

“COMPARATIVE STUDY ON THE INFLUENCE OF POLYPROPYLENE AND BRASS COATED MICRO STEEL FIBERS ON FRESH, MECHANICAL, DURABILITY, AND MICROSTRUCTURAL BEHAVIOR OF MINERAL ADMIXTURES-BASED SELF-COMPACTING CONCRETE”

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Abstract - Self-Compacting Concrete (SCC) is a high-performance concrete that flows and consolidates under its own weight without the need for external vibration. This study investigates the influence of incorporating of Brass coated micro steel fiber and Polypropylene fiber with supplementary cementitious materials (SCM'S) on fresh, mechanical, and durability properties of SCC and microstructure analysis of SCC. In this study, the mineral admixtures such as silica fume, fly ash and GGBS were incorporated as partial replacement of cement which improves workability, stability, durability, and long-term strength of SCC with fibers. The high-range water-reducing admixtures (superplasticizers) which is known as chemical admixture, also incorporated in the SCC mixes with fibers. A total eight concrete mixes were developed with varying compositions of SCM's and with optimum dosage of brass coated micro steel and polypropylene fibers with constant water to cement ratio of 0.2%. The first four mixes with PPF of 0.2% using quaternary blends of Ordinary Portland Cement (OPC 53), Silica fume, Fly ash, and GGBS and the other four mixes of same blend composition with 0.5% of brass coated micro steel fiber. The control mix was prepared using 100% Ordinary Portland Cement. In the remaining mixes, 60% of OPC was replaced with mineral admixtures, such as silica fume (SF) of 10% which is fixed for all the eight mixes, but the fly ash (FA) and ground granulated blast furnace (GGBS) were varied at replacement levels of 20%, 30% and 25%. In this study, the fresh properties test such as Slump, J-Ring, V-Funnel and L-box tests were conducted to determine the workability of SCC mixes and also mechanical properties tests such as compressive strength, split tensile strength and flexural strength tests were conducted to determine mechanical properties of SCC mixes. Durability performance was also evaluated using sulphate attack test. The SEM-EDX test was conducted to examine the microstructure, hydration products, fiber-matrix interaction, and elemental composition of SCC at the microscopic level. The comparative study of both fibers concludes that brass-coated micro steel fibers exhibited significant enhancement in split tensile strength and flexural strength, along with marginal improvement in compressive strength as compared to polypropylene fiber.

Key Words: Self-Compacting Concrete (SCC), Polypropylene Fiber (PPF), Brass Coated Micro Steel Fiber (BCMSF), Sulphate Attack, SEM-EDX Test.

1. INTRODUCTION

Self-Compacting Concrete (SCC) is an advanced form of concrete characterized by its ability to flow under its own weight, completely fill formwork, and pass through congested reinforcement without the need for mechanical vibration. This unique property makes SCC a highly efficient and reliable construction material, particularly in complex and heavily reinforced structural applications.

The widespread adoption of SCC in the construction industry has been supported by advancements in chemical admixtures and mix design techniques, allowing SCC to achieve high strength and durability while maintaining workability. The use of supplementary cementitious materials such as fly ash, silica fume, and slag further enhances performance and promotes sustainable construction by reducing cement consumption and carbon emissions. Fiber incorporation in SCC improves crack control across different stages of concrete behaviour. Fibers act as micro-reinforcements that bridge cracks, restrict their initiation, and delay crack propagation. Durability is one of the most important performance requirements of Self-Compacting Concrete (SCC), especially when it is exposed to aggressive environmental conditions. SEM-EDX which is carried out to visualize, analyze, and quantify the microstructural and elemental changes in SCC. Therefore, this research focuses on evaluating the mechanical, durability and microstructure behavior of SCC containing mineral admixtures and fibers.

2. OBJECTIVES

1. To design and develop Self-Compacting Concrete (SCC) mixes incorporating micro steel fibers (MSF) and polypropylene fibers (PPF) at introduced dosages while satisfying fresh property requirements accordance with EFNARC or according to Okamura mix design.
2. To evaluate the effect of MSF and PPF on the mechanical properties of SCC, such as compressive strength, split tensile strength and flexural strength test.
3. To study the resistance of SCC containing two types of fibers to magnesium sulphate attack.
4. To analyse and study about the elemental composition and fiber matrix interaction of SCC containing polypropylene and micro steel fibers by performing SEM-EDX test.
5. To compare the overall performance of polypropylene and micro-steel fibers in SCC in terms of strength and durability properties.

3. MATERIALS AND MATERIAL PROPERTIES

Cement: Cement is a fundamental component of concrete, acting as the primary binder that imparts strength and durability by bonding the constituent materials. In the present study, Ordinary Portland Cement (OPC) of 53 grade (Dalmia), conforming to IS: 12269:2013 was employed. The physical and chemical properties of the cement play a significant role in governing the mechanical performance and durability of concrete.

Fine Aggregate: Fine aggregate consists of small particles that fill the voids between coarse aggregates and play an important role in improving the workability and strength of concrete. In the present study, manufactured sand (M-sand) was used as the fine aggregate. M-sand is produced by mechanically crushing hard rocks under controlled conditions, followed by washing and grading to obtain a uniform and well-defined particle size distribution. The M-sand used in this study falls under Grading Zone II, which is considered suitable for producing a stable and well-proportioned Self-Compacting Concrete (SCC) mix.

