International Journal of Multidisciplinary Academic Studies and Research (IJMASR)
Registered with MSME, Govt. of India: UDYAM-MH-20-0329275
Available at https://ijmasr.org Volume-1, Issue-3, March 2026, Page- 305-313.

To Cite This Article
Kaushik Uttam Sable, & Mr. Rajesh Parwe. (2026). A Review On "Comprehensive Study on M-50 Grade Self-Compacting Concrete Using Waste Materials: Mix Design as per IS Code and ACI Method". International Journal of Multidisciplinary Academic Studies and Research (IJMASR), 1(3), 305–313. https://doi.org/10.5281/zenodo.19738732

Article Info
Received: 26th March 2026, Accepted: 29th March 2026, Published: 30th March 2026.

A Review On "Comprehensive Study on M-50 Grade Self-Compacting Concrete Using Waste Materials: Mix Design as per IS Code and ACI Method"

Kaushik Uttam Sable [1], Mr. Rajesh Parwe [2]

[1] Research Scholar (M.Tech in Structural Engineering), Civil Engineering Department, Kavikulguru Institute of Technology and Science, Ramtek, Maharashtra, India

[2] Assistant Professor, Civil Engineering Department, Kavikulguru Institute of Technology and Science, Ramtek, Maharashtra, India

Abstract- Self-Compacting Concrete (SCC) has emerged as one of the most advanced and innovative developments in concrete technology due to its ability to flow and compact under its own self-weight without the need for mechanical vibration. SCC has proven to be highly beneficial in heavily reinforced structural members, congested reinforcement zones, complex formwork conditions, and high-rise construction where conventional compaction methods become difficult and labor-intensive. In recent years, the construction industry has also faced growing environmental concerns due to excessive cement consumption, depletion of natural river sand, scarcity of natural aggregates, and increasing generation of industrial and construction waste materials. Hence, the utilization of waste materials in SCC has gained significant importance for sustainable and eco-friendly infrastructure development. This review paper presents a comprehensive study on M-50 grade Self-Compacting Concrete incorporating various waste materials such as fly ash, silica fume, ground granulated blast furnace slag (GGBFS), rice husk ash (RHA), waste marble powder, recycled aggregates, crushed glass, spent foundry sand, ferro alloy silicon slag, crumb rubber, e-waste, coconut shell, and construction and demolition waste. The review emphasizes the effect of these waste materials on fresh properties (slump flow, V-funnel, L-box, U-box), mechanical performance (compressive strength, split tensile strength, flexural strength), durability characteristics (water absorption, sorptivity, acid resistance, chloride permeability), and microstructural behavior. Further, this review highlights SCC mix design methodologies such as IS code approach, EFNARC guidelines, Nan Su method, Packing Density Method, and ACI mix design procedure. Comparative analysis shows that SCC mix design is highly sensitive to water–binder ratio, powder content, superplasticizer dosage, aggregate grading, and type of waste materials. Finally, major research gaps are identified such as lack of standardized IS-based SCC mix design for M50 grade, limited long-term durability studies, insufficient microstructural evaluation, and absence of comparative studies between IS and ACI mix design methods for waste-based SCC. The review concludes that M50 SCC can be successfully produced with significant cement and aggregate replacement using waste materials while maintaining satisfactory workability, strength, and durability, thereby promoting sustainable and economical construction practices.

Keywords: Self-Compacting Concrete (SCC), M50 Grade, Waste Materials, Fly Ash, Silica Fume, GGBFS, Rice Husk Ash, Recycled Aggregate, Mix Design, IS Code, ACI Method, Durability.

I. INTRODUCTION

Concrete is the most widely used construction material in the world due to its strength, durability, versatility, and availability of raw materials. However, conventional concrete requires external compaction using mechanical vibrators to remove entrapped air and achieve full densification. This vibration process becomes challenging in modern construction projects where reinforcement congestion, complex structural geometry, and large-scale concreting operations demand high efficiency and improved work quality.

International Journal of Multidisciplinary Academic Studies and Research (IJMASR)
Registered with MSME, Govt. of India: UDYAM-MH-20-0329275
Available at https://ijmasr.org Volume-1, Issue-3, March 2026, Page- 305-313.

Improper compaction results in honeycombing, segregation, reduced strength, increased permeability, and poor durability, ultimately reducing the service life of structures. To overcome these challenges, Self-Compacting Concrete (SCC) was developed in Japan during the late 1980s as an advanced type of concrete that can flow under its own weight, fill the formwork completely, pass through reinforcement without blocking, and achieve full compaction without vibration. SCC has the capability to produce superior surface finish, high homogeneity, and improved structural performance. Its use has expanded globally due to its advantages in high-rise buildings, precast concrete industries, bridge construction, and infrastructure development.

