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Performance Assessment of High-Strength Self-Compacting Concrete Containing Alccofine and Glass Fibres

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Abstract: *Self-compacting concrete (SCC) is a high-performance concrete capable of flowing under its own weight without external vibration, making it suitable for heavily reinforced structural members. This study investigates the combined influence of Alccofine and glass fibres on the fresh and compressive strength properties of M60-grade SCC. Cement was partially replaced with Alccofine at replacement levels of 5%, 7.5%, and 10%, while glass fibres were incorporated at dosages of 0.5%, 1.0%, and 1.5%. The total powder content and water-to-powder ratio were maintained at 600 kg/m³ and 0.30, respectively. Fresh properties were evaluated using slump-flow, T_{50}, L-box, U-box, and V-funnel tests in accordance with EFNARC guidelines, whereas compressive strength was determined at 7 and 28 days. All SCC mixtures satisfied the EFNARC acceptance criteria, although increasing Alccofine and glass fibre contents gradually reduced flowability and passing ability because of increased mixture viscosity. The incorporation of Alccofine and glass fibres significantly enhanced compressive strength compared with the control mix. The optimum performance was obtained for the mixture containing 7.5% Alccofine and 1.5% glass fibres (N3), which achieved compressive strengths of 61.03 MPa and 80.42 MPa at 7 and 28 days, respectively. The results demonstrate that the combined use of Alccofine and glass fibres can produce sustainable, high-strength SCC with satisfactory fresh properties while reducing cement consumption, making it suitable for advanced structural applications.*
Keywords: *Self-compacting concrete, Alccofine, glass fibre, slump flow, compressive strength, split tensile strength, flexural strength, EFNARC.*

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I. Introduction

Concrete is the most widely used construction material because of its high compressive strength, durability, and versatility. Rapid infrastructure development has significantly increased concrete consumption, resulting in higher demand for cement[1], [2]. However, cement production is responsible for considerable carbon dioxide emissions and intensive natural resource consumption, making it a major contributor to environmental degradation[3], [4]. Consequently, the development of sustainable concrete through the incorporation of supplementary cementitious materials has become an important area of research. Self-compacting concrete (SCC), first developed in Japan in the late 1980s, is a high-performance concrete capable of flowing under its own weight, completely filling formwork, and passing through congested reinforcement without external vibration. SCC offers several advantages over conventional concrete, including improved workability, reduced labour requirements, faster construction, enhanced surface finish, and lower noise pollution due to the elimination of mechanical compaction[5], [6], [7]. Nevertheless, achieving an appropriate balance between flowability and mechanical performance remains a key challenge, particularly when mineral admixtures and fibres are incorporated. Alccofine is an ultrafine supplementary cementitious material with high pozzolanic reactivity and excellent particle packing characteristics. Owing to its fine particle size, Alccofine enhances the hydration process, refines the pore structure, and improves the strength and durability of concrete while reducing cement consumption[8], [9], [10]. Glass fibres, on the other hand, are widely used to improve the tensile strength, flexural strength, crack resistance, and ductility of concrete by bridging microcracks and delaying crack propagation. Although previous studies have separately investigated the influence of Alccofine and glass fibres on concrete properties, limited research has examined their combined effect on high-strength self-compacting concrete.[11], [12] Furthermore, identifying an optimum combination that maintains the fresh properties of SCC while enhancing its mechanical performance remains an important research need.

Research Significance

Therefore, the present study investigates the combined effect of Alccofine and glass fibres on the fresh and hardened properties of M60-grade self-compacting concrete. Cement was partially replaced with Alccofine at 5%, 7.5%, and 10%, while glass fibres were incorporated at 0.5%, 1.0%, and 1.5%. Fresh properties were evaluated in accordance with EFNARC guidelines using slump-flow, T-50, L-box, U-box, and V-funnel tests, whereas hardened properties were assessed through compressive, split tensile, and flexural strength tests at 7 and 28 days. The study aims to determine the optimum combination of Alccofine and glass fibres that provides an appropriate balance between workability, mechanical performance, and sustainability.

