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Study On Self Compacting Concrete with Different Minerals as Admixture- A Review

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Abstract- Self-Compacting Concrete (SCC) is an advanced form of high-performance concrete that flows under its own weight and achieves complete compaction without the need for external vibration. The incorporation of mineral admixtures such as fly ash, Ground Granulated Blast Furnace Slag (GGBS), silica fume, metakaolin, and nano-materials has significantly enhanced the performance and sustainability of SCC. This review paper critically analyzes previous studies on SCC incorporating various mineral admixtures with respect to fresh, mechanical, durability, and microstructural properties. The findings indicate that mineral admixtures improve workability, long-term strength, durability, and reduce environmental impact by lowering cement consumption. However, several research gaps exist in areas such as mix design standardization, long-term durability, shrinkage behavior, and optimization techniques. This paper identifies these gaps and suggests future research directions for developing sustainable and high-performance SCC.

Keywords- Self-Compacting Concrete, Mineral Admixtures, Fly Ash, GGBS, Silica Fume, Workability, Strength, Durability, Sustainable Concrete.

I. INTRODUCTION

Concrete is the most widely used construction material in the world due to its versatility, strength, and durability. Conventional concrete requires adequate compaction through vibration to eliminate entrapped air and achieve the desired strength and durability. However, improper vibration often leads to defects such as honeycombing, segregation, and poor surface finish, especially in heavily reinforced structures. To address these challenges, Self-Compacting Concrete (SCC) was developed in Japan in the late 1980s. SCC is characterized by its ability to flow under its own weight, completely filling formwork and encapsulating reinforcement without the need for external vibration. This property makes SCC particularly suitable for complex structural elements, precast concrete, and high-rise construction. The performance of SCC is governed by three key fresh properties: filling ability, passing ability, and resistance to segregation, as specified by EFNARC guidelines. Despite its advantages, SCC requires higher amounts of cement and chemical admixtures, leading to increased cost and carbon emissions. The cement industry is a major contributor to global CO_2 emissions, making sustainability a critical concern in concrete technology. The use of mineral admixtures as partial replacements for cement offers an effective solution by improving performance while reducing environmental impact. Mineral admixtures such as fly ash, GGBS, silica fume, and alccofine improve particle packing, enhance rheological properties, and refine the microstructure of concrete. These materials not only improve workability and long-term strength but also enhance durability by reducing permeability and resistance to aggressive environments. This review paper aims to critically analyze existing research on SCC with different mineral admixtures to identify trends, benefits, limitations, and future research directions.

II. LITERATURE REVIEW

Several researchers have studied the performance of SCC with different mineral admixtures and reported considerable improvements in workability, strength, and durability.

[1] Mora Raja Kumar and Naga Sreenivasa Rao (2026) in their study titled *"Self-Compacting Concrete with Mineral Admixtures: An Experimental Study"* investigated the effect of mineral admixtures such as fly ash, ground granulated blast furnace slag (GGBS), and silica fume on the performance characteristics of self-compacting concrete (SCC). The study focused on partial replacement of cement with these admixtures at varying proportions to enhance both fresh and hardened properties while improving sustainability. The experimental program included detailed evaluation of fresh properties of SCC using slump flow test, T_{50} time test, V-funnel test, and L-box test to assess filling ability, passing ability, and segregation resistance. Hardened properties were examined through compressive strength, split tensile strength, and flexural strength tests at different curing periods. The results revealed that the incorporation of mineral admixtures significantly improved the flowability and workability of SCC, ensuring better compaction without the need for vibration. It was also observed that the use of fly ash and GGBS reduced the heat of hydration and enhanced long-term strength development, while silica fume contributed to improved early strength and microstructural densification. The optimum combination of mineral admixtures demonstrated superior performance compared to conventional SCC mixes.

[2] Pahsha et al. (2026) in their study titled *"Statistical Evaluation of Fresh Properties of Self-Compacting Concrete Incorporating Construction and Industrial Waste: A Sustainable Approach"* investigated the use of recycled concrete aggregates (RCA) and ground granulated blast furnace slag (GGBS) in self-compacting concrete (SCC) to enhance sustainability while maintaining desirable fresh properties. The study emphasized the application of advanced statistical tools to optimize SCC performance. The experimental program involved preparing SCC mixes with varying proportions of GGBS (15% to 45%) as cement replacement and RCA (20% to 100%) as coarse aggregate replacement. Fresh properties were evaluated using standard tests such as slump flow, T_{50}, J-ring, V-funnel, L-box, and U-box to assess filling ability, passing ability, and segregation resistance. Microstructural and chemical characterization of materials was conducted using Scanning Electron Microscopy (SEM) and X-ray Fluorescence (XRF). The results indicated that increasing RCA content reduced workability due to higher water absorption and surface roughness, whereas GGBS improved workability up to an optimum level of 30% by enhancing paste volume and reducing internal friction. Strong statistical correlations were observed between key fresh property parameters, such as slump flow and T_{50} ($R^2 = 0.971$), J-ring and V-funnel ($R^2 = 0.880$), and L-box and U-box ($R^2 = 0.947$). Two-way ANOVA confirmed that both RCA and GGBS significantly influence SCC performance ($p < 0.001$).

[3] Wang et al. (2025) in their article titled *"The Properties of Self-Compacting Ultra-High-Performance Concrete with Different Types of Mineral Admixtures"* investigated the influence of silica fume, cenosphere, fly ash, and ground slag powder on the rheological and mechanical behavior of self-compacting ultra-high-performance concrete (UHPC). The experimental program considered mineral admixture dosages ranging from 0% to 15% with water-binder ratios of 0.18, 0.20, and 0.22. Fresh properties were evaluated through slump flow and plastic viscosity tests, while hardened properties were assessed by flexural and compressive strength measurements at 3 and 28 days. Additionally, microstructural analysis was carried out using scanning electron microscopy (SEM) and X-ray diffraction (XRD). Results demonstrated that silica fume and slag powder reduced the fluidity of fresh UHPC but enhanced plastic viscosity, whereas cenosphere and fly ash improved fluidity but reduced viscosity. Mechanically, silica fume contributed to superior strength development, while cenosphere, fly ash, and slag powder initially reduced early strength (3 days) but enhanced long-term strength (28 days). SEM and XRD findings revealed that UHPC containing silica fume had denser hydration products and lower $Ca(OH)_2$ content, confirming its role in strengthening the microstructure. The study concluded that tailoring the type and dosage of mineral admixtures can balance workability and mechanical performance in UHPC, making it suitable for sustainable high-performance structural applications.