Coarse aggregate: Coarse aggregate plays an important role in providing strength, stability, and dimensional resistance to concrete. In self-compacting concrete, where high flowability without the need for vibration is essential, proper selection of coarse aggregates becomes particularly important. In this study, crushed granite aggregates of 20 mm and 12.5 mm (down) sizes were used. The aggregates were locally sourced and conform to the specifications of IS: 383-2016.

Water: Water is an essential component of concrete, as it initiates cement hydration and governs workability and uniformity of the mix. In self-compacting concrete, the quality of water significantly influences the strength, durability, and long term performance of concrete; therefore, potable water free from harmful impurities was used in this study.

Admixtures: Admixtures are materials added to concrete in addition to cement, water, and aggregates to modify and enhance its properties. They play an important role in improving workability, strength, durability, setting characteristics, and resistance to environmental effects, thereby increasing the versatility of concrete for various construction applications. Admixtures are generally classified into two categories: mineral admixtures and chemical admixtures.

Mineral Admixtures: Mineral admixtures are finely divided inorganic materials incorporated into concrete either as partial replacements for cement or as supplementary components. In the presence of water, these materials react with calcium hydroxide released during cement hydration to form additional cementitious compounds. Although they do not act as primary binding agents, their pozzolanic or hydraulic activity enhances the strength, durability, and resistance of concrete to chemical attack.

Silica Fume: Silica fume, also referred to as micro silica or condensed silica fume, is a highly reactive pozzolanic material widely used as a mineral admixture in concrete. It is a byproduct generated during the manufacture of silicon or ferrosilicon alloys in electric arc furnaces. During this process, silica is released as oxidized vapor, which subsequently cools, condenses, and is collected using filtration systems before being processed to control impurities and particle size. Silica fume consists predominantly of amorphous silicon dioxide (SiO_2) and is characterized by an extremely fine particle size, typically less than 1 μm , making it significantly finer than cement. Owing to its high surface area and strong pozzolanic activity, silica fume refines the pore structure of concrete, resulting in improved microstructural density and enhanced performance characteristics.

Fly ash: Fly ash is a fine, powdery by-product obtained from the combustion of pulverized coal in thermal power plants. It is captured from flue gases using electrostatic precipitators or other dust collection systems before release into the

atmosphere. Rich in silica and alumina, fly ash is a widely used pozzolanic material in concrete. Its spherical, fine particles improve workability, packing density, and cohesion, enhancing the flowability of self-compacting concrete (SCC). Through pozzolanic reactions with calcium hydroxide generated during cement hydration, fly ash forms additional calcium silicate hydrate (C-S-H), which strengthens the concrete and reduces permeability over time.

Ground Granulated Blast-Furnace Slag (GGBS): Ground Granulated Blast-Furnace Slag (GGBS) is a supplementary cementitious material obtained as a by-product of iron production. During the manufacturing process, molten slag is rapidly cooled, dried, and finely ground into a powder. Its chemical composition, rich in silica, alumina, lime, and magnesia, promotes latent hydraulic reactions that produce calcium silicate hydrate (C-S-H), enhancing both strength and durability. When incorporated into self-compacting concrete (SCC), GGBS improves workability, lowers permeability, and reduces the heat of hydration.

Chemical admixtures:

Superplasticizer: Superplasticizers, also referred to as high range water-reducing admixtures, are an advanced class of plasticizing agents used in concrete technology. These admixtures are typically organic compounds, commonly based on polycarboxylate ether, which enable a substantial reduction in water content while maintaining the desired level of workability, or alternatively, enhance workability at a constant water-cement ratio. Suitable for the production of self-compacting concrete (SCC), which has high flowability, adequate cohesion, and resistance to segregation. In this project, commercially available superplasticizer PC-300, manufactured by Aaradhya Chemicals, is used.

Polypropylene fiber: Polypropylene fibers are synthetic fibers manufactured from thermoplastic polymers and are widely used as secondary reinforcement in self-compacting concrete (SCC). Owing to their high tensile strength, chemical inertness, and low density, these fibers contribute to improved performance of concrete in both the fresh and hardened states. When incorporated into self-compacting concrete (SCC), polypropylene fibers reduce plastic shrinkage cracking, decrease drying shrinkage, improve durability, particularly in aggressive environments. In this study, RECRON-3S polypropylene fibers are used. These fibers have a nominal length of 12 mm and diameter ranging from 0.025 to 0.04 mm, contributing effectively to the crack-bridging mechanism and matrix integrity.

Micro Steel Fiber: Micro steel fibers are short, discrete steel filaments added to concrete to enhance its mechanical performance, crack control, and durability. They are widely used in Self-Compacting Concrete (SCC), high-performance concrete, and fiber-reinforced concrete applications. Micro steel fibers typically have a small diameter (0.1–0.3 mm) and short length (6–20 mm), which allows them to be easily dispersed even in highly flowable SCC mixes when proper mix design and chemical admixtures are used. In this study, the brass coated micro steel fiber of length 12 mm (straight) and diameter of 0.2 mm with specific gravity of 7850 kg/m³ was used. Brass-coated micro steel fibers are steel fibers coated with a thin layer of copper-zinc alloy (brass) to improve interfacial bonding, corrosion resistance, and durability performance when embedded in cementitious matrices such as SCC.

