International Journal for Modern Trends in Science and Technology, 9(05): 140-149, 2023

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST0905021
Available online at: http://www.ijmtst.com/vol9issue05.html

Supplementatary Cementitious Materials Effect of Fiber Reinforced Concrete

Yerra Sri Rasagna[1], Addepalli Mallinadh Kashyap[2], Dr.D.Venkateswarlu[3]

[1]P.G Scholar, Department of Civil Engineering, Godavari Institute of Engineering & Technology (A), Rajahmundry, Andhra Pradesh, India
[2]Assistant Professor, Department of Civil Engineering, Godavari Institute of Engineering & Technology (A), Rajahmundry, Andhra Pradesh, India
[3]Professor & Head, Department of Civil Engineering, Godavari Institute of Engineering & Technology (A), Rajahmundry, Andhra Pradesh, India

To Cite this Article
Yerra Sri Rasagna, Addepalli Mallinadh Kashyap and Dr.D.Venkateswarlu. Supplementatary Cementitious Materials Effect of Fiber Reinforced Concrete. International Journal for Modern Trends in Science and Technology 2023, 9(05), pp. 140-149. https://doi.org/10.46501/IJMTST0905021

Article Info
Received: 28 March 2023; Accepted: 28 April 2023; Published: 11 May 2023.

ABSTRACT

This study focuses on the production of high-performance concrete (HPC) using pozzolanic materials as partial replacements for cement, with the aim of achieving high strength, flow ability, and durability. XRD tests were conducted to analyse the constituents of the pozzolanic materials. A water-reducing additive, such as a superplasticizer, was used to maintain a low water-cement ratio. Synthetic fiber was added in different percentages to the concrete mix, and two types of cement were used. Various tests, including compressive, splitting, and flexural tests, were conducted on mortar, cubes, cylinders, and prisms. The porosity and permeability of the concrete were also tested. The study concludes that a significant number of trial mixes are required to select the appropriate combination of ingredients to achieve unique performance that cannot be attained from standard concrete using existing approaches.

Keywords: High Performance Concrete, Supplementary Materials, Fibers, Combination

INTRODUCTION

Concrete is a man-made building material that is made by combining cementitious ingredients, water, aggregate, and occasionally admixtures. When newly mixed, concrete can be moulded into any shape, but it hardens into a mass resembling rock due to a long-lasting chemical reaction between water and cement. One of the primary challenges with concrete is its declining durability, particularly for structures built after 1970, due to the increased use of high-strength rebars, changes to cement composition, and the addition of supplementary materials without proper consideration. Additionally, the manufacture of cement releases significant amounts of carbon dioxide into the atmosphere, contributing to global warming.

One potential solution is to partially substitute cement with pozzolanic materials such as fly ash, ground granulated blast furnace slag, rice husk ash, high reactive metakaolin, and silica fume. Studies on the use of these materials are promising, and they have a lower environmental impact. High-performance concrete is defined by the American Concrete Institute as concrete that satisfies unique sets of performance and uniformity standards that aren't always possible to fulfil when utilizing ordinary components and customary mixing, putting, and curing procedures. Essential qualities of high-performance concrete include simple positioning, consolidation without separation, youthful strength, permanent mechanical characteristics, permeability, density, hydration heat, toughness, volume constancy, and long life under harsh conditions. However, changing one of these qualities can affect others, making high-performance concrete a challenging and specific material to work with.

Fiber reinforced concrete (FRC) has been used in construction for several decades due to its high tensile strength and durability. However, the use of supplementary cementitious materials (SCMs) in FRC has gained popularity in recent years due to its potential to enhance the properties of FRC. This literature review will discuss the influence of SCMs on FRC and their effect on various properties. One of the commonly used SCMs is fly ash, which is a by-product of coal combustion. Several studies have reported that the addition of fly ash to FRC improves its compressive strength, flexural strength, and durability (Sata et al., 2014; Singh & Siddique, 2019; Teng et al., 2018). Another SCM that is widely used in FRC is slag, which is a by-product of the iron and steel industry. The addition of slag to FRC has been reported to increase its compressive strength, flexural strength, and toughness (Khaloo et al., 2011; Lin et al., 2018; Saafi et al., 2017).