[4] Manoharan et al. (2024) in their study titled *"Performance Evaluation of Mechanical and Durability Properties of Self-Compacting Concrete Replaced with Nano-Mineral Additives"* investigated the effectiveness of nano-mineral admixtures as partial replacements of cement in self-compacting concrete (SCC) to enhance both mechanical and durability properties while addressing environmental concerns associated with cement production. The experimental program considered replacement levels of 0%, 2.5%, 5%, and 30% using nano-sized mineral materials such as fly ash, silica fume, phosphogypsum, and alccofine. Fresh properties of SCC were evaluated using slump flow test, J-ring test, and L-box test to assess flowability, passing ability, and segregation resistance. Hardened properties were examined through compressive strength, split tensile strength, and flexural strength tests. In addition, durability characteristics were studied using Rapid Chloride Permeability Test (RCPT), water absorption test, and alkaline resistance tests. The results indicated that the incorporation of nano-mineral admixtures significantly enhanced both mechanical strength and durability performance of SCC. It was observed that optimum replacement levels improved compressive, tensile, and flexural strengths due to the nano-filling effect and enhanced pozzolanic reactions, which resulted in a denser and more refined microstructure. Durability performance was also improved, as indicated by reduced chloride permeability, lower water absorption, and better resistance to aggressive environmental conditions.

[5] Aziz et al. (2024) in their research titled *"Enhancing Sustainability in Self-Compacting Concrete by Optimizing Blended Supplementary Cementitious Materials"* investigated the use of blended supplementary cementitious materials (SCMs) such as metakaolin (MK) and limestone powder (LP) as partial replacements of cement in self-compacting concrete (SCC) to improve sustainability without compromising performance. The study adopted an advanced experimental approach using the Response Surface Method (RSM) to optimize mix proportions. A total of 16 mix combinations were analyzed, where the combined content of cement, metakaolin, and limestone powder was maintained constant, while parameters such as water-to-binder ratio and aggregate proportions were varied. Fresh properties of SCC were evaluated using slump flow test, L-box test, and sieve segregation test to assess workability and stability. Mechanical properties were determined through compressive strength tests at 7 and 28 days. The results indicated that higher percentages of metakaolin tend to reduce workability due to its fine particle size and high reactivity, while also affecting hardened properties when used in excess. However, an optimum replacement level of 40% to 55% of cement with blended SCMs was found to provide a balanced performance in terms of both rheological and mechanical properties. Furthermore, the study emphasized the importance of using blended materials rather than single admixtures to achieve improved sustainability and performance. The incorporation of SCMs significantly reduced cement consumption, thereby lowering carbon emissions and contributing to environmental sustainability goals aligned with global standards such as the United Nations Sustainable Development Goals (SDGs).

[6] Amala and Umarani (2024) in their article titled *"Experimental Investigation on Mechanical and Microstructural Properties of Self-Compacting Geopolymer Concrete with Different Mineral Admixtures"* investigated the potential of self-compacting geopolymer concrete (SCGC) incorporating mineral admixtures such as fly ash, ultra-fine GGBS, and micro-silica. The study focused on addressing the high viscosity challenge of geopolymer concrete by developing SCGC that flows and compacts under its own weight. Mixes were designed with a constant water-to-powder ratio of 0.35 and a binder content of 400 kg/m³, with 1.5% glass fibers added. Fresh properties were assessed through slump flow, L-box, V-funnel, T50, and J-ring tests, while mechanical properties were evaluated for specimens cured at 70 °C across different molarities (8M, 10M, and 12M). Additionally, advanced microstructural studies such as X-ray diffraction (XRD), scanning electron microscopy (SEM), and Fourier transform infrared spectroscopy (FT-IR) were carried out to understand hydration and bonding mechanisms. The results showed that mineral admixtures significantly improved both fresh and hardened properties, while the ANN (Artificial Neural Network) model demonstrated its effectiveness in predicting optimal mix proportions. The study concluded that SCGC not only provides a sustainable and low-carbon alternative to conventional SCC but also exhibits excellent mechanical integrity and durability, supported by strong microstructural evidence.

[7] Sekar et al. (2024) in their study titled *"A Study on Fresh Concrete Properties by Self-Compacting Concrete Using Mineral Admixture as a Fine Aggregate"* investigated the use of mineral admixtures, particularly quarry dust as a replacement for river sand, in the development of self-compacting concrete (SCC). The study focused on evaluating fresh properties and identifying research gaps in SCC applications. The research involved an extensive literature review of nearly 5,000 published articles from reputed databases such as Scopus and Elsevier, covering developments in SCC from 1980 to 2021. The study emphasized the role of fine aggregate replacement using quarry dust in improving the performance and sustainability of SCC. The results indicated that the use of quarry dust as a partial or full replacement for natural sand can significantly influence the fresh properties of SCC, including flowability, passing ability, and segregation resistance. The study highlighted that proper proportioning of mineral admixtures is essential to control the rheological behavior of SCC and maintain its self-compacting characteristics. Furthermore, the study identified that most existing research is limited to basic mechanical and durability properties, while areas such as shrinkage behavior, microstructural analysis, and long-term performance are less explored. It also emphasized the need for more comprehensive investigations on design parameters and optimization techniques for SCC.