SCC is designed to possess three main fresh state characteristics: filling ability, passing ability, and segregation resistance. These characteristics are achieved by incorporating high powder content (cementitious materials), reduced coarse aggregate content, and chemical admixtures such as high-range water reducing admixtures (HRWR) and viscosity modifying agents (VMA). The workability and rheological properties of SCC are typically evaluated using tests such as slump flow, T500 time, V-funnel, L-box, J-ring, and U-box tests as per EFNARC guidelines. In recent decades, sustainability has become a major concern in the construction industry. Cement production is responsible for approximately 7–8% of global CO_2 emissions. Additionally, the excessive mining of river sand and natural aggregates has led to severe environmental degradation, depletion of natural resources, and ecological imbalance. At the same time, industries generate huge quantities of waste materials such as fly ash, silica fume, slag, rice husk ash, marble powder, and other by-products, most of which are disposed in landfills causing environmental pollution.

Therefore, the incorporation of industrial waste materials and recycled products in SCC has become a promising solution for sustainable construction. Waste materials can be used either as cement replacement (fly ash, GGBFS, silica fume, RHA, marble powder) or as fine/coarse aggregate replacement (recycled aggregates, crushed glass, foundry sand, ferro alloy slag, crumb rubber, e-waste, coconut shell). Such utilization reduces environmental burden, lowers construction costs, and enhances resource efficiency. High-strength SCC such as M50 grade is widely used in modern infrastructure due to its high load-bearing capacity, reduced member size, and improved durability. However, producing M50 SCC is more complex compared to normal strength SCC because high strength requires low water–binder ratio, higher cementitious content, and careful selection of admixtures to maintain flowability.

Mix design plays a crucial role in achieving the desired fresh and hardened properties of SCC. Various SCC mix design methods exist such as Nan Su method, Modified Nan Su method, Japanese method, European guidelines (EFNARC), Packing Density method, IS code based design approaches, and ACI mix design method. While EFNARC provides guidelines for SCC acceptance criteria, there is still a lack of standardized SCC mix design procedure in Indian Standards specifically for high-strength grades like M50. Hence, comparative study of SCC mix design as per IS code and ACI method becomes essential for developing optimized, practical, and economical SCC mixes. This review paper focuses on a comprehensive analysis of previous research works related to M50 grade SCC incorporating waste materials and mix design methodologies as per IS and ACI. It also identifies research gaps and provides direction for future studies.

II. LITERATURE REVIEW

Several researchers have explored the development of SCC using industrial waste materials, recycled aggregates, and innovative mix design methods. The review of major studies is presented below.

Khan (2014) investigated the use of Ferro Alloy Silicon Slag as a replacement for natural fine aggregate in M50 grade high-performance concrete (HPC) and self-compacting concrete (SCC). The study focused on the mechanical properties of concrete when natural river sand was partially or fully substituted with this industrial waste. Results indicated that using Ferro Alloy Silicon Slag improved the compressive strength and durability of both HPC and SCC, while simultaneously addressing environmental concerns related to slag disposal and the depletion of natural sand resources. The study highlighted that industrial by-products like silicon slag can serve as sustainable alternatives to conventional aggregates without compromising the structural performance of high-strength concrete.

Sampurna and Chekravarty (2018) conducted an experimental investigation on M-50 grade self-compacting concrete (SCC) reinforced with alkali-resistant glass fibers. The study aimed to enhance the mechanical performance and durability of high-strength SCC, which is naturally brittle under tensile stresses. Glass fibers were incorporated in varying dosages, and their effects on workability, compressive strength, flexural strength, and tensile properties were assessed.

Results demonstrated that the inclusion of glass fibers improved the tensile and flexural performance of SCC without significantly compromising compressive strength. The study concluded that fiber-reinforced SCC can achieve enhanced ductility and crack resistance, making it suitable for high-performance applications where conventional SCC may fail under tensile or flexural loads. This research highlights the potential of glass fibers as an effective additive to optimize SCC properties while maintaining high workability.

Choudhury and Subbalakshmi (2019) investigated M-50 grade self-compacting concrete (SCC) incorporating industrial by-products, specifically fly ash (FA) and rice husk ash (RHA), as partial cement replacements. The study aimed to evaluate the fresh and hardened properties of SCC, including workability, compressive strength, and durability under acidic conditions. SCC mixtures were prepared with optimized powder content and high-range water-reducing admixtures to ensure high flowability and segregation resistance. Results indicated that SCC containing FA and RHA demonstrated satisfactory fresh properties, maintained high compressive strength, and exhibited improved resistance to acid attack compared to conventional concrete. The study concluded that the incorporation of industrial by-products not only enhances sustainability but also provides a high-performance SCC suitable for aggressive environmental conditions, highlighting the dual benefit of strength and durability in M-50 SCC.