4. MIX DESIGN APPROACH

The mix design was developed following established principles to produce a stable self-compacting concrete (SCC) with sufficient flowability and strength. The key considerations in the mix design process included:

- Coarse aggregate content: Particles larger than 4.75 mm up to the maximum nominal size were maintained at 50–60% of the total solid volume, roughly 700–900 kg per cubic meter of concrete.
- Fine aggregate content: Particles between 0.125 mm and 4.75 mm were fixed at 40–50% of the total mortar volume.
- Water-to-powder ratio: This was assumed to range between 0.9 and 1.0 by volume, depending on the properties of the powder materials, including cement and fillers with particle sizes smaller than 0.125 mm.
- Superplasticizer dosage and final water-to-powder ratio: These were optimized through a series of trial mixes to achieve the desired self-compactability, as assessed using U-flow, slump-flow, and V-funnel tests.

MIX VARIATIONS

A total of eight distinct SCC mixtures were designed, divided into two groups:

- Fiber-Reinforced SCC Mixes (With 0.2% PPF): Four mixes incorporate 0.2% polypropylene fibers (PPF) by weight of

binder to improve durability, crack resistance, and overall performance.

- Fiber-Reinforced SCC Mixes (With 0.5% Brass-Coated Micro Steel Fibers): The remaining four mixes include 0.5% brass-coated micro steel fibers (BCMSF) by volume of concrete to enhance strength, toughness, and durability of the concrete.

Table -1: Typical Range of SCC Mix Composition [as per EFNARC 2005]

Constituent	Typical range by mass (kg/m ³)	Typical range by volume (liters/m ³)
Powder	380 - 600	
Paste		300 - 380
Water	150 - 210	150 - 210
Coarse aggregate	750 - 1000	270 - 360
Fine aggregate (sand)	Typically, 48 - 55% of total aggregate weight	
Water/Powder ratio By Volume		0.85 - 1.10

5. MAGNESIUM SULPHATE ATTACK TEST

The Magnesium Sulfate (MgSO₄) test is a durability evaluation method used to determine the resistance of Self-Compacting Concrete (SCC) against sulphate attack under aggressive environmental conditions. It represents the ability of concrete to withstand chemical deterioration caused by the penetration and reaction of sulphate ions (SO₄²⁻) with cement hydration products, which can lead to expansion, cracking, mass loss, and reduction in strength. Among various durability threats, sulphate attack is considered a major cause of deterioration in concrete structures. In SCC, the incorporation of supplementary cementitious materials (SCMs) such as fly ash, Ground Granulated Blast Furnace Slag (GGBS), and silica fume plays a significant role in improving sulphate resistance. These materials refine the pore structure, reduce permeability, and decrease calcium hydroxide content through pozzolanic reactions, thereby enhancing durability. Furthermore, the addition of fibers such as brass coated micro steel fibers (BCMSF) and polypropylene fibers (PPF) improves crack resistance and structural integrity.

Methodology for Sulphate Attack Test:

The magnesium sulphate attack test was conducted to evaluate the durability performance of Self-Compacting Concrete (SCC) specimens under sulphate exposure. The study aimed to assess mass variation, visual deterioration, and compressive strength retention after exposure to a 5% magnesium sulphate solution. The procedure was conducted in accordance with ASTM C267. In the present investigation, concrete specimens were exposed to a controlled acidic environment after 28 days of standard water curing to simulate aggressive service conditions. This exposure was intended to assess the resistance of the concrete to chemical deterioration and to evaluate its durability performance in terms of mass variation, surface degradation, and strength retention.

A 5% sodium sulphate (MgSO₄) solution was prepared to simulate a sulphate-rich aggressive environment. The cured specimens were completely immersed in the sulphate solution and maintained under continuous exposure for a predetermined period. The concentration of the sulphate solution was kept constant throughout the test duration to ensure uniform chemical exposure. During the exposure period, the specimens were periodically observed for visible signs of deterioration such as surface cracking, scaling, or discoloration. At the end of the exposure period, the specimens were removed from the solution, cleaned, and weighed to determine mass variation. Compressive strength tests were then conducted to evaluate the reduction in strength caused by sulphate attack.

6. SEM-EDX TEST

Scanning Electron Microscopy (SEM) is a high-resolution imaging technique that uses a focused beam of electrons to examine the surface morphology and microstructural features of materials at magnifications far beyond the capability of optical microscopes. SEM provides detailed information about micro cracks, porosity, hydration products, and fiber-matrix interactions in concrete. Energy Dispersive X-ray Spectroscopy (EDX or EDS) is often coupled with SEM to provide qualitative and semi-quantitative elemental analysis of the specimen. By detecting characteristic X-rays emitted from the material, EDX identifies the presence and relative abundance of elements such as calcium, silicon, aluminium, sulphur, and magnesium, which are critical in understanding chemical reactions, including sulfate attack, in cementitious systems.

SEM-EDX which is carried out to visualize, analyze, and quantify the microstructural and elemental changes in SCC, thereby providing a comprehensive understanding of how fibers, hydration products, and chemical exposure affect the performance and durability of concrete.