In addition to fly ash and slag, other SCMs such as silica fume, metakaolin, and rice husk ash have also been used in FRC. The addition of silica fume to FRC has been reported to improve its compressive strength, flexural strength, and toughness (Ganesan & Rajagopal, 2014; Teng et al., 2018). Metakaolin has also been found to enhance the properties of FRC, such as its compressive strength, flexural strength, and durability (Chen et al., 2019; Singh & Siddique, 2019). Rice husk ash has been reported to improve the workability of FRC and its compressive strength (Haneef et al., 2019).It is important to note that the amount of SCM added to FRC affects its properties. Several studies have reported that an increase in the amount of SCM results in an increase in the compressive strength, flexural strength, and durability of FRC (Ganesan & Rajagopal, 2014; Khaloo et al., 2011; Saafi et al., 2017; Singh & Siddique, 2019). However, some studies have also reported that excessive addition of SCM may lead to a decrease in the strength of FRC (Chen et al., 2019). In conclusion, the addition of SCMs to FRC has been found to enhance its properties, such as its compressive strength, flexural strength, toughness, and durability. Fly ash, slag, silica fume, metakaolin, and rice husk ash are commonly used SCMs in FRC. The amount of SCM added to FRC should be carefully controlled to ensure optimal results.

2.0 EXPERIMENTATION

The study focuses on using rice husk ash and ground granulated blast furnace slag as partial replacements for cement in mortar, while also incorporating synthetic Recron fiber to create fiber-reinforced concrete. The research examines the effects of different percentages of these materials on the compressive strength, splitting tensile strength, and flexural strength of concrete after 7 and 28 days. Portland slag cement and regular Portland cement are used, and XRD is performed to analyse the microstructural behaviour of supplementary cementitious materials. Porosity and capillary absorption tests are also conducted to study the impact of silica fume on concrete.

2.1 TEST RESULTS

2.1 XRD Analysis

To ensure optimal pozzolanic activity, GGBS with a fineness of 275-550 m2/kg passing through a 75 micron filter was selected, as fineness plays a critical role. The specific gravity test was performed using Le-Chatelier equipment and produced a value of 2.77. X-ray diffraction testing was conducted, as shown in Figure 1

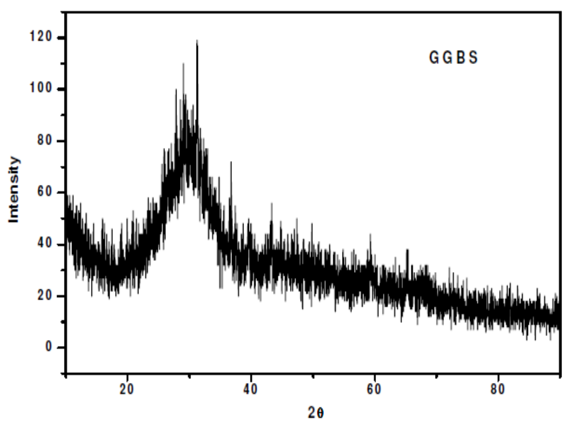

Fig.1 GGBS

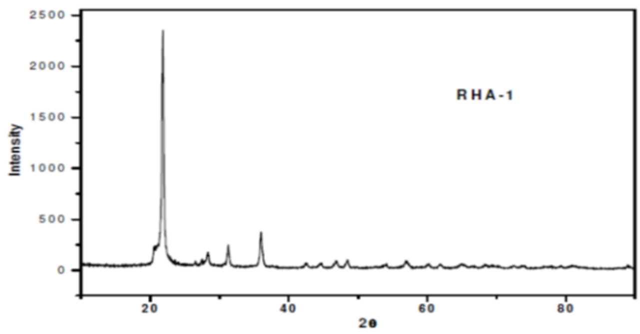

Fig.2 RHA

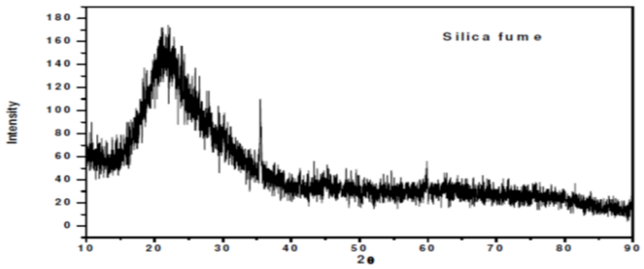

Fig.3 Silica Fume

The study examined the chemical compositions of RHA-I, RHA-II, GGBS, and silica fume using XRD analysis. The results indicated that GGBS is present only in amorphous form. The XRD graphs of RHA-I and RHA-II showed that RHA-I is crystalline in comparison to RHA-II, but both forms of rice husk ash contained crystabalite low-temperature silica.The study also investigated the effect of GGBS and RHA on the properties of cement through consistency and compressive strength tests. The consistency test measured the water volume required to create a cement paste that can withstand a certain pressure. The results indicated that the fineness of cement affects its consistency, and GGBS and RHA were used in the test with varying percentage contents.Finally, standard-sized mortars were made using different amounts of GGBS and RHA, and the compression test was conducted. The results showed that the addition of 20% RHA improved the compressive strength of mortar, while the addition of GGBS had varying effects depending on the percentage content. The study suggests that the use of RHA and GGBS can enhance the properties of cement and improve the performance of mortar.