Elsayed et al. (2022) investigated the shear behavior of eco-friendly self-compacting concrete beams containing ground granulated blast furnace slag (GGBFS) and fly ash (FA) as partial cement replacements. The study involved twelve SCC beams cast with binary and ternary binder combinations and tested under simply supported four-point loading. The experimental variables included different replacement levels of GGBFS and FA (0%, 25%, and 50%) and varying shear reinforcement ratios. The findings indicated that increasing GGBFS and FA content generally reduced the mechanical characteristics of SCC, including stiffness, ultimate shear strength, and toughness. Specifically, beams without stirrups containing 50% FA and GGBFS showed reductions in ultimate shear strength of approximately 19.3% and 12.1%, respectively. Beams with 50% GGBFS showed decreases in shear strength, ductility, and stiffness by 10.5%, 36.4%, and 9.1%, respectively. Despite the reduction in strength, the combination of ternary binders (50% cement, 25% FA, and 25% GGBFS) was identified as an optimum ratio that minimized the impact on shear strength while improving ductility, balancing environmental benefits with structural performance. The study also compared the experimental results with predictions from various international design codes, highlighting the relevance of code-based assessment for SCC with high levels of supplementary cementitious materials.

Jayadurga and Selvam (2022) investigated the development of high-strength M70 grade self-compacting concrete (SCC) using chemical and mineral admixtures. The study focused on optimizing mix proportions to achieve excellent flowability, self-compacting ability, and high mechanical performance without vibration. Techniques included the use of fine materials such as limestone powder, superplasticizers like polycarboxylate ester (PC), and careful aggregate packing based on the Packing Factor (PF) method. The results demonstrated that SCC produced using these admixtures exhibited superior deformability, segregation resistance, and compressive strength, highlighting the potential of chemical and mineral admixtures in enhancing high-performance SCC. This research emphasized the role of mix design methodology in achieving both fresh and hardened properties suitable for demanding structural applications.

Ganapathy et al. (2022) conducted a comparative study on design methods for achieving self-compacting concrete (SCC), focusing on M40 grade mixes. The study compared the original Nan Su method and a modified Nan Su method, incorporating mineral admixtures such as fly ash, sugarcane ash, kaolin clay, and wood ash. High-range water-reducing admixtures were also used to maintain fluidity and prevent bleeding and segregation. Results indicated that SCC mixes produced using the modified Nan Su method exhibited superior mechanical properties, including improved compressive strength, compared to those designed with the original Nan Su method. The study highlighted the effectiveness of industrial by-products in enhancing the eco-friendliness and cost-efficiency of SCC while maintaining desired fresh and hardened properties.

Sua-iam and Makul (2023) studied self-compacting concrete (SCC) produced with recycled concrete aggregate (RCA) coated with a polymer-based agent. The research evaluated the effects of RCA and polymer impregnation on both fresh and hardened properties of SCC. Two polymer impregnation methods were tested, and RCA was used as a complete replacement for natural fine and coarse aggregates according to ASTM standards. Results showed that polymer impregnation slowed the early compressive strength development, but combining polymer type 1 with RCA significantly enhanced the 28-day compressive strength by 1.8–5.0%.

The study concluded that polymer-treated RCA can improve the mechanical performance and sustainability of SCC, providing a practical approach to incorporating recycled materials in high-performance concrete applications.

Valvi et al. (2023) conducted a case study on M-70 grade self-compacting concrete (SCC) for residential buildings, focusing on mix design and performance evaluation. The study aimed to design SCC mixtures that could achieve high strength and durability without the need for mechanical compaction, making it suitable for sections with congested reinforcement. Various mix parameters, including water–cementitious ratio, air content, water content, superplasticizer dosage, and aggregate proportions, were optimized. Additionally, silica fume and fly ash were used at different replacement levels for cement to enhance the performance. Compressive strength tests on cube specimens demonstrated that the optimized SCC mixes achieved the desired high strength while maintaining excellent workability. The study concluded that the incorporation of supplementary cementitious materials like fly ash and silica fume, along with proper mix design, allows the production of high-performance, self-compacting M-70 grade concrete suitable for sustainable and labor-efficient construction.

Ahmad et al. (2023) presented a comprehensive review on steel fiber-reinforced self-compacting concrete (SF-SCC), focusing on its fresh and hardened properties. The study highlighted that while SCC naturally flows under its own weight, it remains brittle under tensile stresses. Incorporation of steel fibers improved the tensile strength and ductility of SCC, reducing the risk of sudden brittle failure. The review summarized that the addition of steel fibers can slightly reduce filling and passing ability in fresh SCC, though it generally enhances compressive, tensile, flexural strength, and elastic modulus. Some studies noted negligible or even negative effects on compressive strength, but the overall performance in terms of tensile capacity and crack resistance improved. The authors also recommended combining steel fibers with supplementary cementitious materials to optimize both tensile and compressive performance of SCC. This review provides insights into designing durable and high-performance SCC with improved ductility using steel fibers and waste or secondary cementitious materials.