Recent studies have extensively investigated the use of supplementary cementitious materials and fibre reinforcement to enhance the performance and sustainability of self-compacting concrete (SCC). Alccofine has been reported to improve the strength, durability, and microstructure of cementitious composites owing to its ultrafine particle size and high pozzolanic reactivity. Similarly, the incorporation of fibres has been shown to enhance tensile strength, flexural performance, crack resistance, and post-cracking behaviour. However, relatively few studies have examined the combined influence of Alccofine and glass fibres on high-strength SCC, particularly with respect to achieving an optimum balance between fresh and hardened properties. To establish the current state of research and identify existing knowledge gaps, a summary of representative studies related to Alccofine, fibre-reinforced SCC, and sustainable cement-based composites is presented in Table 1.

Table 1: Summary of Previous Research on Alccofine- and Fibre-Reinforced Self-Compacting Concrete

No.	Authors	Year	Study title	Main material/variable	Study focus	Relevance to the present study	Ref.
1	S. S. Vivek, B. Karthikeyan, and Marc Azab	2023	Impact and durability properties of alccofine-based hybrid fibre-reinforced self-compacting concrete	Alccofine, hybrid fibres, self-compacting concrete	Impact resistance and durability performance	Highly relevant because it examines fibre-reinforced self-compacting concrete containing alccofine. It may provide a basis for comparing the mechanical and durability effects of glass-fibre addition.	[13]
2	Bode Venkata Kavyateja, J. Guru Jawahar, and C. Sashidhar	2020	Effectiveness of alccofine and fly ash on mechanical properties of ternary blended self compacting concrete	Alccofine, fly ash, ternary blended SCC	Mechanical properties of self-compacting concrete	Relevant for understanding how alccofine affects the strength of self-compacting concrete when used with another supplementary cementitious material.	[14]
3	L. Nishanth, Nayana N. Patil, and Debasish Kar	2023	Influence of E-Coli on workability and strength characteristics of self-consolidating geopolymer concrete based on GGBFS, flyash and alccofine	Alccofine, GGBFS, fly ash, geopolymer SCC	Workability and strength characteristics	Provides supporting information on the influence of alccofine on fresh and hardened properties, although the binder system differs from conventional cement-based SCC.	[15]
4	B. Ramesh, V. Gokulnath, and M. Ranjithkumar	2020	Review on the flexural properties of fiber reinforced self compacting concrete by the addition of M-sand	Fibres, manufactured sand, SCC	Flexural behaviour of fibre-reinforced SCC	Useful for discussing the contribution of fibres to flexural performance and crack control in self-compacting concrete.	[16]
5	Puja Haldar and Somnath Karmakar	2024	Experimental and numerical performance analysis of alccofine-based crumb rubber concrete under quasi-static cyclic load	Alccofine, crumb rubber concrete	Cyclic-load performance and numerical analysis	Offers evidence on the role of alccofine in modified concrete under repeated loading, though it does not specifically address SCC or glass fibres.	[17]
6	K. Srinivas, L. Ponraj Sankar, and C. Kumara Swamy	2021	Experimental investigation on rapid strength gain by adding alccofine in high strength concrete	Alccofine, high-strength concrete	Early and rapid strength development	Relevant for explaining the possible filler and pozzolanic effects of alccofine on early-age strength.	[18]

7	G. Gautham Kishore Reddy and P. Ramadoss	2020	Influence of alccofine incorporation on the mechanical behavior of ultra-high performance concrete	Alccofine, UHPC	Mechanical behaviour	Supports the discussion of alccofine as a fine mineral additive capable of influencing strength and matrix densification.	[19]
8	D. Akhil Varma, Prabir K. Sarker, and Karingamanna Jayanarayanan	2024	Experimental and analytical assessment of strengthening of concrete cylinders using jute/basalt hybrid textile fiber reinforced mortar	Jute and basalt hybrid textile fibres	Strengthening and load-carrying behaviour	Indirectly relevant for understanding how hybrid fibre systems can improve the tensile and confinement behaviour of cement-based materials.	[20]
9	Yubo Jiao, Hua Yang, and Hongjun Shi	2024	Effects of fiber properties on flexural and fracture characteristics of manufactured sand concrete based on acoustic emission	Fibre properties, manufactured sand concrete	Flexural and fracture behaviour	Useful for discussing how fibre type and characteristics may affect crack initiation, fracture resistance, and post-cracking behaviour.	[11]
10	Rahul Raj Kundanati, Tanmay Malpani, and V. Sairam	2020	Study on mechanical properties of mortar using alccofine and graphene oxide	Alccofine, graphene oxide, mortar	Mechanical properties	Provides supporting evidence on the combined use of alccofine and reinforcing additives in cementitious matrices.	[8]