2.2 Mix Design

Concrete specimens were produced to investigate the impact of silica fume on Recron fibre reinforced concrete, using Portland slag cement and regular Portland cement. Different percentages of Recron fibre and silica fume were used to maintain a consistent fibre percentage. Sika was used to maintain the water-cement ratio and superplasticizer ranges. Concrete specimens were cast and tested for compressive strength, splitting tensile strength, and flexural strength after 7- and 28-day curing periods. A water absorption analysis and half-cylinder porosity and capillary absorption test were also performed. The study analyzed the effects of fibre and silica fume on the strength of concrete using both types of cement.

3.0 Test Results

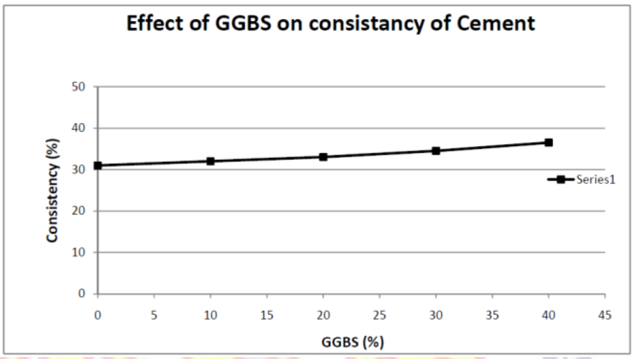

Fig. 1 Variation of Consistency of cement containing different % of GGBS

Fig.1 represents the variation of consistency of cement containing different percentages of GGBS and the consistency increases with the increase in the percentage of GGBS

Table 1. Effect of GGBS on Compressive strength of cement mortar

% of GGBS with cement	3 days strength (MPa)	7 days strength (MPa)
replacement		
0	11.176	24.31
10	9.66	15.63
20	7.117	10.85
30	6.10	9.15
40	4.74	7.46

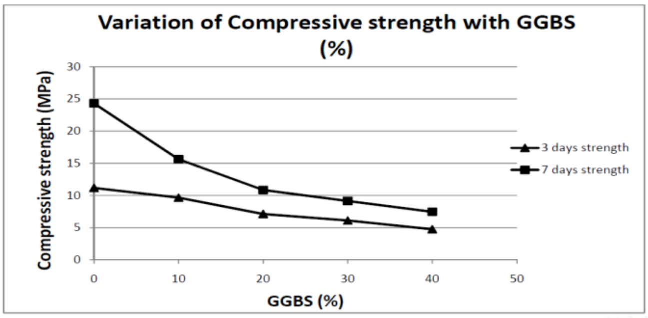

Fig. 2 Variation of Compressive strength of mortar with different GGBS %

Table 3. Effect of RHA on Normal Consistency of cement:

% of cement replaced by RHA	Consistency (%)
0	31.0
10	45.0
20	48.0
30	52.0

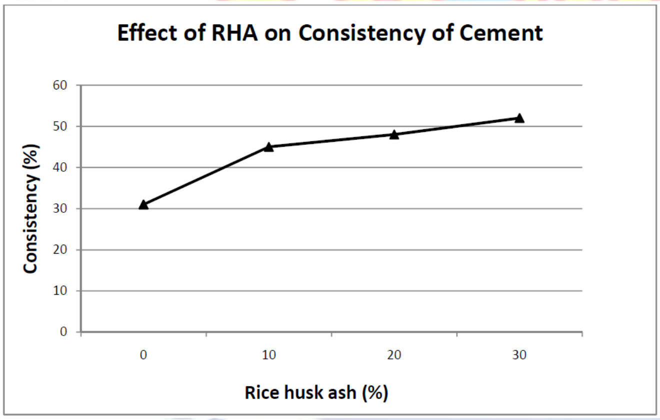

Fig. 3 Variation in Consistency of cement with different % of RHA

Table 4. Effect of RHA on Compressive strength of cement:

% of cement replaced by RHA	3 days strength (MPa)	7 days strength (MPa)
0	11.176	24.31
20% (RHA I)	2.23	4.74
20% (RHA II)	3.65	7.45