7. RESULTS AND DISCUSSIONS

7.1. Fresh Properties of Self-Compacting Concrete:

Fresh properties of Self-Compacting Concrete (SCC) refer to the characteristics of SCC in its plastic or unhardened state that enable it to flow under its own weight, completely fill formwork, pass through congested reinforcement, and remain homogeneous without segregation or bleeding, all without the application of external vibration. These properties are mainly expressed in terms of filling ability, passing ability, and segregation resistance, which collectively ensure the self-compacting behaviour and workability of SCC during mixing, transportation, placement, and finishing.

The fresh properties of SCC are significantly influenced by mix design parameters such as powder content, water-to-powder ratio, type and dosage of superplasticizers, viscosity-modifying admixtures, and the shape, size, and grading of aggregates. The inclusion of fibers, such as micro steel fibers or polypropylene fibers, further affects the rheological behaviour of SCC. The fresh property test results for Mix-1 to Mix-4 containing polypropylene fibers (PPF) and Mix-1 to Mix-4 containing brass coated micro steel fibers (BCMSF) in Quaternary Blended Self-Compacting Concrete (QBSCC) showed clear differences in workability. The tests conducted were slump flow diameter, T₅₀₀ flow time, V-funnel flow time, L-box blocking ratio, and J-ring slump flow and J-ring height differences. These tests help to check filling ability, passing ability, and resistance to segregation of SCC.

Table 2 Fresh Properties of SCC

	Slump flow (mm)	T500 Time (sec)	V funnel (sec)	L box ratio	J ring slump (mm)	J ring h (mm)
MIX-1 PPF	624	5.3	13	0.89	605	8
MIX-2 PPF	570	6.8	17	0.84	562	6
MIX-3 PPF	612	4.9	14	0.88	590	7
MIX-4 PPF	650	4.5	13	0.94	637	8
MIX-1 MSF	610	6.5	16	0.84	600	11
MIX-2 MSF	565	7.0	19	0.82	558	8

MIX-3 MSF	600	6.4	16	0.83	580	9
MIX-4 MSF	630	6.3	15	0.85	595	10

Slump Flow and T₅₀₀ flow time: The slump flow and T₅₀₀ results indicate that polypropylene fiber (PPF) mixes consistently showed better workability than brass-coated micro steel fiber (BCMSF) mixes. In MIX-1 (100% OPC), PPF achieved higher slump flow and lower T₅₀₀ time, indicating better flowability. MIX-2 recorded the lowest workability for both fibers due to high GGBS content increasing viscosity and internal friction. In MIX-3, increased fly ash improved flow, particularly for PPF. MIX-4 exhibited the best overall performance, with the highest slump flow and lowest T₅₀₀ time, due to balanced fly ash and GGBS content enhancing paste volume and lubrication. Overall, PPF provided superior fresh properties compared to BCMSF.

J-Ring Test: The J-ring results indicate that all SCC mixes achieved satisfactory passing ability under simulated reinforcement conditions. MIX-1 showed good flow with a small height difference, while the BCMSF variant exhibited slightly higher blocking due to increased internal friction from steel fibers. MIX-2 recorded reduced J-ring flow because of higher powder content and viscosity from mineral admixtures, with BCMSF showing slightly greater blocking tendency. MIX-3 demonstrated improved performance due to higher fly ash content enhancing lubrication and paste quality. MIX-4 exhibited the best overall J-ring performance, as balanced fly ash and GGBS content improved flowability and minimized fiber-induced blocking. All mixes satisfied SCC permissible limits.

V-Funnel Test: The V-funnel test was conducted to evaluate the flowability and viscosity of self-compacting concrete mixes containing polypropylene fibers (PPF) and brass coated micro steel fibers (BCMSF). The measured flow time indicates the ability of concrete to flow under its own weight and reflects the cohesiveness and internal resistance of the mix. PPF mixes generally showed lower flow times compared to BCMSF mixes, indicating relatively better flowability. In contrast, BCMSF mixes exhibited slightly higher flow times due to the stiffness and higher internal friction of steel fibers, which increased viscosity. However, all mixes satisfied the recommended limits of EFNARC, confirming that both PPF and BCMSF reinforced concretes meet the requirements for self-compacting concrete.

L-Box Test: The L-box results show that PPF mixes consistently achieved higher passing ability than BCMSF mixes. In MIX-1, PPF (0.89) performed better than BCMSF (0.84) due to lower internal resistance. MIX-2 recorded the lowest ratios (0.84 for PPF and 0.82 for BCMSF) because higher GGBS content increased viscosity and blocking tendency. MIX-3 demonstrated improved performance with higher fly ash content enhancing lubrication. MIX-4 showed the best results, with PPF achieving the highest ratio (0.94) and BCMSF 0.85. Overall, all mixes exceeded 0.8, indicating acceptable SCC passing ability despite slightly reduced flow in BCMSF mixes.

7.2. Mechanical Properties of Self-Compacting Concrete Compressive Strength Test:

The compressive strength of SCC mixes incorporating polypropylene fibers (PPF) and brass coated micro steel fibers (BCMSF) was evaluated at 7, 28, and 56 days to study both early- age and long-term strength development. The results show that the type of fiber and the composition of the binder (OPC, fly ash, silica fume, and GGBS) had a significant influence on the overall strength performance of the concrete. BCMSF mixes showed higher compressive strength than PPF mixes at all ages due to better bonding and crack resistance. MIX-2 had lower early strength because high GGBS slowed hydration. MIX-4 achieved the highest strength due to balanced fly ash and GGBS. Overall, BCMSF improved strength more effectively than PPF.

