International Research Journal in Global Engineering and Sciences. (IRJGES)
ISSN : 2456-172X | Vol. 9 Issue 1 - March 2024 to May 2024| Pages 10-16

EXPERIMENTAL INVESTIGATION ON HIGH PERFORMANCE CONCRETE USING GLASS FIBRE AND FLY ASH

[1]DHAVAMANI DOSS SAKTHIDOSS, [2]MOHAMED MEERA MAIDHEEN, [3]PALANIKUMAR B, LOGARAJA R.
[1]Associate Professor, Civil Engineering, Sethu Institute of Technology, Virudhunagar.
[2]Assistant Professor, Civil Engineering, Sethu Institute of Technology, Virudhunagar.
[3] Assistant Professor, Civil Engineering, Sethu Institute of Technology, Virudhunagar.
[4]Assistant Professor, Civil Engineering, Sethu Institute of Technology, Virudhunagar.

ABSTRACT

The global construction industry currently uses high-performance concrete (HPC) extensively. High-performance concrete seems to be a superior option for a robust and enduring structure. This uniquely engineered concrete uses standard and specialised materials to meet a set of performance criteria. This project examined the strength properties, such as compressive strength, split tensile strength, and flexural strength, of M40-grade high-performance concrete (HPC) mixes. The study included varying replacement levels of cement by fly ash at 25%, 30%, 35%, and 40%, as well as equivalent percentages of glass fibre, sand, using a water-binder ratio of 0.35. We use BASF superplasticizer to improve the workability of high-performance concrete. We formulate the HPC mix, grade M40 concrete, in accordance with conventional standards IS: 10262-2019 and IS: 456-2000. We analysed the mechanical properties of compressive strength, split-tensile strength, and flexural strength. The findings of these investigations illustrate the strength attributes of stone dust and the properties of concrete mixtures incorporating fly ash. The results indicate that substituting glass fibre at the same percentage along with 25% fly ash and 1.2% superplasticizer yielded superior characteristics. This report presents the details and results of the investigations.

1.0 Introduction

High-performance concrete (HPC) is a concrete variant engineered to attain superior mechanical and durability properties, exceeding those of traditional concrete. Due to its exceptional mechanical properties, including high compressive strength, tensile strength, and modulus of elasticity, high-performance concrete (HPC) is increasingly favoured for constructing structures that demand superior load-bearing capacity and durability. The enhanced properties are achieved by optimising mix designs, often incorporating low water-cement ratios, high-reactivity supplementary cementitious materials (SCMs), and advanced chemical admixtures [1], [2]. The results from the densification of the microstructure and the use of pozzolanic materials, such as silica fume, fly ash, and Ground Granulated Blast-furnace Slag (GGBS). These materials not only augment the strength of the cement matrix by occupying voids, but they also enhance the durability of the cement by diminishing the penetration of deleterious agents such as chlorides and sulphates. Besides its mechanical advantages, high-performance concrete (HPC) enhances sustainability by enabling thinner structural sections and decreasing cement content through the partial substitution with short-cycle materials (SCMs). This leads to a decrease in the carbon footprint associated with construction projects, aligning with the growing focus on sustainable building practices [5], [6]. Consequently, high-performance computing is extensively utilised in sectors like marine infrastructure, skyscrapers, and long-span bridges, all of which necessitate exceptional mechanical performance and durability for operational success.