II. Materials and Methods

2.1 Materials

Ordinary Portland Cement (OPC) of Grade 53 conforming to IS 12269 was used as the primary binder. The cement possessed a specific gravity of 3.15 and a 28-day compressive strength of 61.21 MPa. Alccofine 1203, an ultrafine supplementary cementitious material with a specific gravity of 2.90, was employed as a partial replacement for cement because of its high pozzolanic activity and particle-packing ability. Natural river sand conforming to Zone II of IS 383:2016 was used as the fine aggregate. The fine aggregate had a specific gravity of 2.61, fineness modulus of 2.82, and water absorption of 1.22%. Crushed angular coarse aggregate of 10 mm nominal maximum size with a specific gravity of 2.73 and water absorption of 0.61% was used throughout the study. Portable water conforming to IS 456:2000 was utilized for both mixing and curing. A polycarboxylate ether-based superplasticizer with a dosage of 0.5% of the total powder content was incorporated to achieve the desired workability of self-compacting concrete. Alkali-resistant glass fibres having a length of 15 mm and a density of 2550 kg/m³ were used as discrete reinforcement.

2.2 Mix Proportions

The SCC mixtures were designed following the EFNARC guidelines using the absolute-volume method. A constant powder content of 600 kg/m³ and a water-to-powder ratio of 0.30 were maintained for all mixes. Cement was partially replaced with Alccofine at replacement levels of 5%, 7.5%, and 10%, while glass fibres were incorporated at dosages of 0.5%, 1.0%, and 1.5% by weight of binder. A control mix without Alccofine and glass fibres was also prepared for comparison. The water, fine aggregate, coarse aggregate, and superplasticizer contents were kept constant at 180, 1094, 563, and 3 kg/m³, respectively, to isolate the effects of Alccofine and fibre addition. The detailed mix proportions are presented in Table 1.

Table 2: Mix proportions of self-compacting concrete containing Alccofine and glass fibres

Mix designation	Alccofine replacement (%)	Glass fibre dosage (%)	Cement (kg/m³)	Alccofine (kg/m³)	Total powder (kg/m³)	Water (kg/m³)	Fine aggregate (kg/m³)	Coarse aggregate (kg/m³)	Superplasticizer (kg/m³)	Glass fibres (kg/m³)

CM	0	0	600	0	600	180	1094	563	3	0
M1	5	0.5	570	30	600	180	1094	563	3	3
M2	5	1	570	30	600	180	1094	563	3	6
M3	5	1.5	570	30	600	180	1094	563	3	9
N1	7.5	0.5	555	45	600	180	1094	563	3	3
N2	7.5	1	555	45	600	180	1094	563	3	6
N3	7.5	1.5	555	45	600	180	1094	563	3	9
O1	10	0.5	540	60	600	180	1094	563	3	3
O2	10	1	540	60	600	180	1094	563	3	6
O3	10	1.5	540	60	600	180	1094	563	3	9

2.3 Experimental Program

Concrete constituents were mixed in a laboratory pan mixer until a homogeneous mixture was obtained. After mixing, fresh concrete tests were performed immediately in accordance with EFNARC recommendations. The workability characteristics of SCC were evaluated using slump-flow diameter, T_{50} flow time, L-box ratio, U-box height difference, and V-funnel flow time. For hardened-property evaluation, 150 × 150 × 150 mm cube specimens, 100 × 200 mm cylindrical specimens, and 100 × 100 × 500 mm prism specimens were cast for compressive, split tensile, and flexural strength tests, respectively. All specimens were demoulded after 24 h and cured in potable water until the testing ages of 7 and 28 days. Compressive strength tests were conducted according to IS 516, split tensile strength tests were performed in accordance with IS 5816, and flexural strength was determined using third-point loading on prism specimens.