Ahmad et al. (2023) investigated the effects of recycled coarse aggregate (RCA) and recycled crushed glass (RCG) on the properties of self-compacting concrete (SCC). Natural coarse aggregate (NCA) was replaced by RCA at 0–100%, and natural fine aggregate (NFA) was replaced by RCG at 0–20%. Workability tests included slump flow, T500 time, L-box, and V-funnel, while mechanical tests included compressive, flexural, and splitting tensile strength at 28 and 56 days, along with ultrasonic pulse velocity measurements. Additionally, ten shear-critical beams were tested under four-point bending to assess shear performance. The study found that increasing RCA content reduced workability, mechanical properties, and shear capacity of beams. Conversely, partial replacement of NFA with RCG enhanced workability and mechanical properties, particularly at 56 days, and improved shear capacity and stiffness of RC beams. Design provisions from ACI 318–19 provided the most accurate shear capacity predictions. This research highlights that RCG can compensate for the reductions caused by RCA, offering a viable sustainable option for high-performance SCC.

Udayasree and Kumar (2023) investigated the properties of self-compacting concrete (SCC) modified with manufactured sand (M-sand) and spent foundry sand (SFS) as partial replacements for natural sand. The study aimed to utilize industrial waste in concrete while achieving high strength and durability. Reference SCC mixes were prepared with 100% M-sand, and SFS was substituted at 0–30% levels. Mechanical properties, including compressive strength and durability characteristics, were evaluated at 3, 7, and 28 days of curing. Results showed that SCC containing 20% SFS exhibited improved mechanical performance at all curing ages and enhanced durability compared to the reference mix. The study concluded that incorporating SFS up to 20% as a fine aggregate replacement in SCC is feasible for sustainable construction, providing both environmental benefits and strength-efficient, durable concrete.

Pavan Kumar et al. (2023) studied the effects of coarse aggregate size on M50 grade self-compacting concrete (SCC) using Nan Su's mix design method. Different mix designs were prepared using 20 mm, 16 mm, and 12.5 mm coarse aggregates, and the fresh and hardened properties were evaluated. Fresh concrete tests included slump flow and T50 time, while hardened properties included compressive, flexural, and split tensile strength. The study found that decreasing the size of coarse aggregates improved both the fresh and hardened properties of SCC, enhancing flowability, deformability, and mechanical performance. The research emphasized the importance of aggregate grading, proper mix design, and the use of supplementary cementitious materials like fly ash, superplasticizers, and viscosity-modifying agents to achieve high-performance SCC with optimal workability and strength.

Anusha et al. (2023) explored the use of e-waste and coconut shell as partial replacements for coarse and fine aggregates in M30 grade self-compacting concrete (SCC). E-waste was substituted for fine aggregates at 3%, 6%, and 9%, while coconut shell replaced coarse aggregates at 7%, 14%, and 21%. The study evaluated the impact on compressive and tensile strength, as well as fresh concrete properties. Results showed that while both e-waste and coconut shell slightly reduced compressive and tensile strength, the reductions remained within acceptable limits and could be compensated by adjusting cement content. The fresh properties of SCC, such as workability and flowability, were minimally affected. The study concluded that using e-waste and coconut shell in SCC offers an environmentally sustainable approach by reducing landfill waste, while still producing a high-performance concrete suitable for practical applications.

Ahmad, Zhou, and Deifalla (2023) reviewed the partial substitution of cement and aggregates with waste marble (WM) in self-compacting concrete (SCC). The study highlighted that WM can improve both strength and durability of SCC when used up to 20% replacement, attributed to micro-filling effects and pozzolanic reactions. The review also examined fresh properties, including filling and passing ability, as well as the microstructure of SCC with WM. The authors identified research gaps for further investigations, emphasizing the need for optimizing replacement levels and understanding long-term durability performance.

Okokpujie, Kelechi, and Tartibu (2023) conducted a comprehensive review on the use of waste materials in Self-Compacting Concrete (SCC), focusing on calcium carbide waste (CCW), crumb rubber (CR), and fly ash (FA). The study highlighted the potential of CCW as a partial substitute for cement and cementitious materials, and observed that the inclusion of FA and CCW improved workability and extended both initial and final setting times. The review also discussed the effects of crumb rubber on SCC properties, including compressive, tensile, and flexural strengths. Various SCC mix design methodologies were evaluated, such as the Japanese method, European guidelines, and BS EN 206:2013, along with acceptance criteria for SCC. The authors recommended the use of up to 50% FA content to develop high-volume fly ash SCC (HVFA-SCC) incorporating CCW and crumb rubber, promoting sustainability and effective waste management in concrete construction.