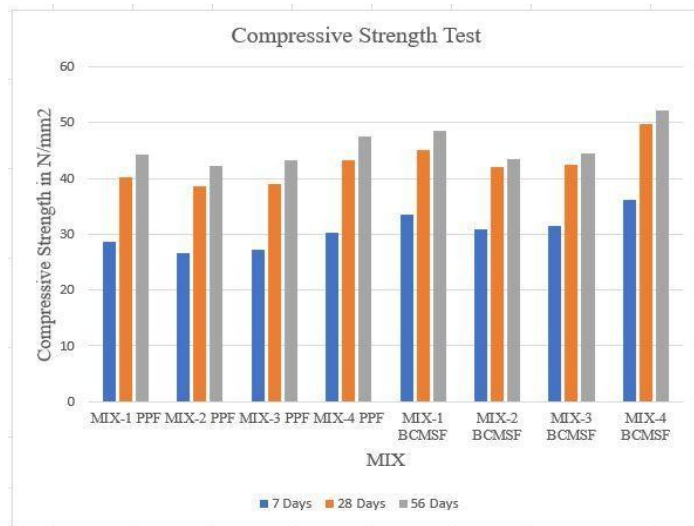


Chart -1: Compressive Strength

Split Tensile Strength Test: The split tensile strength results indicate that BCMSF mixes consistently performed better than PPF mixes at 7, 28, and 56 days due to higher stiffness, stronger bonding, and superior crack-bridging capacity of steel fibers. MIX-2 and MIX-3 showed slightly lower early strength because higher GGBS and fly ash contents delayed hydration. However, strength improved at later ages due to pozzolanic reactions and improved microstructure. MIX-4 achieved the highest tensile strength for both fibers, owing to balanced fly ash and GGBS proportions enhancing matrix density and bonding. Overall, BCMSF significantly improved tensile resistance and crack control compared to PPF mixes.

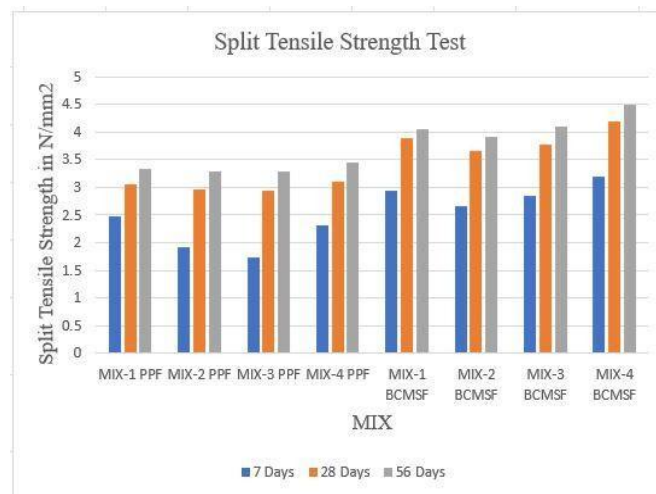


Chart-2: Split Tensile Strength

Flexural Strength Test: The flexural strength test was conducted at 7, 28, and 56 days to evaluate the post-cracking behaviour and load-carrying capacity of SCC mixes reinforced with polypropylene fibers (PPF) and brass coated micro steel fibers (BCMSF). Flexural performance is strongly influenced by fiber stiffness, the quality of fiber–matrix bonding, and the crack-bridging efficiency of the fibers within the concrete matrix.

The flexural strength results show that BCMSF mixes consistently achieved higher values than PPF mixes at all curing ages due to superior stiffness and crack-bridging ability of steel fibers. MIX-2 and MIX-3 showed moderate performance, with slight variations influenced by GGBS and fly ash content affecting early hydration and matrix stiffness. MIX-4 demonstrated the best overall flexural performance for both fibers, owing to balanced fly ash and GGBS proportions that improved matrix density and bonding. BCMSF significantly enhanced bending resistance and post-cracking load capacity compared to PPF. Overall, steel fibers provided better flexural strength and crack control than polypropylene fibers.