[8] Patil et al. (2024) in their study titled *"Performance Analysis of Self-Compacting Concrete with Use of Artificial Aggregate and Partial Replacement of Cement by Fly Ash"* investigated the utilization of industrial by-products such as artificial aggregate (silico-manganese slag) and fly ash in the development of sustainable self-compacting concrete (SCC). The study focused on evaluating both fresh and hardened properties of SCC while promoting environmental sustainability. The experimental program involved preparing M30 grade SCC mixes with partial replacement of coarse aggregate by artificial aggregate at levels of 20%, 40%, and 60%, and further replacing cement with fly ash at 15%, 25%, and 35%. Fresh properties were evaluated using standard SCC tests such as slump flow, V-funnel, L-box, and J-ring to assess flowability, passing ability, and segregation resistance. Hardened properties were analyzed through compressive strength, flexural strength, and split tensile strength tests. The results indicated that partial replacement of natural aggregate with 20% artificial aggregate resulted in an increase in compressive strength by approximately 8.27% compared to conventional SCC. However, higher replacement levels (40% and 60%) led to a reduction in strength. Further optimization showed that replacing cement with 15% fly ash in combination with 20% artificial aggregate yielded the best performance, with an increase in compressive strength by about 7.41%. Beyond this level, strength decreased due to excess replacement. Microstructural analysis using SEM and XRD confirmed that the optimum mix resulted in a denser and more compact matrix, leading to improved mechanical performance. The study also highlighted that the use of industrial waste materials reduces dependency on natural resources and promotes eco-friendly construction practices.

[9] Rudnicki (2024) in his study titled *"Design of Self-Compacting Concrete with Reduced Cement Content by Aggregate Packing Method"* investigated an innovative approach for designing self-compacting concrete (SCC) with reduced cement consumption while maintaining required mechanical and durability properties. The study focused on optimizing the aggregate packing density to minimize voids and enhance the efficiency of the concrete matrix. The experimental program involved the analysis of 36 different mix proportions using CEM I 42.5 R cement and fly ash as a mineral admixture. The aggregate packing method was employed to achieve a highly compacted mineral skeleton with minimal free space. Fresh and hardened properties of SCC were evaluated to ensure that the designed mixes satisfied the requirements of workability, strength, and durability. The results indicated that by optimizing the aggregate packing, the free space in the concrete matrix could be reduced to approximately 17%, allowing a significant reduction in cement content from 500 kg/m³ to 350 kg/m³ without compromising performance. The SCC mixes achieved compressive strength exceeding 68 MPa after 90 days of curing. Additionally, durability performance was confirmed through freeze–thaw resistance tests, which showed only a minor reduction (about 2.1%) in compressive strength after 100 cycles.

[10] Appaji and Chethan (2023) in their study titled *"Study on Properties of SCC Mixed with Mineral Admixtures and Fibres Subjected to Elevated Temperature"* investigated the performance of self-compacting concrete (SCC) incorporating mineral admixtures and polypropylene fibres under aggressive environmental conditions and elevated temperatures. The study aimed to evaluate both mechanical strength and durability of SCC when exposed to chemical attack and thermal variations. The experimental program involved the use of mineral admixtures such as fly ash and ground granulated blast furnace slag (GGBFS) along with polypropylene fibres at different percentages (1% and 2%). The concrete specimens were subjected to chemical curing environments using sulphuric acid (H_2SO_4) and sodium hydroxide (NaOH) for durations of 60, 80, and 120 days. Further, the specimens were exposed to elevated temperatures of 200°C and 400°C to assess thermal resistance. Compressive strength tests were conducted to evaluate the mechanical performance under these extreme conditions. The results indicated that the inclusion of polypropylene fibres significantly improved the compressive strength and resistance of SCC under elevated temperatures and chemical exposure. It was observed that fibre-reinforced SCC exhibited better structural integrity and reduced deterioration compared to conventional SCC without fibres. The presence of mineral admixtures such as fly ash and GGBFS contributed to improved durability by enhancing resistance against acid and alkaline attack.

[11] Chandramouli et al. (2023) in their paper titled *"A Study on Self Compacting Concrete with Different Minerals as Admixture"* investigated the performance of SCC by incorporating Ground Granulated Blast Furnace Slag (GGBS) and silica fume as partial replacements for cement. The study highlighted that SCC, being a highly fluid and non-segregating concrete, offers better stability, deformability, and strength compared to conventional vibrated concrete, while also eliminating the need for external vibration. The researchers observed that partial replacement of cement with GGBS at levels of 10%, 20%, 30%, and 40% improved the compressive and split tensile strength, with optimum results obtained at 30% replacement. Further, by keeping GGBS constant at 30% and varying silica fume content at 5%, 7.5%, and 12.5%, it was found that the addition of silica fume enhanced the mechanical strength and durability characteristics of SCC. The study concluded that the combination of GGBS and silica fume with suitable dosages of superplasticizer not only improves workability but also contributes to sustainable concrete production by reducing cement usage.

[12] Jayadurga and Selvam (2022) in their study titled *"Analysis and Study of High Strength Self Compacting Concrete by Using Chemical and Mineral Admixtures"* investigated the development of high-strength self-compacting concrete (SCC) using a combination of chemical and mineral admixtures. The study focused on producing M70 grade SCC with enhanced mechanical properties and improved workability suitable for high-performance structural applications. The research emphasized that SCC is a type of high-performance concrete (HPC) characterized by excellent deformability, high segregation resistance, and the ability to flow and compact under its own weight without external vibration. The mix design was based on the Nan Su method, where aggregate proportioning is determined using the packing factor concept to achieve optimal flowability and self-compaction. The study highlighted the importance of maintaining a low water-to-cementitious material ratio, high powder content, and high paste-to-aggregate ratio for achieving the desired SCC properties. Mineral admixtures such as limestone powder were used along with chemical admixtures like polycarboxylate ether (PCE) based superplasticizers to enhance flow characteristics and strength. The results indicated that the incorporation of mineral and chemical admixtures significantly improved both fresh and hardened properties of SCC. The use of superplasticizers enhanced fluidity and workability, while mineral admixtures contributed to increased compressive strength and improved durability. The developed SCC mix achieved high strength suitable for applications such as tall buildings, long-span bridges, and structures exposed to aggressive environmental conditions.