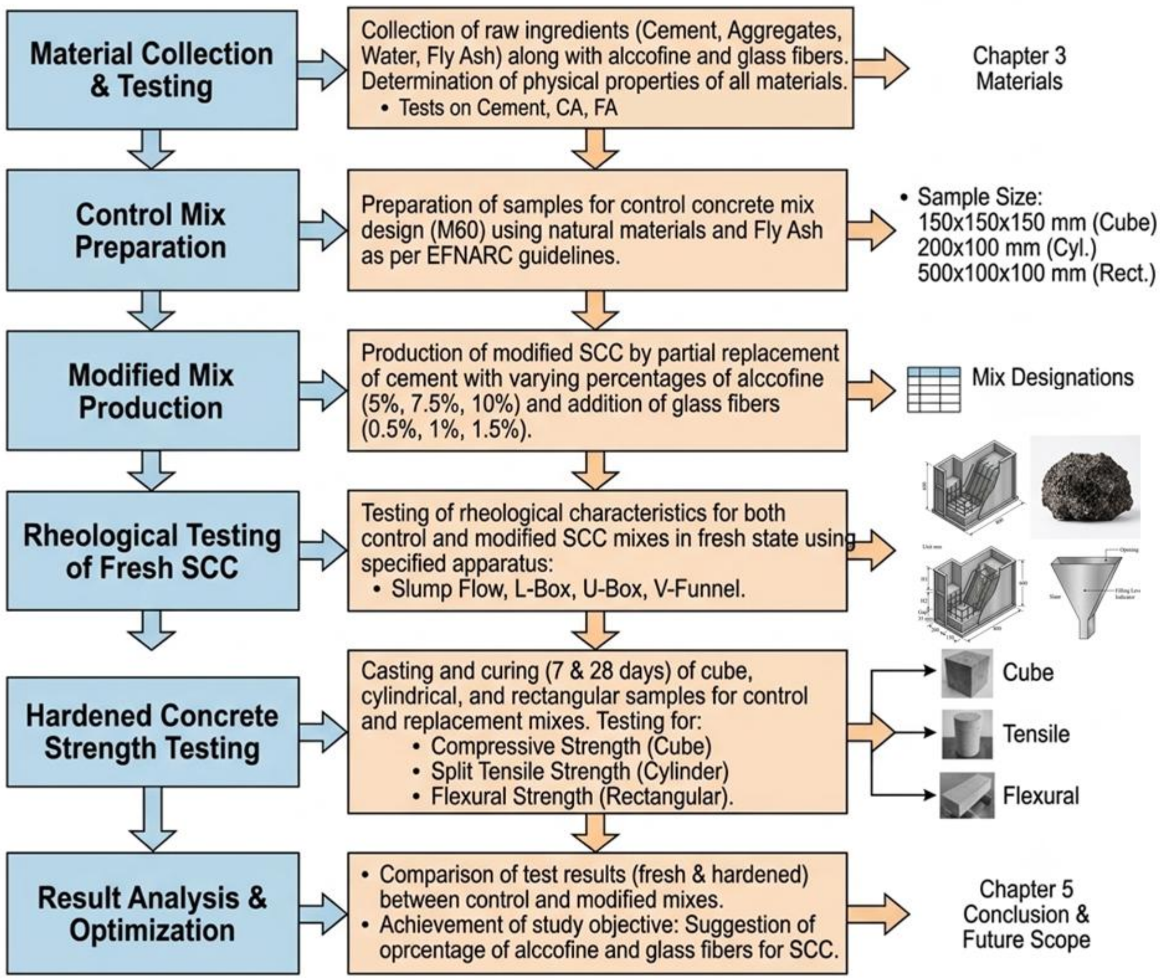

Figure 1: Methodology flowchart adopted for this research study

2.4 Experimental Variables

The investigation considered two independent variables: (i) Alccofine replacement levels of 5%, 7.5%, and 10%, and (ii) glass fibre dosages of 0.5%, 1.0%, and 1.5%. Fresh properties were evaluated in terms of filling ability, passing ability, and viscosity, whereas hardened properties included compressive strength, split tensile strength, and flexural strength at 7 and 28 days. The optimum SCC mixture was identified by considering both fresh-state performance and mechanical properties.