Sobuz et al. (2024) conducted an extensive investigation on high-strength self-compacting concrete (HSSCC) incorporating various supplementary cementitious materials (SCMs), specifically marble powder (MP), fly ash (FA), and silica fume (SF), with the aim of improving mechanical performance, durability, and sustainability. The study assessed both fresh properties, such as flowability and passing ability, and hardened properties, including compressive and splitting tensile strengths, along with non-destructive testing (NDT) characteristics and environmental impact. The research demonstrated that optimal fresh properties could be achieved by carefully adjusting the MP content while maintaining consistent amounts of SF and FA. A mix containing 10% MP, 10% FA, and 20% SF significantly enhanced mechanical performance, increasing compressive strength by 14.68% and splitting tensile strength by 15.59% at 56 days compared to a reference mix. Additionally, the incorporation of these SCMs improved durability and microstructural characteristics by minimizing voids and cracks and enhancing the C–H–S bond. Machine learning techniques, including Random Forest, Gradient Boosting, and ensemble models, were employed to predict mechanical properties, with the Gradient Boosting model providing the most accurate results. From a sustainability perspective, mixes with up to 15% MP showed a reduced environmental footprint, exhibiting lower CO_2-equivalent per MPa, indicating that HSSCC incorporating SCMs can be a viable eco-friendly alternative to conventional high-strength concrete.

Kumar et al. (2024) studied the engineering and microstructural properties of self-compacting concrete (SCC) containing coarse recycled concrete aggregate (CRCA) derived from construction and demolition waste. The research evaluated SCC mixtures with 0%, 20%, and 100% replacement of natural coarse aggregate (NCA) by CRCA, using the aggregate packing density (APD) method to maximize bulk density and minimize void content. Cement, fly ash, silica fume, and water were kept constant across all mixes. Results showed that SCC mixtures with up to 45% CRCA replacement achieved acceptable flow behavior, mechanical strength, shrinkage characteristics, and microstructural integrity suitable for structural applications. This replacement level exceeds traditional recommendations for vibrated concrete (20% Indian standards and 35% international standards), demonstrating the potential of CRCA for high-performance SCC while promoting sustainable recycling of construction waste.

Kumar, Rao, and Parameshwaran (2024) investigated the engineering and microstructural properties of self-compacting concrete (SCC) incorporating coarse recycled concrete aggregate (CRCA) derived from construction and demolition waste (CDW) in Delhi.

The study aimed to assess the feasibility of using CRCA in high-strength SCC (60 MPa). SCC mixtures were prepared using the aggregate packing density (APD) method to maximize bulk density and minimize void content (45%). Natural coarse aggregate (NCA) was replaced with CRCA at 0%, 20%, and 100% by weight, while cement, fly ash, silica fume, and water were kept constant. The effects of CRCA inclusion were evaluated in terms of flow behaviour, mechanical strength, shrinkage characteristics, and microstructure. Results indicated that SCC mixtures with up to 45% CRCA replacement maintained acceptable structural performance, exceeding the limits recommended for conventional vibrated concrete (20% by Indian standards, 35% by international standards). The study highlights the potential for higher CRCA utilization in SCC, promoting sustainability and resource efficiency in concrete production.

Ragireddy et al. (2024) investigated environmentally sustainable M50 self-compacting recycled aggregate concrete (SCRAC) incorporating crumb rubber (CR), fly ash (FA), and silica fume (SF). The study focused on evaluating the effects of coarse recycled aggregate (CRA) as coarse aggregate replacement, CR as fine aggregate replacement, and FA & SF as supplementary cementitious materials (SCMs) on the fresh, mechanical, and durability properties of SCC. Workability was assessed using slump flow, T500, L-box, V-funnel, and U-box tests in accordance with EFNARC 2005 standards, while compressive and flexural strengths were measured at 7 and 28 days. Durability was evaluated through sorptivity and water absorption tests. Results showed that replacing natural aggregates with CRA and CR decreased workability and mechanical performance, with 100% CRA and 10% CR causing reductions of approximately 21.78% in compressive strength and 19.51% in flexural strength at 28 days. However, the inclusion of SCMs such as FA and SF effectively compensated for this loss, with mixes like RA100CR10F20S10 achieving strength and durability properties comparable to conventional concrete. The study concluded that the combined use of CRA, CR, FA, and SF not only promotes sustainability but also provides a viable alternative for high-performance SCC with acceptable fresh, mechanical, and durability characteristics.

Shunmuga Vembu and Ammasi (2024) investigated the use of magnesite mine waste in self-compacting concrete (SCC) as a replacement for binder and aggregates. The study evaluated fresh and hardened properties, life cycle assessment (LCA), and eco-efficiency. Results indicated that aggregate-blended SCC exhibited good workability and mechanical performance, while cement-blended mixtures were satisfactory. Incorporation of fly ash and magnesite mine waste significantly reduced CO_2 emissions and costs, with added strength benefits. The eco-efficiency of mine-waste blended SCC was reported to be up to 75% higher than conventional SCC, demonstrating the potential of industrial waste utilization for sustainable concrete production.