2.0 Literature Review

High-performance concrete (HPC) is characterised by its compliance with particular criteria for superior mechanical properties and durability in extreme conditions. It generally includes premium ingredients and expertly formulated mixtures to attain superior strength, workability, and enduring durability [3]. Fly ash, a by-product of coal combustion, is frequently utilised as a supplementary cementitious material in high-performance concrete. Research indicates that fly ash improves the workability and durability of concrete by decreasing permeability and enhancing resistance to sulphate attack, chloride penetration, and freeze-thaw cycles [1]. Glass fibres are utilised to enhance concrete properties owing to their exceptional tensile strength, durability, and resistance to cracking. The inclusion of glass fibres in high-performance concrete enhances flexural strength, crack control, and impact resistance, rendering it appropriate for high-stress conditions [2]. Research indicates that the combination of fly ash and glass fibre in high-performance concrete (HPC) yields synergistic benefits, enhancing mechanical properties and durability. Glass fibres reduce the brittleness of concrete, whereas fly ash improves workability and decreases heat generation [5]. The influence of fly ash on the compressive strength of concrete is contingent upon the replacement ratio and the specific type of fly ash utilised. Studies indicate that fly ash enhances compressive strength at later ages through its involvement in pozzolanic reactions [1]. Glass fibre reinforcement enhances the tensile strength of concrete by regulating crack propagation. [6] found that incorporating 1% to 2% glass fibre content notably improved the tensile strength of high-performance concrete. Glass fibre and fly ash enhance the durability of high-performance concrete (HPC) by decreasing permeability and improving resistance to chemical attack. Fly ash decreases the porosity of concrete, whereas glass fibre mitigates cracking, thereby prolonging the service life of concrete structures [8]. Fly ash enhances the workability of high-performance concrete, particularly at elevated replacement levels, by decreasing the water-cement ratio. Studies indicate that fly ash may prolong the setting time, a challenge that can be mitigated by employing chemical accelerators [3]. Glass fibres are incorporated into concrete in different forms, such as chopped strands or continuous filaments. [11] demonstrate that the addition of 0.5% to 1% glass fibre by weight enhances the flexural strength of concrete. The integration of fly ash and glass fibres leads to notable enhancements in crack resistance. Research indicates that fibres contribute to crack arrest, whereas fly ash mitigates shrinkage and the potential for cracking due to its lower heat of hydration [10]. Studies on the structural behaviour of high-performance concrete (HPC) mixes indicate that incorporating fly ash and glass fibres enhances the load-bearing capacity and deformation properties of concrete structures subjected to dynamic loading conditions [8]. The incorporation of glass fibre enhances the impact resistance of concrete. Recent studies indicate that concrete reinforced with glass fibres exhibits enhanced resistance to impact loads, which is advantageous for construction subjected to dynamic forces, including seismic activity [6]. Long-term performance studies demonstrate that high-performance concrete (HPC) incorporating fly ash retains its strength and durability in adverse environmental conditions. The reduced permeability of concrete largely accounts for the prevention of harmful chemical ingress [7]. Fly ash and glass fibre both play a role in promoting sustainability. Fly ash minimises environmental impact by decreasing the quantity of Portland cement needed, while glass fibre enhances the durability of concrete, thus reducing the frequency of repairs [4]. Fly ash utilisation lowers concrete costs by serving as a partial substitute for cement. While the inclusion of glass fibre reinforcement increases material costs, the long-term advantages related to durability and decreased maintenance expenses render this combination economically viable over time [9]. The type of fly ash utilised can significantly impact the performance of high-performance concrete (HPC). Class F fly ash typically exhibits superior strength and durability relative to Class C fly ash, which demonstrates greater reactivity. The choice of fly ash type must align with the intended performance attributes of the concrete [10]. Research indicates that incorporating glass fibres at a volume fraction of 0.5% to 2% by weight leads to notable enhancements in strength and crack resistance, with no further significant advantages beyond this range [8]. Fly ash improves concrete's resistance to harsh environments, such as those involving chlorides and sulphates. The use of HPC with fly ash demonstrates significant effectiveness in marine environments, offering long-term durability against chloride-induced corrosion [2]. Recent experimental studies have investigated the effects of varying proportions of fly ash and glass fibre in concrete mixes on both fresh and hardened properties. The findings indicate that a combination of 10-20% fly ash and 1% glass fibre produces concrete with enhanced performance [11]. Challenges persist in optimising high-performance concrete (HPC) mix designs that incorporate glass fibre and fly ash, particularly in achieving an appropriate balance among strength, workability, and durability. Future research may investigate the application of hybrid fibres or nanomaterials to improve the properties of HPC [3].

3.0 Experimental Investigation

This study examines the integration of glass fibres and fly ash in high-performance concrete to assess their joint impacts on mechanical properties, including compressive, tensile, and flexural strength. Glass fibres reinforce the concrete matrix, increasing toughness and crack resistance, whereas fly ash partially replaces cement, thereby improving sustainability and reducing the carbon footprint of the concrete mix. This study seeks to identify optimal ratios of glass fibre and fly ash to enhance the mechanical performance of concrete, thereby ensuring its suitability for high-strength, durable applications. To find out the pros and cons of using these materials in high-performance concrete (HPC), this study uses controlled laboratory tests to measure their compressive, tensile, and flexural strengths. This will help come up with possible solutions for using sustainable and high-performing concrete in a variety of situations.