III. Results and Discussion

3.1 Fresh Properties of Self-Compacting Concrete

The fresh properties of SCC mixtures are summarized in Table 3. All mixtures satisfied the EFNARC acceptance criteria for slump flow, T_{50} time, L-box ratio, U-box, and V-funnel tests, confirming their suitability as self-compacting concrete.

Table 3: Various Properties of Fresh Self Compacting Concrete.

Mix Designation	Slump Flow (mm)	T-50 (sec)	L-Box (H2/H1)	U-Box (H2-H1)	V-Funnel (sec)
CM	760	2.92	0.95	15	6.74
Mix 1	735	3.31	0.92	17	7.46
Mix 2	713	3.95	0.91	18	8.05
Mix 3	685	4.26	0.88	21	8.61
Mix 4	728	3.24	0.94	16	7.53
Mix 5	700	3.63	0.93	18	8.13
Mix 6	670	3.84	0.89	19	8.76
Mix 7	715	3.51	0.9	20	8.85
Mix 8	690	4.12	0.85	24	9.43
Mix 9	655	4.69	0.83	26	10.21
EFNARC limits	650 to 800	2 to 5	0.8 to 1.0	0 to 30	6 to 12

The slump-flow values ranged from 655 to 760 mm, while the T_{50} flow time varied between 2.92 and 4.69 s. Similarly, the L-box ratio, U-box value, and V-funnel time ranged from 0.83–0.95, 15–26 mm, and 6.74–10.21 s, respectively. Increasing the Alccofine replacement and glass fibre dosage resulted in a gradual reduction in flowability and passing ability, as indicated by lower slump-flow and L-box values and higher T_{50}, U-box, and V-funnel values. The reduction in workability is attributed to the increased surface area of Alccofine and the interlocking effect of glass fibres, which increased the viscosity of the concrete mixture. Nevertheless, all mixtures remained within the EFNARC limits, indicating satisfactory fresh performance.