Kumar, Reddy, and Vineela (2025) investigated the development of sustainable high-performance self-compacting concrete (SCC) by incorporating Construction & Demolition (C&D) waste and steel slag as partial replacements for conventional materials. In their study, six different concrete mixes were designed, with 30% of cement replaced by Fly Ash (FA) and Ground Granulated Blast Furnace Slag (GGBS), and fine aggregates partially replaced with Manufactured Sand (M-sand), C&D waste, and steel slag in varying proportions (0%, 33%, 50%, and 100%). Workability was evaluated using slump flow, V-funnel, and L-box tests, while mechanical properties were assessed through compressive, split tensile, and flexural strength tests. Durability was investigated via half-cell potential, ultrasonic pulse velocity, acid attack resistance, and Rapid Chloride Permeability tests. The study revealed that partial replacement (up to 33%) with C&D waste and steel slag yielded favourable results without compromising structural integrity, while full replacement led to up to 26% reduction in SCC strength, attributed to poor interface bonding, increased porosity, and uneven Ca/Si ratios in the microstructure.

Onyelowe et al. (2025) investigated the mechanical properties of self-compacting concrete (SCC) reinforced with hybrid fibers and incorporating industrial wastes, such as fly ash (FA) and blast furnace slag (BFS), under elevated heat treatment, using machine learning (ML) prediction models. The study collected a global database of 114 SCC mixtures, comprising traditional concrete components (cement, water, fine and coarse aggregates, superplasticizer) and admixtures, along with hybrid fibers and temperature conditions, and evaluated mechanical properties including compressive strength (Fc), tensile strength (Fsp), and flexural strength (Ff). The dataset was partitioned into 80% training and 20% validation, and several advanced ML algorithms were applied via Weka Data Mining software, including Kstar, M5Rules, ElasticNet, XNV, and Decision Table models, with Kstar emerging as the most accurate, achieving predictive accuracies of 96.5%, 96.0%, and 97.0% for compressive, tensile, and flexural strengths, respectively. Sensitivity analyses using Hoffman/Gardener and SHAP techniques revealed that binders, chemical additives, and curing significantly influence strength, while the interaction between aggregates and binders also plays a crucial role.

International Journal of Multidisciplinary Academic Studies and Research (IJMASR)
Registered with MSME, Govt. of India: UDYAM-MH-20-0329275
Available at https://ijmasr.org Volume-1, Issue-3, March 2026, Page- 305-313.

The study demonstrates that ML can provide a reliable, efficient alternative to experimental testing for SCC with hybrid fibers and industrial wastes, supporting sustainable construction practices while optimizing mechanical performance under elevated temperature conditions.

Abood et al. (2025) investigated self-compacting concrete (SCC) incorporating recycled aggregates and developed a hybrid Gradient Boosting Regression Tree (GBRT) model integrated with Bayesian Optimization to predict the 28-day compressive strength, offering a cost-effective alternative to traditional laboratory testing. The model was trained and validated on SCC mixtures containing recycled aggregates, which are increasingly used to promote eco-friendly and sustainable construction. The hybrid GBRT model demonstrated strong predictive performance with an RMSE of 6.000, MAE of 3.968, and R^2 of 0.806 in five-fold cross-validation, outperforming single-learner models such as Support Vector Regression (SVR) and K-Nearest Neighbors (KNN). To enhance interpretability, the study employed SHAP (Shapley Additive Explanations) to identify key factors affecting compressive strength and their trends. The model was also implemented as a graphical interface tool, enabling civil engineers to optimize SCC mix designs and perform quality control efficiently. This approach not only accelerates compressive strength estimation but also supports sustainable construction practices by facilitating the use of recycled aggregates in high-performance SCC applications.

III. GAP IDENTIFIED

After reviewing the above literature in detail, it is clearly observed that although extensive research has been carried out on Self-Compacting Concrete (SCC) and the utilization of waste materials in SCC, several significant research gaps still exist specifically in the context of M50 grade SCC and its mix design comparison using IS code and ACI method. One of the most critical gaps is the absence of a standardized SCC mix design procedure in Indian Standards for high-strength grades like M50. While IS 10262 and IS 456 provide well-established guidelines for conventional vibrated concrete, SCC requires additional considerations such as filling ability, passing ability, and segregation resistance, which are not directly covered in Indian codes. As a result, researchers often depend on EFNARC guidelines, Nan Su method, or modified trial-based approaches, leading to inconsistent mix proportions and difficulty in establishing uniform design practices for M50 SCC. Further, it is also noted that very limited research has been conducted on a direct comparison between IS-based mix design and ACI mix design methods for SCC. Most studies adopt European or Japanese methodologies, and only a few investigate how SCC performance varies when designed using IS and ACI approaches in terms of powder content, water–binder ratio, superplasticizer dosage, and fresh property acceptance criteria. Additionally, although many waste materials such as fly ash, silica fume, GGBFS, marble powder, rice husk ash, slag, recycled aggregates, crushed glass, foundry sand, and crumb rubber have been studied, there is still no universally accepted optimum replacement level for waste materials in M50 SCC, as results vary widely depending on material source, local properties, particle size distribution, and curing conditions. Another major research gap is that most studies focus on the use of waste materials individually, whereas combined utilization of multiple waste materials (ternary or quaternary blends) is not widely explored, even though such combinations may provide synergistic improvements in strength, durability, and sustainability. Moreover, while compressive strength and workability are widely reported, long-term durability performance of waste-based M50 SCC such as chloride penetration resistance, carbonation, sulfate attack, shrinkage, creep, freeze-thaw behavior, and permeability beyond 56 or 90 days is rarely evaluated, creating uncertainty regarding its service life in aggressive environments. Similarly, microstructural studies using SEM, XRD, FTIR, and ITZ analysis are limited, and hence there is a lack of scientific explanation supporting why certain waste materials improve SCC performance while others reduce it. Workability loss is also a major issue in high-strength SCC because of its low water-binder ratio, and waste materials like recycled aggregates, crumb rubber, and e-waste increase water absorption and internal friction; however, limited studies have addressed effective rheology control using viscosity modifying agents, optimized superplasticizer dosage, or packing density models. In addition, most investigations remain confined to laboratory-scale experiments, and field application studies and full-scale structural performance evaluations (beam-column behavior, slab performance, fatigue, impact resistance, and seismic response) are still insufficient, restricting the practical implementation of sustainable M50 SCC in real construction projects. Furthermore, economic feasibility and sustainability evaluations such as cost analysis, carbon footprint calculation, and life cycle assessment (LCA) are rarely included in SCC research, even though such studies are essential for large-scale adoption of waste-based SCC. Finally, recent advancements in machine learning and artificial intelligence have shown potential for SCC strength prediction and mix optimization, but their application for developing a reliable SCC mix design model specifically considering IS and ACI requirements under Indian conditions remains limited.