[13] Rawat and Khan (2022) in their study titled *"Self-Compacting Concrete"* discussed the fundamental characteristics, mix design principles, and performance requirements of self-compacting concrete (SCC). The study emphasized SCC as a high-performance concrete capable of flowing under its own weight and achieving full compaction without the need for external vibration, making it suitable for structures with congested reinforcement and complex formwork. The study highlighted that the successful production of SCC depends on achieving an appropriate balance between yield stress and viscosity of the concrete mix. High-range water-reducing admixtures (superplasticizers) are used to reduce yield stress and enhance flowability, while adequate viscosity must be maintained to prevent segregation and ensure stability of the mix. The research also discussed the importance of mix design in SCC, focusing on achieving the required strength, durability, and workability in an economical manner. The mix design for M30 grade concrete was carried out as per IS 10262:1982, considering proper selection and proportioning of materials such as cement, aggregates, water, and admixtures.

[14] Ganapathy et al. (2022) in their study titled *"Comparative Study on the Design Methods to Achieve Self-Compacting Concrete"* investigated different mix design approaches for developing self-compacting concrete (SCC) with improved mechanical properties and workability. The study primarily compared the conventional Nan Su method and the Modified Nan Su method for designing SCC mixes. The experimental program focused on developing M40 grade SCC by incorporating mineral admixtures such as fly ash, sugarcane ash, kaolin clay, and wood ash as partial replacements of cement. The study highlighted that SCC requires the use of mineral admixtures and high-range water-reducing admixtures to maintain its fluidity, cohesion, and resistance to segregation. The results indicated that the Modified Nan Su method produced better mechanical performance compared to the conventional Nan Su method. It was observed that the inclusion of mineral admixtures improved the workability and reduced the cement content, thereby enhancing the sustainability and cost-effectiveness of SCC. Fly ash, due to its spherical particle shape, significantly improved flowability, while other pozzolanic materials contributed to strength and durability. Furthermore, the study emphasized that SCC mix design is still largely based on trial-and-error approaches due to the absence of a universally accepted standard method. EFNARC guidelines were used to evaluate fresh properties such as filling ability, passing ability, and segregation resistance.

[15] Shaker and Kumar (2022) in their study titled *"A Study on Understanding the Effects of Admixtures on the Properties of Self-Compacting Concrete"* investigated the influence of various mineral and chemical admixtures on the performance of self-compacting concrete (SCC). The experimental work was carried out using a water-cement ratio of 0.42, incorporating silica fume and superplasticizer (SP-430) in different proportions to evaluate their combined effect on fresh and hardened properties of SCC. The fresh properties of SCC were assessed using slump cone test and V-funnel test to evaluate flowability and viscosity characteristics. The hardened properties were determined through compressive strength, split tensile strength, and flexural strength tests conducted at 7 and 28 days of curing. Various combinations of chemical admixtures along with superplasticizer were also analyzed to understand their role in enhancing performance. The results indicated that the inclusion of 10% silica fume along with 1% superplasticizer (SP-430) provided optimum performance in terms of both workability and strength. It was observed that mineral admixtures such as silica fume significantly improved the mechanical properties due to their pozzolanic activity, while chemical admixtures enhanced the flow characteristics and reduced the need for additional water. The study also emphasized that the proper combination of mineral and chemical admixtures is essential for achieving desired SCC properties.

[16] Goutam and Tiwari (2021) in their review titled *"A Review on Effect of Various Mineral Admixtures on Self Compacting Concrete"* analyzed the influence of different mineral admixtures such as fly ash, silica fume, and rice husk ash on the performance of self-compacting concrete (SCC). The study focused on SCC mixes of M30 grade developed using the Modified Nan Su mix design method, incorporating these mineral admixtures as supplementary cementing materials. The review highlighted that SCC is a specialized concrete capable of flowing and compacting under its own weight without vibration, while maintaining sufficient cohesion to prevent segregation and bleeding. The addition of mineral admixtures along with superplasticizers plays a significant role in achieving the desired fresh properties such as filling ability, passing ability, and resistance to segregation. The study emphasized that the use of fly ash improves both fresh and hardened properties of SCC when used as a partial replacement of cement (typically up to 35%), enhancing workability and long-term strength. Silica fume was found to be effective at around 15% replacement, contributing to improved strength and reduced permeability due to its fine particle size and pozzolanic nature. Rice husk ash, being a highly reactive pozzolanic material, enhanced the microstructure of SCC by improving the interfacial transition zone, thereby increasing durability and strength when used up to 20%.

[17] Agnihotri et al. (2021) in their study titled *"Experimental Study of Self Compacting Concrete using Portland Cement and Mineral Admixture"* investigated the influence of mineral admixtures on the fresh and hardened properties of self-compacting concrete (SCC). The study focused on the use of Ordinary Portland Cement (OPC) and fly ash as a mineral admixture to develop a cost-effective and environmentally sustainable SCC mix. The experimental program emphasized the evaluation of fresh properties such as flowability, passing ability, segregation resistance, and viscosity using standard tests including slump flow, V-funnel, J-ring, L-box, and U-box tests. The study highlighted that SCC behaves as a visco-plastic (Bingham) fluid, where parameters such as yield stress and plastic viscosity play a crucial role in determining its performance. The results indicated that the incorporation of mineral admixtures like fly ash, GGBS, and micro silica significantly influenced the rheological properties of SCC by improving flow characteristics and reducing segregation. It was observed that paste volume and thickness govern the fresh behavior of SCC, which in turn depends on water-binder ratio and the type of admixtures used. The inclusion of fly ash improved workability and reduced formwork pressure, while also extending the setting time of concrete. In terms of hardened properties, it was found that SCC exhibited strength characteristics comparable to conventional concrete. However, mineral admixtures resulted in lower early strength but enhanced long-term strength (28 days and beyond). The study also emphasized that proper mix design aiming at higher aggregate packing density and optimized paste volume is essential for achieving desired SCC performance.

