack and sulphate attack.
- All the mix design are free from carbonation.

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