3.1 Material Properties

The material properties plays a vital role in the performance of concrete since the mechanical properties of concrete. The material properties such as specific gravity, fineness modulus of materials are determined by conducting specific gravity and sieve analysis test in the laboratory. The test results are shown in Table 1.

Table 1 Properties of Materials

Sl. No.	Type of Test	Type of Material	Findings	Value
1	Specific Gravity	Cement	Specific Gravity	3.10
2		Fly Ash		2.01
3		Sand		2.64
4		Crushed Stone		2.77
5	Water absorption	Sand	% of water absorption	0.76
6		Crushed Stone		0.296
7	Sieve Analysis	Sand	Fineness Modulus	2.80

8		Crushed Stone		7.25
9	Slump Test	Conventional Concrete	Workability in mm	80
10		Concrete with 1 % of Glass fibre		80
11		Concrete with 2 % of Glass fibre		83
12		Concrete with 3 % of Glass fibre		84
13		Concrete with 4 % of Glass fibre		86

3.2 Mechanical Properties

Construction commonly uses concrete, a composite material known for its versatility, strength, and durability. Cement, water, aggregates (fine and coarse), admixtures, mix design, curing process, and ambient conditions influence its properties. We can divide the properties of concrete material into three categories: mechanical, physical, and durability.

Compressive Strength: Concrete has a high compressive strength, which means it can hold up against axial loads. This property is mostly affected by the amount of water to cement and the quality of the aggregates.

Tensile Strength: The tensile strength of concrete is very low, only about a tenth of its compressive strength. Adding fibres or reinforcements is often a good way to make this better.

Flexural Strength: This shows how well concrete can handle bending stresses and is very important for building parts like slabs and beams. The modulus of elasticity shows how stiff concrete is and how much it can stretch when it's loaded. The test results are shown Table 2.

Table 2 Properties of Materials

Sl.No.	Percentage of Glass Fibre	Percentage of Fly Ash	Compressive Strength	Flexural Strength	Split Tensile Strength
1	0.5	25	48.30	5.80	4.1
2	1.0	25	50.2	6.10	4.3
3	1.5	25	52.1	6.30	4.4
4	2	25	49.1	6.46	4.5

4.0 Result and Discussions

The findings of the experiment make it abundantly evident that the incorporation of glass fibers and the substitution of twenty-five percent fly ash results in an increase in the mechanical strength of the high performance concrete. The mechanical qualities of high-performance concrete (HPC) that contains 25% fly ash are linked to a higher compressive strength, however the strength of the concrete decreases when more than 25% fly ash is used as a replacement for cement. This can be attributed to the filler effect of fly ash, which means that when fly ash is replaced by up to 25 percent, it acts as a binder and contributes to the improvement of strength. However, when the replacement percentage is greater than 25 percent, it will act as filler material and it will not react with water and binder to form calcium silicate hydrate. At the same time, the incorporation of glass fibers into concrete has a significant impact on the mechanical characteristics of the material. The inclusion of glass fibers can up to 1.5 percent increase the compressive strength of high-performance composites (HPC). As more glass fibers are added, the compressive strength of the material decreases. This is because the fibers begin to cluster together with further addition. Increases in the proportion of fibers in high-performance composites (HPC) lead to improvements in both the flexural strength and tensile strength of the material. The workability of high-performance composites (HPC) improves as the proportion of glass fibers in the material increases. However, in general, an increase in the percentage of glass fibers would result in a decrease in the material's workability. However, this issue was resolved by the incorporation of superplasticizer. A comparison of the compressive strength, flexural strength, and split tensile strength of high-performance composites (HPC) with varying percentages of glass fibers is shown in Figure 1, Figure 2, and Figure 3, respectively.