[18] Leelavathi and Sudalaimani (2021) in their research titled *"Study on Self-Compacting Concrete with Sustainable Materials"* investigated the feasibility of incorporating sustainable materials such as ground granulated blast furnace slag (GGBS) and manufactured sand (M-sand) in self-compacting concrete (SCC). The study focused on partial replacement of cement with GGBS at levels of 10%, 20%, 30%, 40%, and 50%, along with replacement of natural fine aggregate by M-sand at 20%, 40%, 60%, and 80% proportions. The experimental program involved evaluation of both fresh and hardened properties of SCC. Fresh properties were controlled using superplasticizers to achieve the desired flow characteristics. Hardened properties were assessed through compressive strength tests. In addition, detailed microstructural analysis was carried out using Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Analysis (EDAX) to understand the internal structure and composition of the concrete matrix. The results indicated that the combined use of GGBS and M-sand significantly enhanced the performance of SCC. It was observed that optimum replacement of cement with 20% GGBS resulted in a compressive strength of approximately 55.55 MPa. The inclusion of M-sand improved particle packing and contributed to better strength and durability characteristics. Microstructural analysis confirmed the formation of a dense and compact matrix, which is responsible for improved mechanical performance.

[19] Tangadagi et al. (2021) in their article titled *"Role of Mineral Admixtures on Strength and Durability of High Strength Self Compacting Concrete: An Experimental Study"* investigated the effect of GGBS and alccofine on high-strength SCC mixes of grades M60, M80, and M100. The study prepared nine different mixes with varying water-binder ratios and admixture dosages, and evaluated fresh properties such as filling ability, flowability, and passing ability using slump flow, T500 mm, V-funnel, J-ring, U-box, and L-box tests in accordance with EFNARC standards. Hardened properties were studied through compressive, split tensile, and flexural strength tests, while durability was assessed by examining creep and shrinkage as per IS 516:1959. The results revealed that incorporating GGBS and alccofine significantly enhanced both fresh and hardened properties, reduced cement consumption, and improved the long-term performance of SCC. A notable contribution of this study was the evaluation of creep and shrinkage behavior in high-grade SCC, which is often less explored in existing literature. The authors concluded that mineral admixtures not only improve strength and durability but also lower the cost and environmental impact of SCC, making it a sustainable material for advanced structural applications.

[20] Albiajawi et al. (2021) in their paper titled *"Influence of Mineral Admixtures on the Properties of Self-Compacting Concrete: An Overview"* presented a comprehensive review of the role of mineral admixtures in improving the performance of self-compacting concrete (SCC). The study focused on commonly used mineral admixtures such as silica fume, fly ash, ground granulated blast furnace slag (GGBS), and coal bottom ash, and their influence on fresh, mechanical, and durability properties of SCC. The review highlighted that mineral admixtures play a crucial role in enhancing the stability of SCC by improving resistance to segregation and bleeding during transportation and placement. These finely divided materials improve the flowability of concrete, enabling it to achieve full compaction under its own weight without the need for vibration, even in heavily reinforced sections. The study further discussed that the use of mineral admixtures helps in reducing the overall cost of SCC by decreasing the consumption of cement and minimizing the requirement of chemical admixtures. It was also observed that mineral admixtures reduce the heat of hydration, thereby lowering the risk of thermal cracking and improving long-term durability. In terms of mechanical and durability performance, the inclusion of mineral admixtures was found to enhance compressive strength, improve microstructure, and increase resistance to environmental effects. The review emphasized that materials such as fly ash and GGBS contribute to long-term strength development, while silica fume improves early strength and densifies the concrete matrix. Coal bottom ash was identified as a potential sustainable alternative material with beneficial effects on concrete properties.

[21] Athiyamaan (2021) in the review titled *"Admixture-Based Self-Compacted Concrete with Self-Curing Concrete Techniques: A State-of-the-Art Review"* presented a comprehensive overview of recent developments in self-compacting concrete (SCC) incorporating mineral admixtures and self-curing techniques. The study focused on improving the durability, workability, and sustainability of SCC through optimized mix design and innovative curing methods. The review emphasized the importance of using industrial by-products such as fly ash, silica fume, and other pozzolanic materials as partial replacements for cement and fine aggregates. These materials not only improve the rheological and mechanical properties of SCC but also help in reducing environmental pollution caused by industrial waste disposal. The study categorized the use of pozzolanic materials into unary, binary, and ternary blends, highlighting their effectiveness in enhancing concrete performance. Furthermore, the study explored the concept of self-curing concrete, which reduces the dependency on external water curing. The use of self-curing agents such as polyethylene glycol (PEG) was discussed as an effective method to maintain internal moisture and improve hydration, thereby enhancing strength and durability. This approach is particularly beneficial in regions with water scarcity and for large-scale construction projects.

[22] Chiranjeevi and Chandrasekhar Rao (2020) in their study titled *"Properties of Self-Compacting Concrete Containing Mineral Admixtures"* investigated the influence of mineral admixtures such as fly ash, silica fume, and ground granulated blast furnace slag (GGBS) on the workability and strength characteristics of self-compacting concrete (SCC). The experimental program involved partial replacement of Portland cement with mineral admixtures at varying percentages of 30%, 40%, and 50%, and the mix design was carried out in accordance with EFNARC guidelines. The fresh properties of SCC were evaluated using slump flow, L-box, U-box, and T_{50} tests to assess flowability, passing ability, and segregation resistance. The hardened properties were analyzed through compressive strength, split tensile strength, and flexural strength tests. The study also considered the role of superplasticizers in enhancing the workability of SCC mixtures. The results indicated that the incorporation of mineral admixtures significantly improved the flow characteristics and reduced the requirement of superplasticizer for achieving desired fluidity. It was observed that the particle size distribution, shape, and surface texture of mineral admixtures played a crucial role in determining the rheological properties of SCC. Furthermore, the inclusion of fly ash, silica fume, and GGBS contributed to improved mechanical properties, particularly at optimum replacement levels.