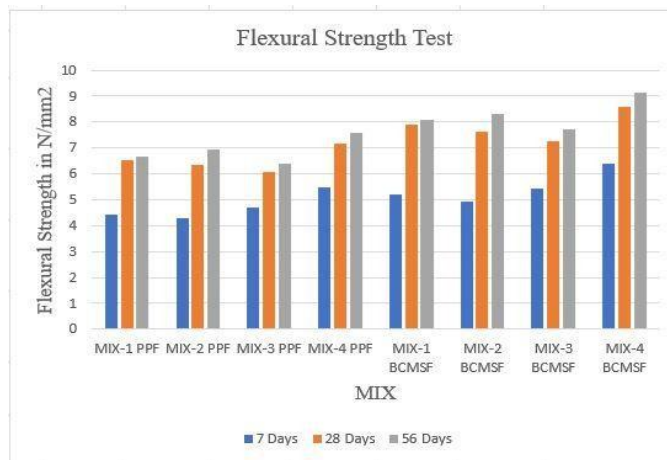


Chart-3: Flexural Strength

7.3. Durability Test

Sulphate Attack Test: The sulphate attack test using magnesium sulphate ($MgSO_4$) solution was conducted to evaluate the durability performance of SCC mixes reinforced with polypropylene fibers (PPF) and brass coated micro steel fibers (BCMSF). The residual compressive strength after 56 days of $MgSO_4$ exposure was taken as the indicator of sulphate resistance. Higher retained compressive strength indicates better resistance to sulphate attack and reduced deterioration of the concrete matrix under aggressive environmental conditions. After 56 days of $MgSO_4$ exposure, BCMSF mixes consistently retained higher compressive strength than PPF mixes, indicating superior sulphate resistance. Among all mixes, MIX-4 demonstrated the best performance because of its balanced binder composition, producing a dense microstructure. BCMSF further enhanced retained strength by resisting crack widening under expansive reactions. Overall, BCMSF provided better durability and structural integrity under sulphate attack compared to PPF mixes.

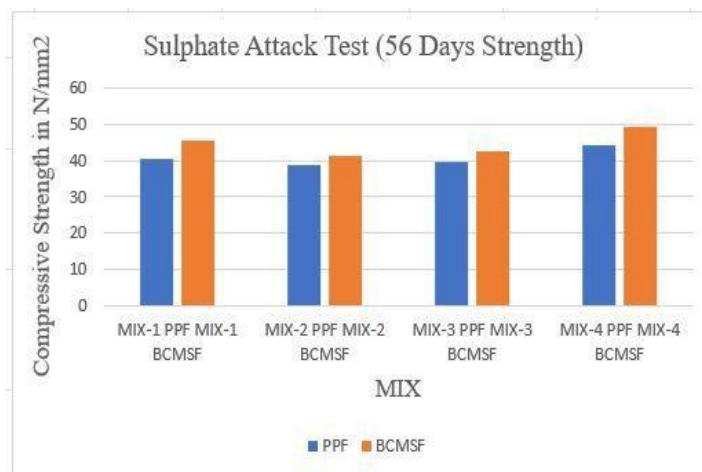


Chart-4: Sulphate Attack Test

The results indicate that all mixes experienced strength loss after 56 days of $MgSO_4$ exposure due to sulphate attack, which causes expansion, microcracking, and deterioration of the cement matrix. However, BCMSF mixes showed lower strength loss (3.8–6.39%) compared to PPF mixes (7.14–8.57%), demonstrating better sulphate resistance. Sulphate ions react with calcium hydroxide and aluminates to form expansive products such as gypsum and ettringite, leading to internal stress and cracking. PPF helps control microcracks but has lower stiffness and bonding capacity. In contrast, BCMSF provides stronger crack-bridging, better stress distribution, and reduced permeability, limiting sulphate ingress.

Among all mixes, MIX-4 showed the least strength loss overall, indicating that balanced fly ash and GGBS improved matrix densification and durability. Overall, BCMSF enhanced resistance to sulphate attack more effectively than PPF.

A comparison of the two sulphate solutions clearly shows that magnesium sulphate ($MgSO_4$) caused greater strength reduction than sodium sulphate (Na_2SO_4) in most mixes, especially in Mix-1 PPF and Mix-3 PPF. This is because $MgSO_4$ is more aggressive in nature. In addition to forming gypsum and ettringite, magnesium sulphate reacts with calcium silicate hydrate (C-S-H) gel and converts it into non-cementitious magnesium silicate hydrate (M-S-H). This process weakens the binding structure of concrete and reduces overall strength.

7.4 SEM-EDX ANALYSIS

Microstructural and elemental analyses are important for understanding the internal structure and performance of PPF-based SCC mixes. Scanning Electron Microscopy (SEM) helps in examining pore structure, fiber distribution, fiber-matrix bonding, and the presence of micro cracks. Energy Dispersive X-ray Analysis (EDX/EDAX) provides information about the elemental composition and hydration products, such as calcium, silica, and alumina, which influence strength and durability.

The SEM analysis of MIX-1 with 0.2% PPF shows a relatively dense cementitious matrix with uniformly dispersed fibers. Fiber pull-out rather than breakage is observed, indicating energy absorption and improved toughness. Minor pores are visible, but no major cracks are detected. EDX confirms high carbon content due to polypropylene fibers, along with Si and Ca peaks indicating proper C-S-H formation and hydration. In contrast, MIX-1 with 0.5% BCMSF exhibits stronger fiber anchorage and improved mechanical interlocking. SEM images show well-embedded metallic fibers with minimal interfacial gaps. EDX results reveal higher Fe_2O_3 content along with significant SiO_2 and CaO, confirming the presence of hydration products and metallic phases. Overall, while PPF improves ductility through fiber pull-out mechanisms, BCMSF provides superior bonding, crack-bridging efficiency, and load transfer capacity, resulting in comparatively better microstructural stability and mechanical performance.