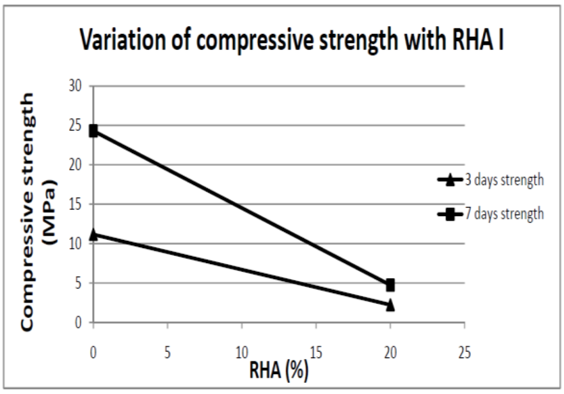

Fig. 4 Variation in Compressive strength of mortar

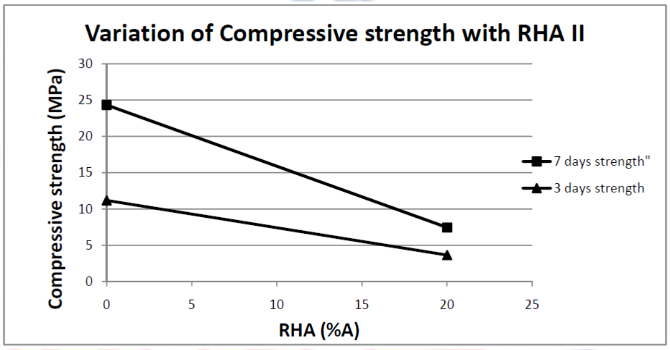

Fig. 5 Variation in Compressive strength of mortar with use of RHA I
with use of RHA I

The consistency % of mortar increases as the amount of rice husk ash used as a cement substitute increases, while the effect is less significant for GGBS. The compressive strength of mortar decreases as the percentage of GGBS used increases, with significant reductions in strength observed at 40% GGBS. The use of rice husk ash did not provide significant results. RHA II is more powerful than RHA I, but still fell short of expectations, while RHA I is not suited for use as a pozzolanic material and provides poor strength. RHA II has a lower carbon content and appears white in colour due to being burned more than RHA I.

Test Result & Discussion:

Table 5 Effect of Recron fiber on Compressive strength using slag cement:

Fiber content (%)	7days compressive strength (N/mm^2)	28 days compressive strength (N/mm^2)
0.0	18.22	42
0.1	15.33	30.44
0.2	16.44	35.55
0.3	10.8	28.22

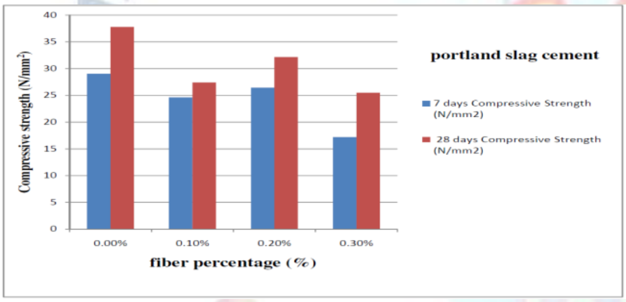

Fig. 6 Effect of Recron fiber on compressive strength

Table 6. Effect of recron fiber on Splitting Tensile Strength using slag cement:

Fiber content (%)	7 days splitting tensile strength (N/mm^2)	28 days splitting tensile strength (N/mm^2)
0.0	2.523	2.873
0.1	2.12	2.452
0.2	2.569	3.018
0.3	1.533	2.280

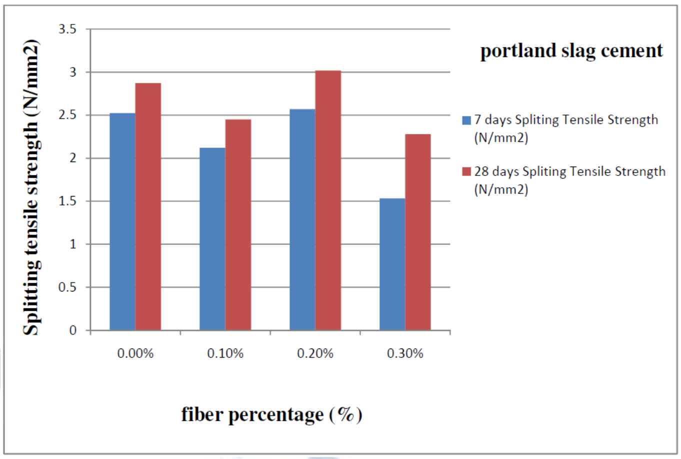

Fig. 7 Effect of Recron fiber on splitting tensile strength

Table 7. Effect of recron fiber on Flexural Strength using slag cement:

Fiber content (%)	7 days flexural strength (N/mm^2)	28 days flexural strength (N/mm^2)
0.0	5.750	7.75
0.1	5.875	6.33
0.2	6.560	8.04
0.3	4.501	6.04