[23] Gnanaraj et al. (2020) in their state-of-the-art review titled *"Effects of Admixtures on the Self-Compacting Concrete"* presented a comprehensive overview of the influence of mineral and chemical admixtures on the fresh and hardened properties of self-compacting concrete (SCC). The study emphasized that proper compaction is a critical factor affecting the strength of concrete, and conventional methods often fail to achieve full compaction in complex structural elements such as beam-column joints and long columns. SCC, due to its self-flowing and self-compacting nature, eliminates the need for external vibration and ensures uniform compaction without segregation. The review highlighted the role of chemical admixtures such as superplasticizers and viscosity modifying agents in enhancing workability, reducing water-cement ratio, and improving pumpability while minimizing segregation and bleeding. It was observed that these admixtures contribute to the development of highly impermeable and durable concrete. Further, the study discussed the significant influence of mineral admixtures such as fly ash, silica fume, rice husk ash, marble powder, limestone powder, and bottom ash on the mechanical and durability properties of SCC. Silica fume was found to increase compressive and flexural strength, reduce porosity, and improve microstructure, although it affects rheological properties by increasing yield stress. Fly ash improved flowability and long-term strength, while rice husk ash enhanced mechanical performance up to an optimum replacement level. Marble powder and limestone powder improved cohesiveness and durability by forming a dense matrix structure. The combined use of mineral admixtures was found to be particularly effective, as it reduced water absorption, enhanced durability, and improved overall performance compared to individual admixture usage. However, the study also pointed out a key limitation of SCC, namely its higher cement content, which leads to increased cost, higher heat of hydration, and elevated CO_2 emissions, potentially causing shrinkage issues if not properly cured.

[24] Boopathi and Sharmila Devi (2019) in their article titled *"Durability Study on Self Compacting Concrete with Mineral Admixture"* examined the effect of incorporating mineral admixtures such as fly ash and GGBS on the workability, strength, and durability performance of M50 grade self-compacting concrete (SCC). The mix design was developed as per EFNARC guidelines, with cement replaced by GGBS and fine aggregate substituted with manufactured sand (M-sand). Fresh concrete properties were evaluated through slump flow and V-funnel tests, while hardened concrete was tested for compressive strength at 7, 28, and 56 days. Durability was assessed through a comprehensive set of tests including water absorption, sulphate attack, acid resistance, rapid chloride penetration (RCPT), sorptivity, linear polarization resistivity, and alkalinity. The results revealed that partial replacement of cement with GGBS and the use of M-sand improved both mechanical and durability characteristics of SCC. The study concluded that mineral admixtures not only enhance sustainability by utilizing industrial waste but also improve tensile strength, impact resistance, toughness, and energy absorption capacity, making SCC more durable and cost-effective for long-term structural applications.

[25] Busari et al. (2018) in their review titled *"Review of Sustainability in Self-Compacting Concrete: The Use of Waste and Mineral Additives as Supplementary Cementitious Materials and Aggregates"* presented a comprehensive analysis of the role of industrial and agricultural waste materials along with mineral additives in enhancing the sustainability of self-compacting concrete (SCC). The study focused on evaluating the impact of these materials on the rheological, mechanical, and structural properties of SCC. The review highlighted that SCC is an innovative concrete with superior workability, capable of flowing under its own weight and achieving full compaction without vibration. The incorporation of waste materials such as agricultural residues and industrial by-products was found to significantly improve both fresh and hardened properties of SCC. It was observed that agricultural waste materials enhance the rheological behavior of fresh concrete by improving flowability and stability, while industrial waste materials contribute to increased strength and durability. The study further emphasized that mineral additives play a vital role in achieving a balance between deformability and stability in SCC. These materials improve particle packing, reduce permeability, and enhance the microstructure of concrete. However, the use of expansive materials was discouraged as it may negatively affect the stability and performance of SCC.

[26] Balavignesh and Sivasankari (2018) in their paper titled *"Influence of Mineral Admixtures on Self Compacting Concrete"* examined the effect of various mineral admixtures such as fly ash, silica fume, marble stone powder, and limestone powder on the performance of self-compacting concrete (SCC). The study focused on developing high-strength SCC of M50 grade using mix proportions designed as per IS 10262:2009. Ordinary Portland Cement (OPC 53 grade) was used as the primary binder, and mineral admixtures were incorporated as partial replacements to enhance concrete properties. The experimental program included evaluation of fresh and hardened properties of SCC. Fresh concrete behavior was assessed using slump flow test, L-box test, and J-ring test in accordance with EFNARC guidelines to ensure proper filling ability, passing ability, and segregation resistance. Hardened concrete properties were evaluated through compressive strength tests. Additionally, structural performance was analyzed by casting beams using both conventional concrete and blended SCC, followed by load-deflection testing under a loading frame. The results indicated that incorporation of mineral admixtures significantly improved the workability and self-compacting characteristics of concrete without the need for external vibration. Among the admixtures, silica fume contributed to higher compressive strength due to its pozzolanic reactivity and micro-filling effect, while fly ash, marble powder, and limestone powder enhanced flowability and overall compaction behavior. The blended SCC mixes demonstrated better performance in terms of uniformity and ease of placement compared to conventional concrete.

[27] Das et al. (2017) in their study titled *"A Study on the Effect of Mineral Admixtures on Self Compacting Concrete"* investigated the influence of mineral admixtures such as silica fume and ground granulated blast furnace slag (GGBS) on the fresh and hardened properties of self-compacting concrete (SCC). The study focused on M35 grade SCC designed using the Nan Su method in accordance with EFNARC guidelines. The experimental work emphasized the evaluation of fresh properties of SCC, including filling ability, passing ability, and resistance to segregation. These properties were assessed through standard tests such as slump flow, ensuring that the concrete achieved adequate flowability (greater than 600 mm) and self-compacting characteristics without the need for vibration. The study highlighted that SCC possesses superior workability, improved surface finish, and the ability to flow through congested reinforcement, making it suitable for complex structural applications. The incorporation of mineral admixtures such as silica fume and GGBS was found to significantly influence the rheological behavior of SCC by enhancing cohesion and reducing segregation. The results indicated that the use of silica fume improved the strength and durability of SCC due to its fine particle size and pozzolanic activity, while GGBS contributed to improved workability and long-term strength development. The combination of these mineral admixtures helped in achieving an optimal balance between flowability and mechanical performance.