The SEM-EDX comparison of MIX-4 with PPF and BCMSF shows clear differences in microstructure and bonding characteristics. In the PPF-based mix, the SEM image reveals a moderately dense matrix with visible pores, micro voids, and small interfacial gaps around fibers, indicating only moderate fiber-matrix bonding. Limited pore refinement is observed due to the absence of supplementary cementitious materials. EDX results show higher calcium content and a higher Ca/Si ratio, suggesting dominant OPC hydration with significant calcium hydroxide presence and partial carbonation. BCMSF performs better due to higher stiffness, stronger bonding, and superior crack-bridging capacity, while PPF has lower stiffness and weaker bonding, resulting in reduced stress transfer.

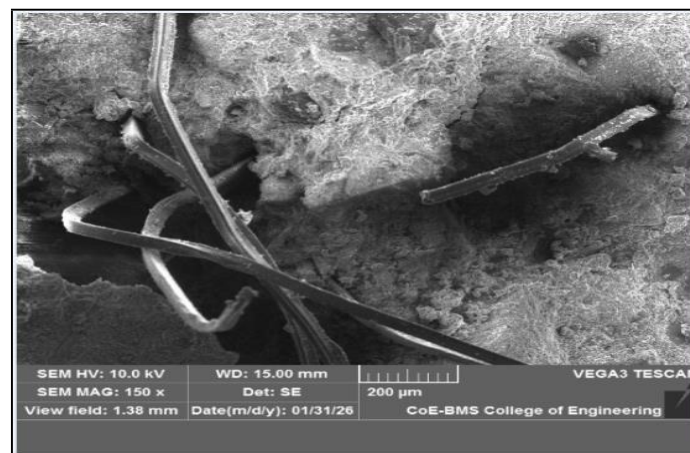


Fig-1 SEM Image of MIX- 1 PP

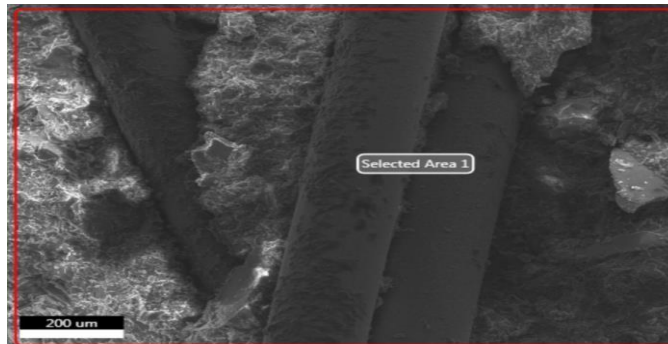


Fig-2 SEM Image of MIX-4 PPF

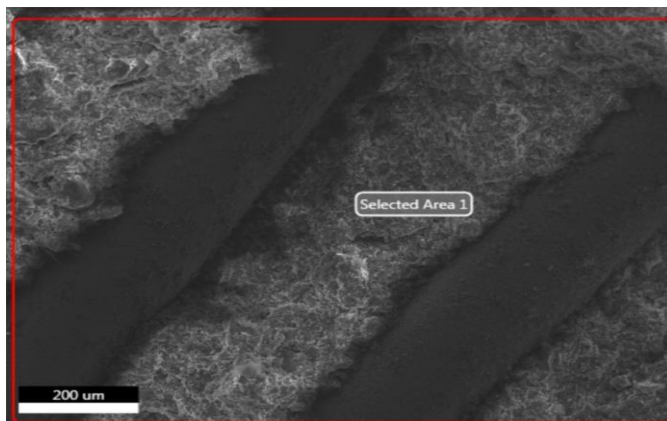


Fig-3 SEM Image of MIX-1 BCMSF

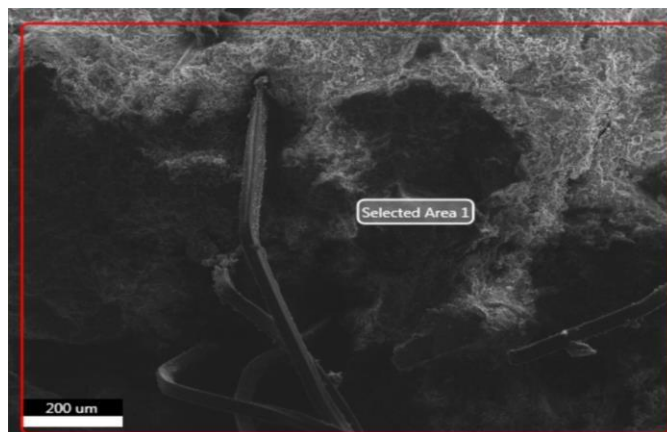


Fig-4 SEM Image of MIX-4 BCMSF

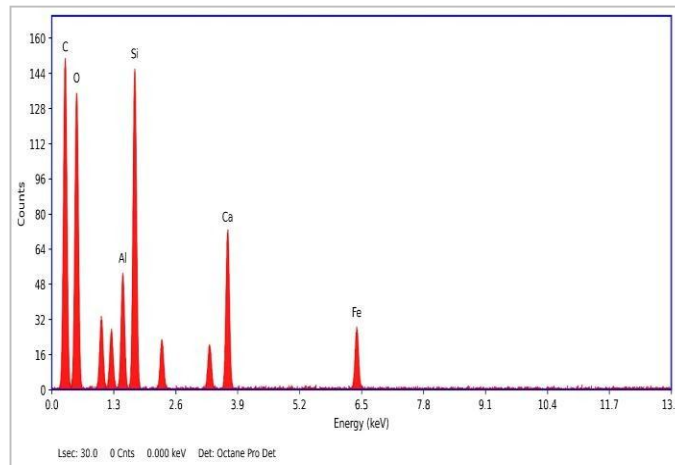


Fig-5 EDX ANALYSIS of MIX-1 PPF

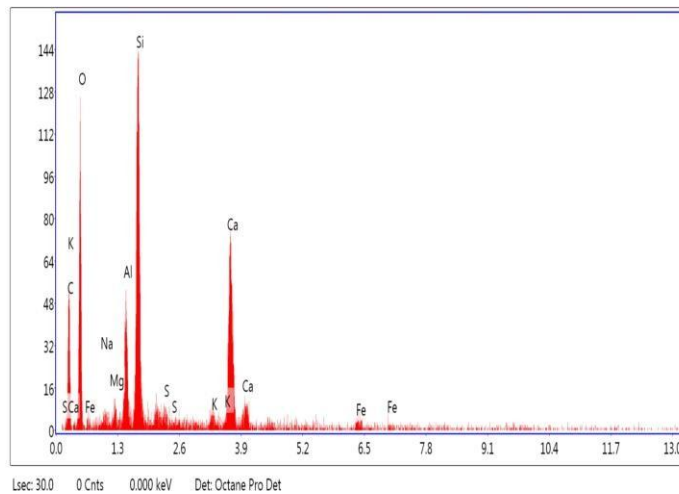


Fig-6 EDX ANALYSIS of MIX-4 PPF

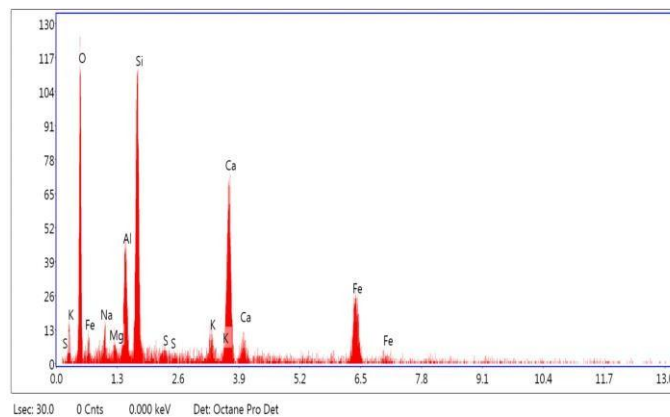


Fig-7 EDX ANALYSIS of MIX-1 BCMSF

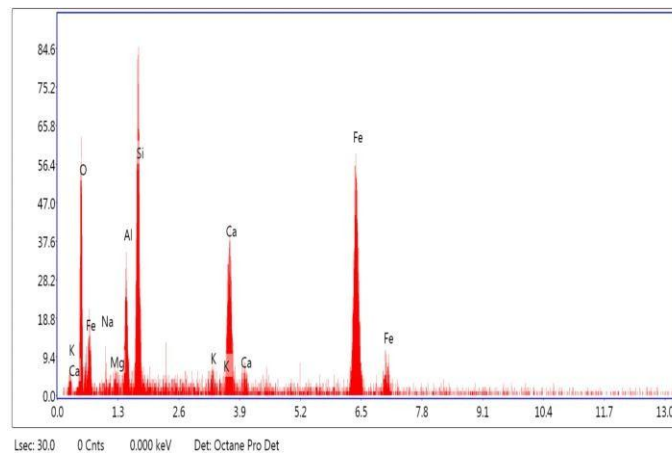


Fig-8 EDX ANALYSIS of MIX-4 BCMSF

8. CONCLUSIONS

- This study investigated the performance of self-compacting concrete (SCC) incorporating mineral admixtures and a comparative study of polypropylene fiber (PF) and brass coated micro steel fiber (BCMSF).