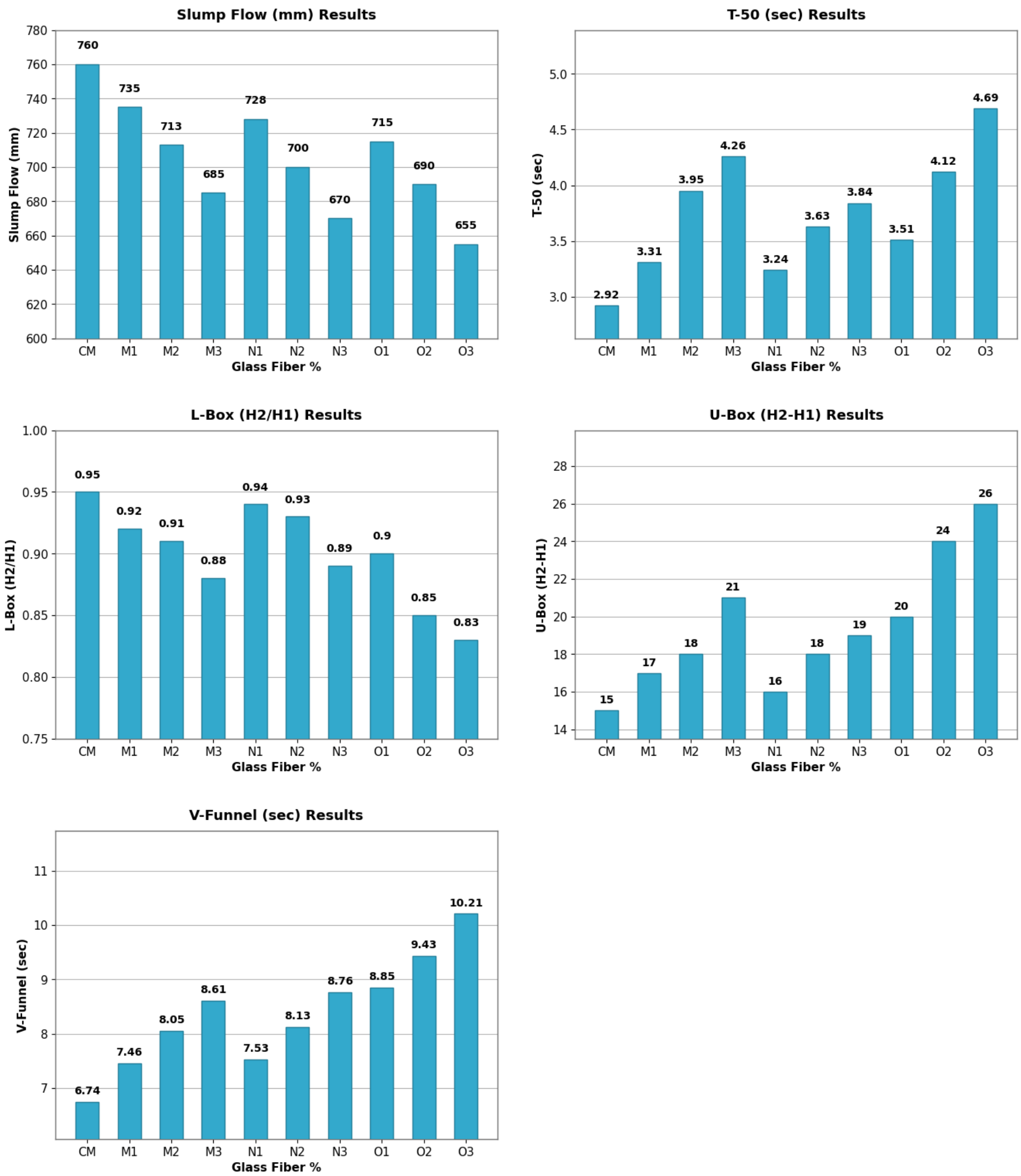

Figure 2: Various Properties of Fresh Self Compacting Concrete.

3.2 Hardened Properties

The compressive of the SCC mixtures at 7 and 28 days are presented in Table 4. All modified SCC mixtures exhibited higher mechanical strength than the control mix, demonstrating the beneficial effect of Alccofine and glass fibres.

Table 4: Compressive Strength of cube samples of SCC.

Mix Designation	Compressive strength at 7 day	Compressive strength at 28 day
CM	51.23	70.25
M1	53.06	72.69
M2	55.98	76.15
M3	58.11	79.12
N1	55.24	73.49
N2	57.35	76.76

N3	61.03	80.42
O1	52.16	71.62
O2	54.35	73.11
O3	57.62	76.39

The highest compressive strength was obtained for mix N3 (7.5% Alccofine and 1.5% glass fibre), achieving 61.03 MPa at 7 days and 80.42 MPa at 28 days, compared with 51.23 MPa and 70.25 MPa for the control mix. Compressive strength increased with increasing fibre dosage up to 1.5%, whereas increasing the Alccofine replacement beyond 7.5% resulted in a slight reduction in strength.