[28] Sathish Raja and Dinesh (2016) in their review article titled *"Study on Self Compacting Concrete – A Review"* provided an extensive overview of the development and applications of SCC, emphasizing its advantages in modern construction. The paper highlighted the unique ability of SCC to flow uniformly into formwork without segregation or bleeding, eliminating the need for vibration, and thereby improving placement in congested reinforcement zones. The authors noted that SCC contributes to faster construction, superior surface finishes, reduced labor, and improved safety at construction sites. A key focus of the review was the incorporation of industrial by-products such as fly ash, silica fume, and marble powder as partial replacements for cement, offering both cost and environmental benefits by utilizing waste materials. The study systematically discussed the fresh properties (flowability, segregation resistance, and filling ability), mechanical properties (compressive, tensile, and flexural strength), and durability characteristics of SCC. The authors concluded that industrial by-products enhance not only the sustainability but also the performance of SCC, making it a highly effective material for durable and eco-friendly civil engineering structures.

[29] Sathish Kumar and Dilli Babu (2015) in their article titled *"A Study on Performance of Self Compacting Concrete with Mineral Admixtures"* investigated the use of fly ash, ground granulated blast furnace slag (GGBS), and micro silica as partial replacements of cement in SCC. The authors pointed out that one of the major disadvantages of SCC is its higher cost due to increased cement and chemical admixture usage, which can be mitigated by incorporating mineral admixtures, particularly industrial by-products. Their experimental study showed that the inclusion of about 15% fly ash and 5% micro silica as partial cement replacements not only reduced the cost but also improved fresh concrete properties such as flowability and filling ability without the need for viscosity-enhancing chemical admixtures. Furthermore, the hardened properties such as compressive, flexural, and split tensile strength showed improvement compared to control mixes, and the reduced water content led to enhanced durability. The study concluded that the judicious use of mineral admixtures improves both the economic and performance aspects of SCC while contributing to sustainable construction practices.

[30] Hodage and Kulkarni (2015) in their article titled *"Effect of Mineral Admixtures on Properties of Polymer Modified Self Compacting Concrete"* examined the influence of silica fume (SF) and marble powder (MP) on the properties of polymer modified self-compacting concrete (PMSCC). The study developed M30 grade SCC mixes using locally available materials and evaluated fresh and hardened properties through tests on cubes, cylinders, and beams. Workability was assessed, while mechanical performance was analyzed using compressive strength, split tensile strength, and flexural strength tests. The experimental results highlighted that the incorporation of silica fume and marble powder in suitable proportions improved the mechanical performance of SCC while simultaneously reducing cement consumption. The authors emphasized that determining the optimum replacement percentage of these mineral admixtures is crucial for achieving maximum strength and sustainability benefits.

[31] Mahesh (2014) in his study titled *"Self-Compacting Concrete and Its Properties"* presented a detailed investigation on the fundamental characteristics and performance of self-compacting concrete (SCC). The study focused on understanding the rheological behavior, mix design considerations, and the role of mineral admixtures in improving the properties of SCC. The study emphasized that SCC is a highly flowable concrete capable of self-compaction under its own weight without the need for external vibration. It highlighted that SCC should possess low yield stress for better flowability, moderate viscosity to resist segregation and bleeding, and sufficient stability to maintain homogeneity during transportation and placement. Fresh properties were evaluated using standard tests such as slump flow, V-funnel, and L-box tests in accordance with EFNARC guidelines. The research incorporated mineral admixtures such as fly ash and metakaolin as partial replacements of cement to enhance the performance of SCC. It was observed that these pozzolanic materials significantly improve the pore structure, reduce permeability, and enhance durability. The study also noted that the use of mineral admixtures improves particle packing and reduces cement content, making SCC more economical and environmentally sustainable. The mix design approach considered volumetric proportions with controlled water-cementitious ratio (0.36) and optimized paste volume. The use of well-graded aggregates and appropriate proportions ensured proper flowability and resistance to segregation.

[32] Aravinth (2014) in his study titled *"Development of High Strength Self Compacting Concrete Using Mineral and Chemical Admixture"* investigated the development of high-strength self-compacting concrete (SCC) using a combination of mineral and chemical admixtures. The study focused on achieving superior strength and workability by incorporating silica fume and superplasticizer in SCC mixes. The experimental work involved the use of Ordinary Portland Cement (OPC 53 grade), silica fume as a mineral admixture, and a high-range water-reducing superplasticizer (Glenium B233) to develop SCC with compressive strength exceeding 60 MPa. The mix proportions were finalized through trial mixes based on EFNARC (2005) guidelines to ensure adequate flowability and self-compacting properties. The study emphasized that SCC requires a high volume of fine powder materials (ranging from 380 to 600 kg/m³) and a controlled water-to-powder ratio to achieve desired rheological properties. Fresh properties were evaluated using standard tests such as slump flow, T_{50}, L-box, V-funnel, and U-box tests to ensure proper filling ability, passing ability, and resistance to segregation. The results indicated that the use of silica fume significantly improved the cohesion, strength, and durability of SCC due to its ultrafine particle size and pozzolanic nature. The incorporation of superplasticizer enhanced flowability without increasing water content, thereby maintaining a low water-cement ratio and improving mechanical performance.