- The incorporation of fibers significantly influenced the performance of self-compacting concrete (SCC). PPF mixes exhibited better flowability and workability due to their low density and smooth surface, whereas BCMSF mixes slightly reduced workability but still satisfied EFNARC requirements for SCC. In terms of mechanical properties, BCMSF-reinforced SCC showed higher compressive, split tensile, and flexural strengths because of stronger fiber-matrix bonding and effective crack-bridging action.
- Durability results under $MgSO_4$ exposure indicated that BCMSF mixes experienced lower strength loss and reduced permeability compared to PPF mixes, demonstrating better sulphate resistance. PPF mainly contributed to microcrack control, shrinkage resistance, and improved matrix uniformity, while BCMSF provided greater structural reinforcement.
- Additionally, the comparison shows that $MgSO_4$ is more aggressive than Na_2SO_4 because it damages both the cement matrix and C-S-H gel, causing greater strength loss. Mixes with high OPC were more vulnerable, while fly ash and GGBS blends improved sulphate resistance by reducing permeability and calcium hydroxide content.
- SEM-EDX analysis further confirmed that BCMSF mixes developed a denser and more compact microstructure with fewer pores and micro cracks compared to PPF mixes, leading to improved overall strength.
- Among all mixes, Mix-4 with 0.5% Brass coated micro steel fiber achieved the best overall balance of workability, strength, resistance to sulphate attack, and better microstructural stability.

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