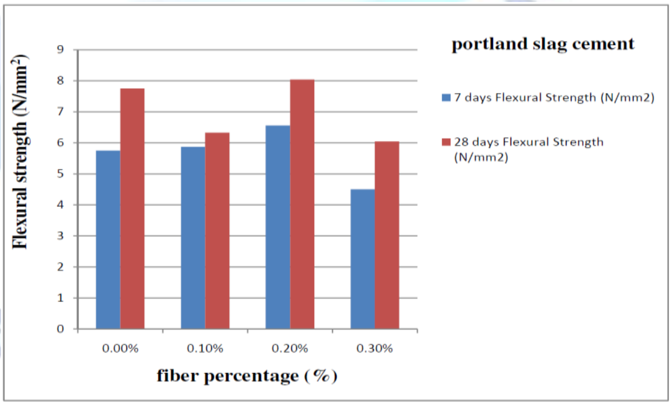

Fig. 8 Effect of Recron fiber on flexural strength

Table 8. Effect of silica fume on normal consistency of cement:

% of cement replaced by silica fume	Normal consistency (%)
0	31.0
10	38.0
20	41.5
30	45.0

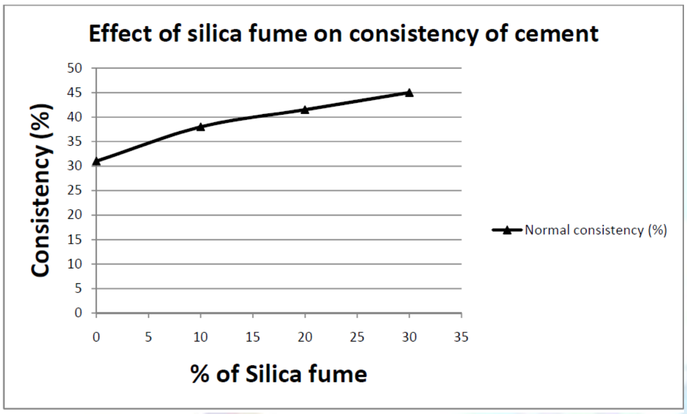

Fig.9 Effect of silica fume on consistency of cement

Table 9. Effect of silica fume on Compressive strength with 0.2%fiber using slag cement:

Silica fume (%)	7 days Compressive strength (N/mm²)	28 days Compressive strength (N/mm²)
0.0	19.77	22.44
10.0	17.55	21.55
20.0	19.33	24.22
30.0	16.22	20.22

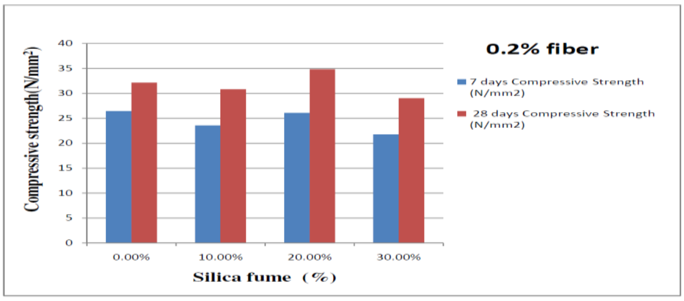

Fig. 10 Effect of silica fume on compressive strength at 0.2% fiber with slag cement

Table 10. Effect of silica fume on splitting tensile strength with 0.2%fiber using slag cement:

Silica fume (%)	7 days splitting tensile strength (N/mm²)	28 days splitting tensile strength (N/mm²)
0.0	2.569	3.018
10.0	2.482	2.92
20.0	2.687	3.206
30.0	2.169	2.782

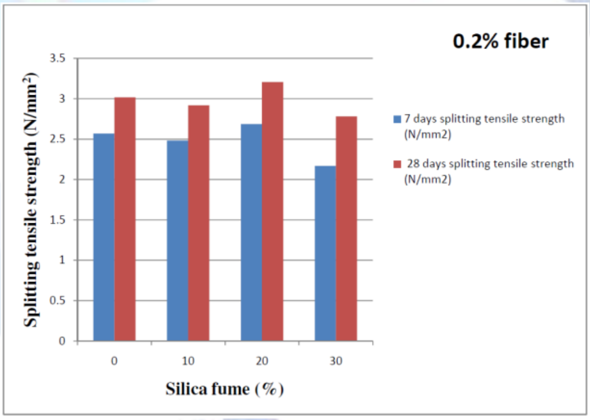

Fig. 11 Effect of silica fume on splitting tensile strength at 0.2% fiber with slag cement

Table 11. Effect of silica fume on flexural strength with 0.2%fiber using slag cement

Silica fume (%)	7 days flexural strength (N/mm²)	28 days flexural strength (N/mm²)
0.0	6.56	8.04
10.0	6.50	8.00
20.0	6.625	8.458
30.0	6.04	7.875