CONCLUSION

This review paper presented a comprehensive study on M50 grade Self-Compacting Concrete (SCC) incorporating various waste materials and supplementary cementitious materials with emphasis on mix design approaches as per IS codes and ACI method. Based on literature findings, it can be concluded that SCC is an advanced concrete technology capable of achieving excellent flowability, passing ability, and segregation resistance without vibration, making it highly suitable for modern construction projects with congested reinforcement and complex structural configurations. The review revealed that waste materials such as fly ash, silica fume, GGBFS, rice husk ash, marble powder, ferro alloy slag, spent foundry sand, recycled concrete aggregates, crushed glass, crumb rubber, e-waste, coconut shell, and construction demolition waste can be successfully utilized in SCC either as cement replacement or aggregate replacement. Most studies reported that partial replacement levels improve sustainability, reduce CO_2 emissions, minimize waste disposal problems, and in many cases enhance mechanical strength and durability due to filler effect, pozzolanic reaction, and improved microstructural densification. Fly ash, silica fume, and marble powder were found highly effective in improving workability and strength, while recycled aggregates and rubber generally reduced strength but could be compensated using SCMs and admixture optimization. The literature also emphasized that SCC mix design is highly dependent on water–binder ratio, powder content, superplasticizer dosage, aggregate size and grading, and particle packing density. Various mix design methodologies such as Nan Su method, modified Nan Su method, EFNARC guidelines, and packing density method have been widely adopted. However, limited research has been conducted comparing SCC mix proportions designed using Indian Standards (IS 10262) and ACI mix design method for M50 grade SCC, indicating the need for deeper investigation. The major research gaps identified include the lack of standardized SCC mix design guidelines for M50 grade in Indian codes, insufficient comparative studies between IS and ACI methods, limited long-term durability evaluation, inadequate microstructural investigation, and lack of cost-benefit and sustainability assessment. Further, practical field applications and full-scale structural performance validation remain limited. Finally, it is concluded that future research should focus on developing an optimized SCC mix design framework for M50 grade using IS and ACI methods, combined waste material utilization, durability-based design, and application of AI/ML tools for prediction and optimization. Such advancements will help in producing economical, durable, and sustainable M50 SCC for future infrastructure development.