[33] Pai, Nandy, Krishnamoorthy, Sarkar, Ganapathy, and George (2014) in their article titled *"Development of Self-Compacting Concrete with Various Mineral Admixtures"* explored the feasibility of producing M25 grade SCC by incorporating multiple mineral admixtures as partial cement replacements. The study employed the Modified Nan Su method to design mixes containing fly ash, ground granulated blast furnace slag (GGBS), silica fume, rice husk ash, and shell lime powder. Fresh properties such as flowability and resistance to segregation were assessed, while hardened properties were evaluated through compressive, split tensile, and flexural strength tests. The findings demonstrated that the inclusion of mineral admixtures not only improved the workability and mechanical performance of SCC but also contributed to enhanced durability by refining the microstructure. Importantly, the study emphasized the environmental benefits of utilizing industrial by-products like fly ash and GGBS, thereby addressing waste disposal challenges while reducing the overall cost of SCC production. The research concluded that the judicious combination of mineral admixtures offers both technical and sustainability advantages, making SCC a viable material for future structural applications.

[34] Ramanathan et al. (2013) in their research paper titled *"Performance of Self-Compacting Concrete Containing Different Mineral Admixtures"* investigated the influence of mineral admixtures such as silica fume, GGBS, and fly ash on the fresh and hardened properties of SCC. The study emphasized that while SCC is highly beneficial due to its self-compaction ability, its cost increases significantly with high cement and chemical admixture content. To address this, the authors replaced cement with mineral admixtures at levels of 30%, 40%, and 50% and conducted workability tests such as slump flow, L-box, U-box, and T50, along with strength tests including compressive, split tensile, and flexural strength. The results demonstrated that the incorporation of mineral admixtures enhanced flowability, filling ability, and stability, while also reducing the demand for superplasticizers due to improved particle packing. Among the admixtures, silica fume improved strength properties significantly, while fly ash and GGBS enhanced workability and long-term durability. The study concluded that a cost-effective and sustainable SCC mix could be developed by appropriately combining these mineral admixtures, thereby reducing cement consumption while maintaining or improving performance.

[35] Uysal and Yilmaz (2011) in their study titled *"Effect of Mineral Admixtures on Properties of Self-Compacting Concrete"* investigated the utilization of waste mineral admixtures such as limestone powder (LP), basalt powder (BP), and marble powder (MP) as partial replacements of Portland cement in self-compacting concrete (SCC). The study aimed to evaluate the feasibility of using these unprocessed waste materials to enhance both performance and economy of SCC. The experimental program maintained a constant water-to-binder ratio of 0.33 for all concrete mixes. Fresh properties were evaluated using slump flow and L-box tests to assess workability and passing ability, while hardened properties were analyzed through compressive strength, ultrasonic pulse velocity, and static and dynamic elastic modulus tests. The results indicated that the incorporation of limestone powder, basalt powder, and marble powder significantly improved the workability of SCC without compromising stability. It was observed that these mineral admixtures contributed to improved mechanical properties, including compressive strength and elastic modulus, due to better particle packing and filler effects.

III. RESEARCH GAP

From the detailed review of previous studies on self-compacting concrete (SCC) incorporating mineral admixtures , it is observed that significant advancements have been made in improving the fresh, mechanical, and durability properties of SCC. However, several important research gaps still exist. Most of the studies primarily focus on individual or binary combinations of mineral admixtures such as fly ash, GGBS, and silica fume, while limited attention has been given to the performance of multi-component or hybrid admixture systems, which have the potential to provide optimized and balanced properties. Additionally, there is a lack of a standardized mix design methodology for SCC, as current practices largely rely on trial-and-error approaches or modified empirical methods like the Nan Su method, leading to inconsistencies in mix proportioning and performance outcomes. Another major limitation identified is that the majority of research is confined to short-term analysis, typically up to 28 or 90 days, whereas long-term performance aspects such as creep, shrinkage, fatigue behavior, and durability under aggressive environmental conditions are not adequately explored. Furthermore, although several studies have investigated the mechanical and rheological properties of SCC, limited work has been carried out on microstructural characterization using advanced techniques and its direct correlation with macroscopic performance. The use of modern optimization tools such as Artificial Intelligence (AI), Machine Learning (ML), and Response Surface Methodology (RSM) is still in the early stages and requires further exploration for developing predictive models for SCC mix design. In addition, there is insufficient research on field applications and real-scale performance of SCC, as most studies are conducted under controlled laboratory conditions, which may not accurately represent site conditions. The issue of balancing sustainability with performance also remains a challenge, as higher replacement levels of cement with mineral admixtures may adversely affect early strength and workability. Moreover, aspects such as thermal behavior, fire resistance, and performance under extreme environmental conditions have not been extensively studied. Therefore, there is a clear need for comprehensive research focusing on optimized multi-admixture systems, long-term durability studies, standardized mix design procedures, and real-world applications to develop sustainable, economical, and high-performance SCC for modern construction practices.

CONCLUSION

Based on the comprehensive review of previous studies on self-compacting concrete (SCC) incorporating mineral admixtures, it can be concluded that SCC has emerged as an advanced and highly efficient construction material capable of overcoming the limitations of conventional concrete. The unique ability of SCC to flow under its own weight and achieve complete compaction without vibration makes it particularly suitable for structures with congested reinforcement and complex geometries. The incorporation of mineral admixtures such as fly ash, ground granulated blast furnace slag (GGBS), silica fume, metakaolin, and other industrial and agricultural waste materials has been found to significantly enhance the fresh, mechanical, and durability properties of SCC. The reviewed studies indicate that mineral admixtures improve workability, increase long-term strength, reduce permeability, and enhance resistance to chemical attack and environmental deterioration. Additionally, the use of these materials contributes to sustainability by reducing cement consumption, lowering carbon emissions, and promoting the utilization of industrial by-products. Advanced materials such as nano-mineral additives and fibre reinforcement further improve the performance of SCC, particularly in terms of durability and resistance to extreme conditions. However, despite these advancements, certain limitations still exist. The absence of a standardized mix design procedure, limited research on long-term durability and field applications, and insufficient exploration of hybrid admixture systems highlight the need for further investigation. Moreover, the challenge of balancing sustainability with mechanical performance requires careful optimization of mix proportions.

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