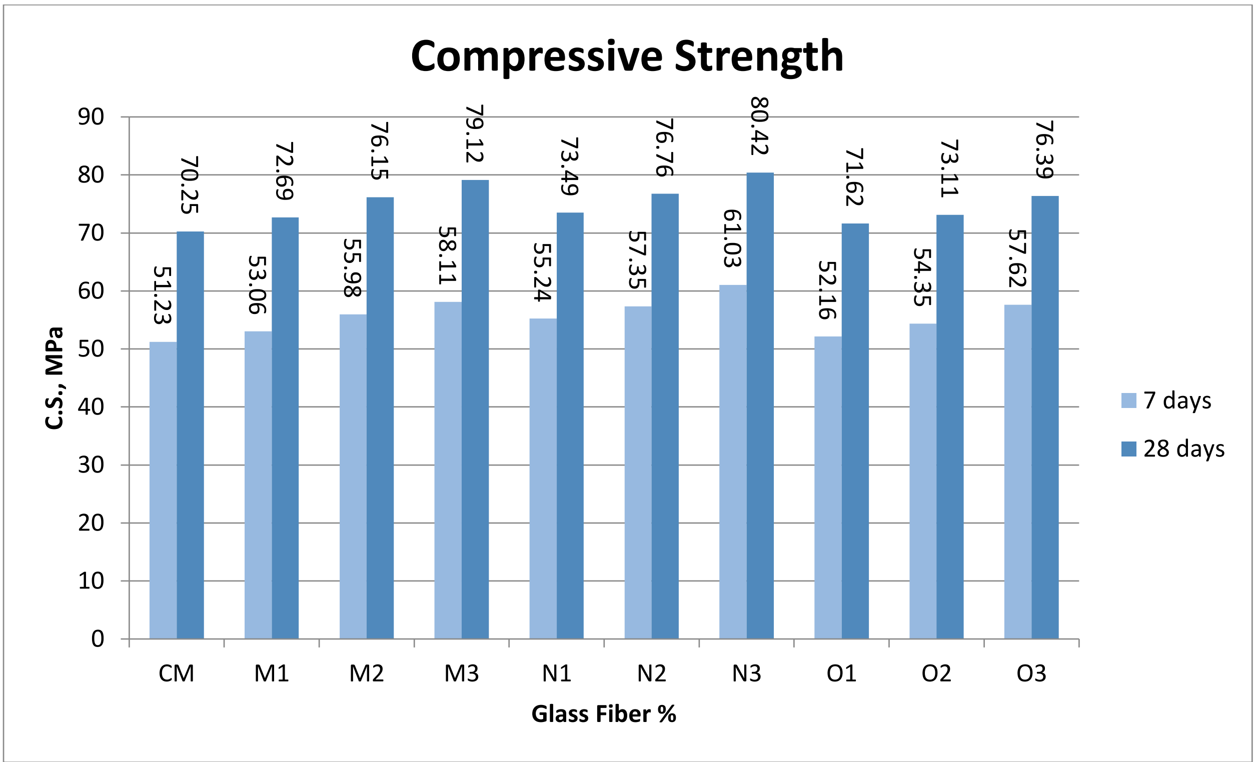

Figure 3: Comparative Graph for Compressive strength.

Overall, the results indicate that incorporating 7.5% Alccofine as a partial cement replacement together with 1.5% glass fibres provides the optimum balance between fresh properties and mechanical performance. Although higher Alccofine contents slightly reduced workability and strength, all SCC mixtures satisfied the EFNARC requirements, confirming the feasibility of producing high-strength, sustainable self-compacting concrete with Alccofine and glass fibre reinforcement.

IV. Conclusion

This study investigated the combined effect of Alccofine and glass fibres on the fresh and hardened properties of M60-grade self-compacting concrete (SCC). The experimental results demonstrated that all SCC mixtures satisfied the EFNARC requirements for fresh-state performance, confirming their suitability for self-compacting applications. However, increasing the Alccofine replacement level and glass fibre dosage gradually reduced workability because of the higher surface area of Alccofine and the fibre interlocking effect, which increased the viscosity of the concrete mixture. The incorporation of Alccofine and glass fibres significantly enhanced the mechanical properties of SCC. Among all mixtures, the combination of **7.5% Alccofine** and **1.5% glass fibre (Mix N3)** exhibited the best overall performance, achieving compressive strengths of **61.03 MPa** and **80.42 MPa** at 7 and 28 days, respectively. The improvement is attributed to the micro-filler and pozzolanic effects of Alccofine, which refined the cement matrix, together with the crack-bridging action of glass fibres that enhanced load-carrying capacity. Increasing the Alccofine content beyond 7.5% resulted in a slight reduction in strength, indicating the existence of an optimum replacement level. Overall, the results demonstrate that the combined use of Alccofine and glass fibres can produce high-strength SCC with satisfactory fresh properties while reducing cement consumption. The optimum mixture containing **7.5% Alccofine and 1.5% glass fibres** offers an effective balance between workability, mechanical performance, and sustainability, making it a promising material for high-performance structural concrete applications. Future research may focus on durability characteristics, long-term performance, and microstructural investigations to further validate the applicability of this composite system in aggressive service environments.

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