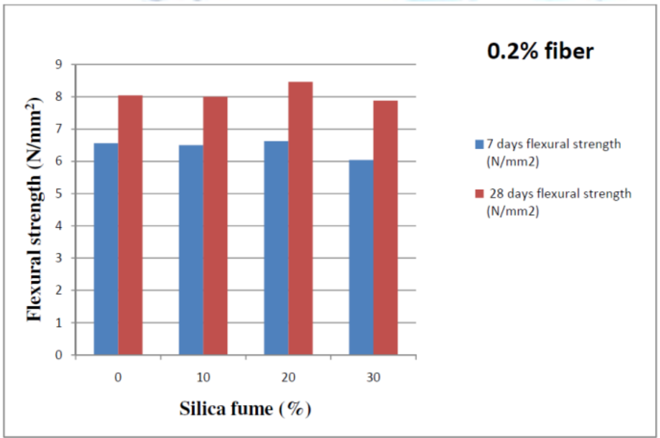

Fig. 12 Effect of silica fume on flexural strength at 0.2% fiber with slag cement

Effect of silica fume with constant fiber percentage (0.2%) using ordinary Portland cement is given below;

Table 12. Effect of silica fume on Compressive strength using OPC:

Silica fume (%)	7 days Compressive strength (N/mm²)	28 days Compressive strength (N/mm²)
0.0(0.2%fibre)	18.66	26.44
10.0(0.2%fibre)	18.88	26.88
20.0(0.2%fibre)	20.44	28.44
30.0(0.2%fibre)	22	31.55

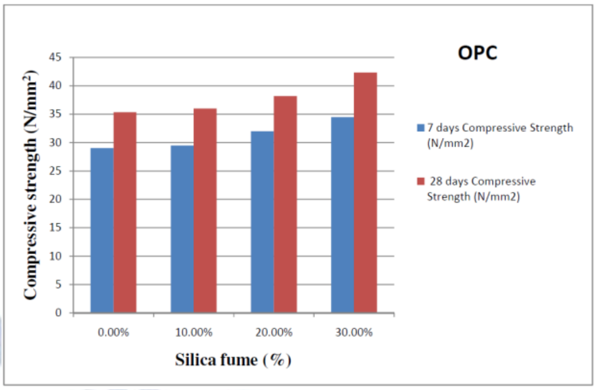

Fig. 13 Effect of silica fume on compressive strength at 0.2% fiber and OPC

Table 13. Effect of silica fume on splitting tensile strength using OPC:

Silica fume (%)	7 days splitting tensile strength (N/mm²)	28 days splitting tensile strength (N/mm²)
0.0(0%fibre)	2.546	2.829
10.0(0.2%fibre)	2.687	3.253
20.0(0.2%fibre)	2.405	2.970
30.0(0.2%fibre)	2.263	2.829

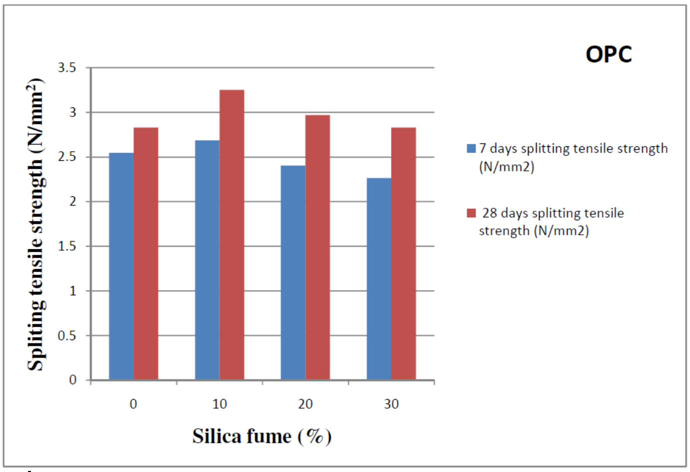

Fig. 14 Effect of silica fume on splitting tensile strength at 0.2% fiber and OPC

Table 14. Effect of silica fume on flexural strength using OPC

Silica fume (%)	7 days flexural strength (N/mm²)	28 days flexural strength (N/mm²)
0.0 (0% fibre)	9.50	11.125
10.0(0.2%fibre)	7.875	9.00
20.0(0.2%fibre)	6.75	8.25
30.0(0.2%fibre)	6.04	6.875