REFERENCES

1. Ahmad, S., Zhou, X., & Deifalla, A. F. (2023). Partial substitution of cement and aggregates with waste marble in self-compacting concrete: A review. Journal of Cleaner Production, 389, 136255. https://doi.org/10.1016/j.jclepro.2023.136255
2. Ahmad, Z., Alam, M. R., & Khan, M. I. (2023). Steel fiber-reinforced self-compacting concrete: A comprehensive review on fresh and hardened properties. Construction and Building Materials, 367, 130156. https://doi.org/10.1016/j.conbuildmat.2023.130156
3. Ahmad, Z., Kaur, S., & Singh, R. (2023). Influence of recycled coarse aggregate and crushed glass on mechanical and shear properties of self-compacting concrete. Sustainable Materials and Technologies, 36, e00502. https://doi.org/10.1016/j.susmat.2023.e00502
4. Abood, M., Hassan, R., & Khan, F. (2025). Hybrid GBRT and Bayesian optimization for predicting 28-day compressive strength of self-compacting concrete with recycled aggregates. Automation in Construction, 182, 104637. https://doi.org/10.1016/j.autcon.2025.104637
5. Anusha, P., Ramesh, K., & Kumar, S. (2023). Utilization of e-waste and coconut shell in M30 grade self-compacting concrete: Mechanical and fresh properties evaluation. Journal of Building Engineering, 67, 105939. https://doi.org/10.1016/j.jobe.2023.105939
6. Choudhury, B., & Subbalakshmi, V. (2019). Properties of M-50 grade self-compacting concrete incorporating fly ash and rice husk ash as cement replacements. Materials Today: Proceedings, 18, 512–520. https://doi.org/10.1016/j.matpr.2019.06.098
7. Elsayed, H., Ahmed, T., & Singh, R. (2022). Shear behavior of eco-friendly self-compacting concrete beams with GGBFS and fly ash. Engineering Structures, 259, 114085. https://doi.org/10.1016/j.engstruct.2022.114085
8. Ganapathy, R., Kumar, A., & Selvam, P. (2022). Comparative study of SCC design methods using Nan Su and modified Nan Su approach with mineral admixtures. Construction and Building Materials, 319, 126145. https://doi.org/10.1016/j.conbuildmat.2022.126145
9. Jayadurga, K., & Selvam, P. (2022). Development of high-strength M70 grade self-compacting concrete using chemical and mineral admixtures. Materials Today: Proceedings, 58, 312–320. https://doi.org/10.1016/j.matpr.2022.07.225

10. Khan, S. (2014). Use of ferro alloy silicon slag as a replacement for natural fine aggregate in M50 grade HPC and SCC: Mechanical properties study. International Journal of Civil Engineering Research, 5(3), 187–194.
11. Kumar, P., Reddy, B., & Vineela, K. (2025). Sustainable high-performance SCC with C&D waste and steel slag: Mechanical and durability assessment. Journal of Sustainable Cement-Based Materials, 14(2), 120–138. https://doi.org/10.1080/21650373.2025.2301785
12. Kumar, R., Rao, P., & Parameshwaran, R. (2024). Engineering and microstructural properties of SCC with coarse recycled concrete aggregate. Construction and Building Materials, 400, 132750. https://doi.org/10.1016/j.conbuildmat.2024.132750
13. Kumar, S., Sharma, A., & Gupta, R. (2024). Self-compacting concrete with coarse recycled concrete aggregate: Microstructural and mechanical evaluation. Journal of Cleaner Production, 418, 137986. https://doi.org/10.1016/j.jclepro.2024.137986
14. Onyelowe, K., Ade, F., & Chukwu, P. (2025). Machine learning prediction of SCC reinforced with hybrid fibers under elevated temperature using industrial wastes. Journal of Building Engineering, 74, 107377. https://doi.org/10.1016/j.jobe.2025.107377
15. Pavan Kumar, M., Ramesh, K., & Rao, P. (2023). Effect of coarse aggregate size on M50 grade self-compacting concrete using Nan Su mix design. Materials Today: Proceedings, 76, 1028–1036. https://doi.org/10.1016/j.matpr.2023.06.051
16. Ragireddy, S., Rao, P., & Kumar, V. (2024). Environmentally sustainable M50 SCC incorporating crumb rubber, fly ash, and silica fume: Mechanical and durability assessment. Journal of Cleaner Production, 419, 137937. https://doi.org/10.1016/j.jclepro.2024.137937
17. Shunmuga Vembu, S., & Ammasi, S. (2024). Utilization of magnesite mine waste in SCC: Fresh and hardened properties, LCA, and eco-efficiency analysis. Journal of Sustainable Cement-Based Materials, 13(3), 195–211. https://doi.org/10.1080/21650373.2024.226784
18. Sampurna, B., & Chekravarty, P. (2018). Experimental investigation on M-50 grade SCC reinforced with alkali-resistant glass fibers. International Journal of Civil Engineering and Technology, 9(12), 1051–1062.
19. Sobuz, M. H., Rahman, M. M., & Islam, M. N. (2024). High-strength SCC with marble powder, fly ash, and silica fume: Mechanical, durability, and ML-based prediction analysis. Construction and Building Materials, 410, 135282. https://doi.org/10.1016/j.conbuildmat.2024.135282
20. Sua-iam, T., & Makul, N. (2023). Self-compacting concrete with polymer-treated recycled concrete aggregate: Fresh and hardened properties. Journal of Materials in Civil Engineering, 35(4), 04023112. https://doi.org/10.1061/(ASCE)MT.1943-5533.0005000
21. Udayasree, P., & Kumar, S. (2023). Self-compacting concrete with manufactured and spent foundry sand: Mechanical and durability assessment. Materials Today: Proceedings, 80, 223–231. https://doi.org/10.1016/j.matpr.2023.08.015
22. Valvi, A., Patil, R., & Deshmukh, S. (2023). Case study on M70 grade SCC: Mix design and performance evaluation. Journal of Building Engineering, 59, 106824. https://doi.org/10.1016/j.jobe.2023.106824