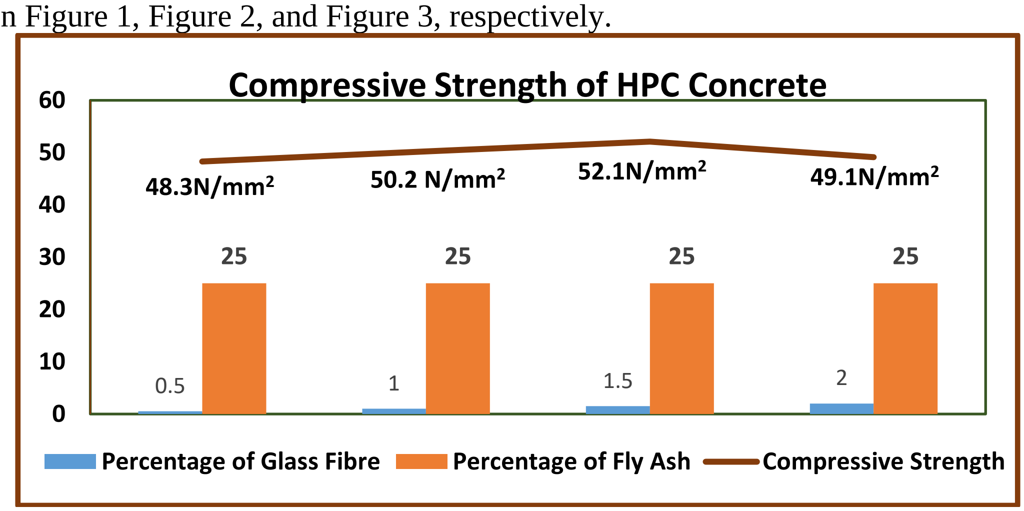

Fig. 1. Compressive Strength of HPC Concrete

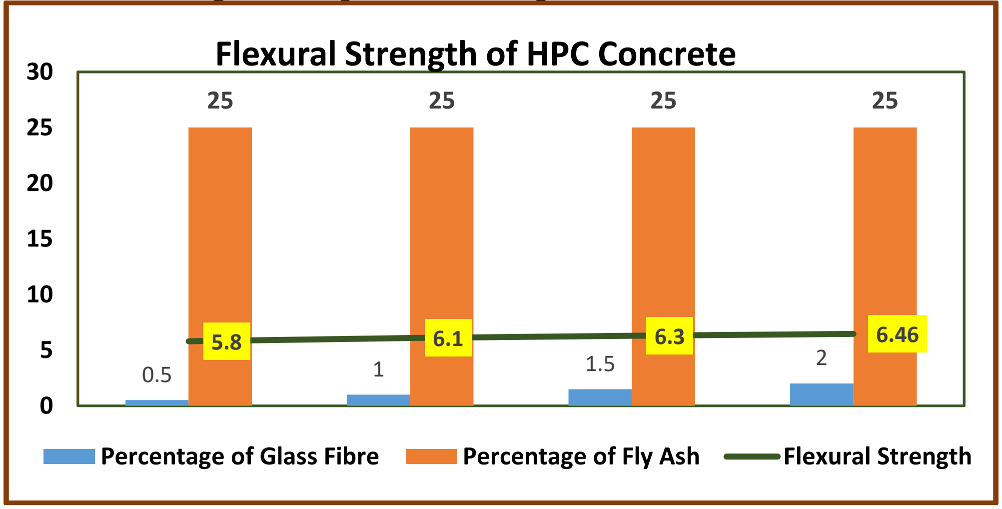

Fig. 2. Flexural Strength of HPC Concrete

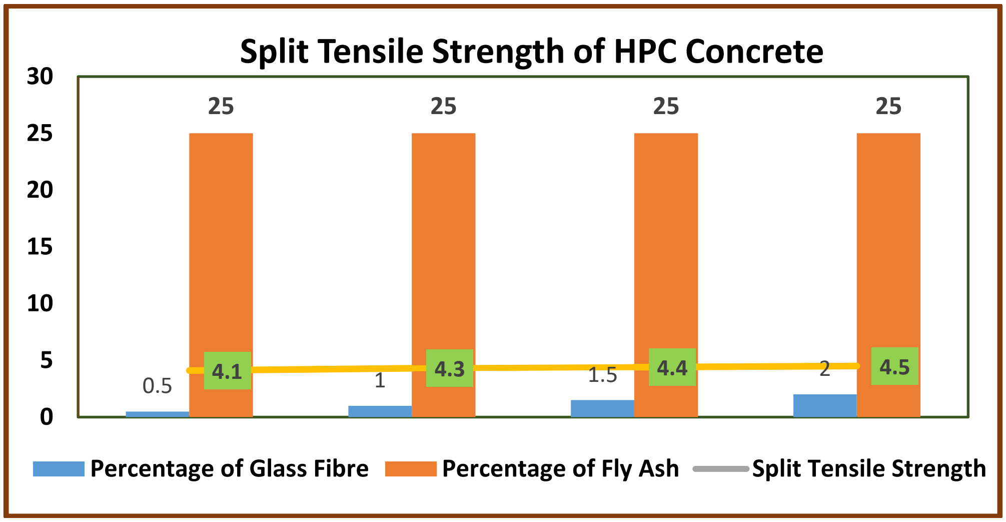

Fig. 3. Split Tensile Strength of HPC Concrete

5.0 Conclusions

1. The specific gravity of cement, fly ash, river sand and crushed stones are found as 3.10, 2.01, 2.64, and 2.77 respectively.
2. The water absorption of river sand and crushed stone aggregate are found as 0.76% and 0.296 respectively.
3. The fineness of modulus of river sand and crushed stone aggregate are found as 2.80 and 7.25 respectively.
4. The workability of conventional concrete is found as 80 mm.
5. The workability of HPC concrete with 1.2 % of super plasticizer and 0.5%, 1.0%, 1.5%, 2.0% are found as 80 mm, 83 mm, 84 mm and 86 mm respectively.
6. The compressive strength, flexural strength and split tensile strength of conventional concrete are found as 48.28 N/mm^2, 4.35 N/mm^2 and 3.85 N/mm^2 respectively.
7. The compressive strength of HPC concrete with 1.2 % of super plasticizer and 0.5%, 1.0%, 1.5%, 2.0% are found as 48.30 N/mm^2, 50.20 N/mm^2, 52.10 N/mm^2 and 49.10 N/mm^2 respectively.
8. The flexural strength of HPC concrete with 1.2 % of super plasticizer and 0.5%, 1.0%, 1.5%, 2.0% are found as 5.80 N/mm^2, 6.10 N/mm^2, 6.30 N/mm^2 and 6.46 N/mm^2 respectively.
9. The flexural strength of HPC concrete with 1.2 % of super plasticizer and 0.5%, 1.0%, 1.5%, 2.0% are found as 4.10 N/mm^2, 4.3 N/mm^2, 4.4 N/mm^2 and 4.5 N/mm^2 respectively.