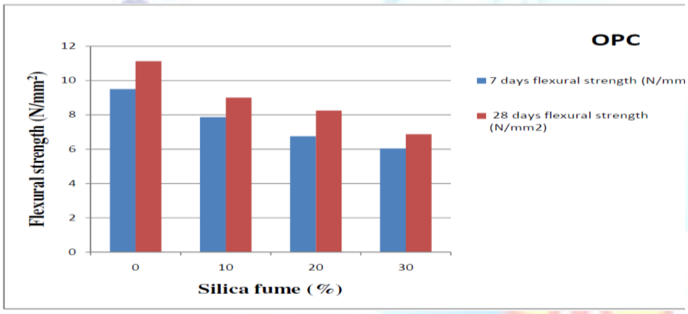

Fig. 15 Effect of silica fume on flexural strength at 0.2% fiber and OPC

The study compares the effects of silica fume and Recron fiber on the strength of regular Portland cement and Portland slag cement. Adding 0.2% Recron fiber improves the compressive and splitting tensile strength of concrete, with the best results achieved when using 20% and 30% silica fume replacement in Portland cement and slag cement, respectively. Flexural strength is also improved by 0.2% fiber content and 20% silica fume replacement in both types of cement. However, increasing the silica fume percentage beyond the optimal level results in a decline in strength. The addition of Recron fiber has little effect on compressive strength but does improve tensile and flexural strength.

Table: 15 Capillary absorption coefficient (k) for different fiber content:

Fiber %	Capillary absorption coefficient (k)
0.0	1.19×10^{-3}
0.1	1.31×10^{-3}
0.2	1.67×10^{-3}
0.3	3.57×10^{-3}

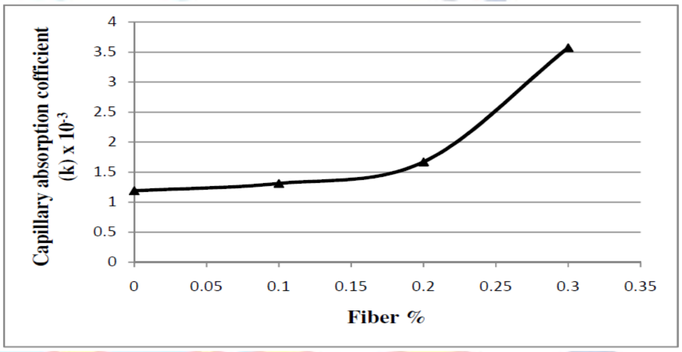

Fig. 16 Capillary absorption coefficient (k) for different fiber content

Table 16. Capillary absorption coefficient (k) for different SF content:

Silica fume%	Capillary absorption coefficient (k)
10 20	7.49×10^{-4} 5.62×10^{-4}
30	1.124×10^{-3}

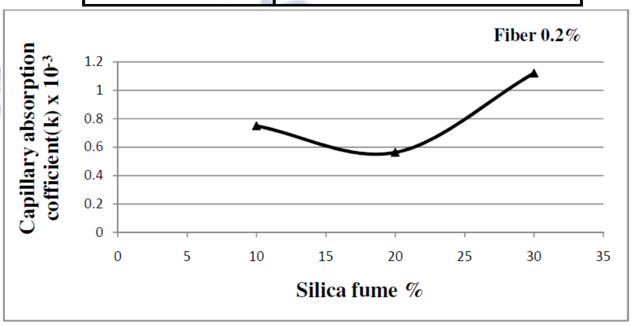

Fig. 17 Capillary absorption coefficient (k) of different SF content

Table 17. Porosity of different fiber mix:

Fiber %	Porosity, η
0.0	3.54
0.1	4.806
0.2	5.51
0.3	8.79

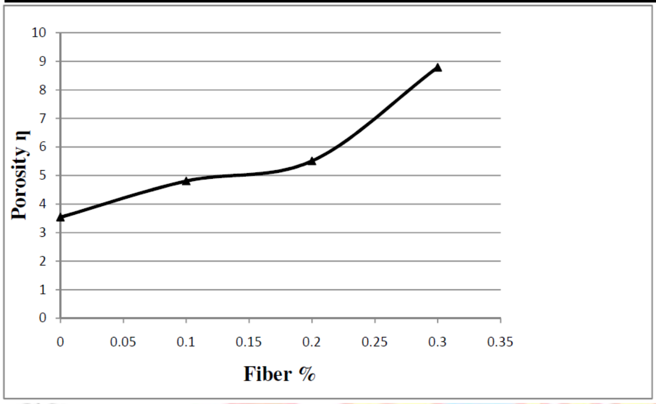

Fig. 18 Porosity of different fiber content

Table 18. Porosity of different Silica Fume mix:

Fiber %	Porosity, η
10	5.54
20	5.03
30	4.89

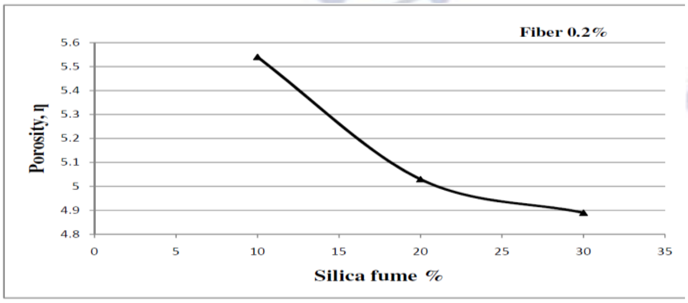

Fig. 19 Porosity of different SF content

The addition of silica fume to Recron fibre reinforced concrete significantly reduces the capillary absorption coefficient and porosity. Capillary absorption is reduced by up to 70% at 20% silica fume concentration, with a slight increase at 30%. Porosity decreases as silica fume concentration rises from 0 to 30%, with a 12% reduction compared to 0.2% fibre reinforcement.

4.0 Conclusion

The study examined the use of pozzolanic materials such as ground granulated blast furnace slag, rice husk, and silica fume in fibre reinforced concrete. The effectiveness of these materials was analyzed in terms of compressive strength, splitting tensile strength, flexural strength, capillary absorption coefficient, and porosity. The results showed that the addition of these materials can improve the strength and durability of the concrete, with optimal combinations of materials achieving the desired results. However, the effectiveness of these materials varied depending on their concentration and combination with other materials.

- GGBS improves uniformity but mortar strength significantly declines with more than 10% usage in Portland slag cement.
- RHA improves consistency and mortar strength if burnt at a specified temperature, but may not produce sufficient strength results.
- Superplasticizer can help achieve desired strength with a mix containing less water than cement.
- 0.2% Recron fiber and 20% SF is the optimum combination for achieving desired strength in concrete.
- Compressive strength increases with proportionate increase in silica fume and Recron fiber content in OPC.
- Splitting tensile strength improves up to 10% with 0.2% Recron fiber and 20% SF but declines with further increase in SF content.
- Capillary absorption coefficient declines significantly as SF content increases while fiber percentage remains constant at 0.2%.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] Chen, B., Liu, Y., & Sun, H. (2019). Effects of metakaolin on mechanical properties and durability of polypropylene fiber reinforced concrete. Construction and Building Materials, 220, 536-546. https://doi.org/10.1016/j.conbuildmat.2019.05.022

[2] Ganesan, K., & Rajagopal, K. (2014). Use of silica fume and fly ash in self-compacting concrete for sustainable development. Arabian Journal for Science and Engineering, 39(5), 3877-3885. https://doi.org/10.1007/s13369-014-1182-2

[3] Haneef, M., Shafiq, N., Memon, S. A., & Hussain, T. (2019). Effect of rice husk ash and fiber types on the workability, mechanical and durability properties of fiber reinforced concrete. Construction and Building Materials, 214, 262-272. https://doi.org/10.1016/j.conbuildmat.2019.04.017

[4] Khaloo, A., Dehestani, M., Rahmatabadi, P., & Tavakoli, M. (2011). Properties of fiber reinforced concrete using ground granulated blast furnace slag as a supplementary cementitious material. Construction and Building Materials, 25(2), 943-948. https://doi.org/10.1016/j.conbuildmat.2010.07.051

[5] Lin, K. L., Jiang, T., Li, L. X., Li, L. H., Li, Y. X., & Li, Q. F. (2018). Experimental study on mechanical and durability properties of high-performance fiber-reinforced slag cementitious composites. Construction and Building Materials, 168, 202-211. https://doi.org/10.1016/j.conbuildmat.2018.02.120

[6] Saafi, M., Ouezdou, M. B., & Kenai, S. (2017). Influence of slag content and fiber reinforcement on compressive strength and toughness of self-compacting concrete. Journal of Materials in Civil Engineering, 29(3), 04016221. https://doi.org/10.1061/(asce)mt.1943-5533.0001732

[7] Sata, V., Jaturapitakkul, C., & Kiattikomol, K. (2014). Influence of fly ash fineness on the mechanical properties of concrete. Construction and Building Materials, 52, 151-159. https://doi.org/10.1016/j.conbuildmat.2013.10.018

[8] Singh, N., & Siddique, R. (2019). Effect of metakaolin and fly ash on mechanical and durability properties of polypropylene fiber-reinforced concrete. Construction and Building Materials, 210, 789-797. https://doi.org/10.1016/j.conbuildmat.2019.03.111

[9] Teng, J., Yu, R., & Wan, J. (2018). Flexural behavior of hybrid fiber-reinforced concrete containing steel fiber and silica fume under high strain rate loading. Construction and Building Materials, 183, 487-499. https://doi.org/10.1016/j.conbuildmat.2018.06.165