10. The fly ash upto 25% replacement for cement is effective and behave as a binder material along with cement but more than 25% it acts as filler material and reduces the strength of HPC.

References:

1) *Mehta, P.K., & Monteiro, P.J.M. (2017). Concrete: Microstructure, Properties, and Materials. McGraw-Hill Education.*
2) *Neville, A.M. (2011). Properties of Concrete. Pearson Education.*
3) *Aitcin, P.-C. (1998). High-Performance Concrete. E&FN Spon.*
4) *Malhotra, V.M., & Mehta, P.K. (2004). High-Performance, High-Volume Fly Ash Concrete: A Sustainable Solution for Concrete Construction.*
5) *Bentur, A., & Mindess, S. (2000). Fibre Reinforced Cementitious Composites. CRC Press.*
6) *Bhargava, S., & Sahu, A.K. (2012). "Influence of Glass Fiber Reinforcement on Concrete Performance." Materials Science and Engineering A, 556, 107–116.*
7) *Mehta, P.K., & Monteiro, P.J.M. (2017). Concrete: Microstructure, Properties, and Materials. McGraw-Hill Education.*
8) *Safiuddin, M., Islam, M.N., & Alam, M.K. (2014). "Performance of High-Strength Concrete Incorporating Fly Ash and Glass Fibers." Construction and Building Materials, 51, 123–132.*
9) *Siddique, R. (2011). "Performance Characteristics of High-Volume Fly Ash Concrete." Materials and Structures, 44, 235–247.*
10) *Thomas, M.D.A. (2007). "Optimizing the Use of Fly Ash in Concrete." Portland Cement Association.*
11) *Zong, Y., Zhang, L., & Liu, L. (2014). "Effects of Glass Fiber on the Mechanical Properties of Concrete." Construction and Building Materials, 65, 229–235.*