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Research Paper

DESTRUCTIVE AND NON-DESTRUCTIVE PERFORMANCE OF CONCRETE CONTAINING ALCCOFINE AS A PARTIAL CEMENT REPLACEMENT

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ABSTRACT
Worldwide concrete production significantly contributes to environmental degradation due to the emission of greenhouse gases from cement production and imbalances of the ecosystem due to the continuous diminution of natural resources. This study investigates a sustainable alternative by using Portland Slag Cement incorporating Alccofine as a partial cement replacement at varying proportions (0%–20%). The mixes were prepared for a relatively higher M40 grade structural concrete with a w/c ratio of 0.36. Mechanical properties were evaluated through non-destructive tests after curing. Outcomes show that a 15% Alccofine yields the highest enhancement in mechanical performance, outperforming traditional concrete. Alccofine high pozzolanic reactivity and fineness contribute to better early-age strength and durability. This study presents a novel, synergistic approach to producing high- performance, eco-friendly concrete, offering a practical solution for reducing constructional hazards and environmental impact while supporting sustainable construction practices.

Keywords: Sustainable concrete, Alccofine, rebound hammer, UPV, Compressive strength

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1. INTRODUCTION:

Globally, concrete is the utmost often utilised building material, but it is made with high environmental costs, mainly in the form of greenhouse gas emissions from cement production (Manna and Banerjee 2019). Cement manufacturing alone has been calculated to account for around 8% of global CO_2 emissions (Cheng et al. 2022). Reducing the substantial consumption of cement in concrete production can be controlled by incorporating supplementary cementitious materials (SCM), either partially or fully [1]. There are several replacements induced for cement, like fly ash, alccofine, bottom ash, silica fume, etc [2–5]. The incorporation of diverse materials can substantially enhance the compressive strength (CS) of concrete up to a specific dosage, which proves beneficial for enhancing CS but also contributes to increased fight against chemical attacks. [2,6–8].

Alccofine is a material with the potential to serve as a substitution for cement, thereby enhancing the overall performance of concrete [2,9]. “Alccofine is a product derived through controlled granulation, characterized by high glass content and an ultra-fine particle size”. This slag-based material exhibits the unique ability to reduce water demand while preserving workability, even at replacement levels of up to 70%, showcasing commendable performance in concrete. Beyond its role in enhancing workability, Alccofine can contributing to the improvement of strength parameters and other concrete properties, such as durable properties. CS is deemed highly significant as it profoundly impacts the durability and safety of structural members [10–12]. According to Saurav et al., the ideal replacement percentage of cement with alccofine is achieved at 10% [9]. M.S. Pawar et al. have suggested that the properties of Self-Compacting Concretes (SCCs), both in terms of fresh & hardened properties, exhibit superior characteristics when incorporating 10% alccofine compared to mixtures with 5%

& 15% alccofine [3]. Despite individual successes, the integrated application of Alccofine in concrete, especially the M40 grade, is unexplored. This work will bridge that gap by investigating the mechanical performance of PSC concrete & different % of alccofine (0% to 20%). The investigation will yield meaningful insights into designing eco-friendly, concrete mixes for sustainable construction.

2. EXPERIMENTAL INVESTIGATION

2.1 Materials and mix combinations

The cementitious material used in this experimental work is PSC, which complies with IS:455 (IS 455, 2015) (IS 455 2015). Table 1 depicts the properties of Portland Slag Cement (PSC). Alccofine, an ultra-fine material made from industrial by-products like GGBS. Alccofine 1203 has been utilised at a 0, 5, 10, 15, and 20% cement replacement level. Table 2 describes the physical properties of Alccofine. Following industry requirements for fibre- reinforced concrete. According to the mass percentage of the overall binder material, a chemical admixture based on poly-carboxylic ether polymers has been employed as a superplasticiser. Pictorial forms of different materials have been depicted in Fig. 1. The M40 grade of concrete was developed by following IS 10262-2019 (IS 10262 2019) and IS 456- 2000 (IS 456 2000). A 0.36 water-to-cement ratio has been used. Table 3 portrays the physical characteristics of aggregates.

Table 1 Properties of PSC

Specifics	Constancy (%)	Specific Gravity (SG)	Setting time (Initial) (min)	Setting time (Final) (min)
Test outcomes	34	3.14	116	208
BIS stats	25–35	3.01–3.15	30	600

Table 2 Physical characteristics of Alccofine

S. No	Particulars	units	Value
1	Particle Size	mm	D4-D6
2	Fineness	cm^2/gm	12000
3	SG	-	2.88
4	Bulk Density	Kg/m^3	650

Table 3 Physical characteristics of aggregates

Features	CA1	CA2	FA	RRB
Size (mm)	12.5 - 20	6.25 – 12.5	0.3 – 4.75	0.3 – 2.36
SG	2.83	2.82	2.65	2.68
Fineness modulus	6.17	5.01	2.30	2.16

(a) (b) (c) (d)

Fig. 1 Pictorial form of different aggregates (a) Cement, (b) Alccofine, (c) FA, (d) CA

2.2 Sample Preparation

Fresh concrete mix prepared using a 200 kg capacity mixer and poured into various moulds. Proper compaction was ensured using a vibrating table. After 24 hrs of casting, the samples were carefully detached from the moulds & kept in water for 7 and 28 days. The outcomes were derived from average values of three specimens per mix ID for each experimental test. Cube specimens used for testing measured 150 × 150 × 150 mm. the specimen preparation have been shown in Fig. 2

Fig. 2 Specimen Preparation

2.3 *Test conducted*

2.3.1 *Fresh properties*

The workability and consistency of the concrete mixes in a wet and fresh state were assessed using the traditional slump cone test, following the guidelines outlined in the IS:1199-2018 [13].

2.3.2 *Hardened properties*

To assess the properties of hardened concrete, various physio-mechanical characteristics, including density, quality, and uniformity, were evaluated through tests such as the rebound hammer test and UPV test. The rebound hammer test, conducted in accordance with IS:516 [14], was used to evaluate the CS of concrete in a non-destructive manner. The UPV test was performed following IS:516 (Part 5/Sec 1) [15] to assess the quality of the concrete. CS tests were performed on hardened concrete specimens utilising a 2000 kN computerised UTM to further investigate the mechanical properties. Following (IS:516(1959)), the test was carried out with a uniaxial load supplied at 2 kN/sec.

3. RESULTS AND DISCUSSION

3.1 Rebound Hammer

The concrete's surface strength, which typically does not pierce the specimens' core, determines the rebound CS. Table 4 describes the NDT results. The average CS for the control mix (0% alccofine replacement) was recorded at 37.53 N/mm². Subsequent replacements yielded CSs of 38.23, 39.15, 42.05, and 37.19 N/mm² for 5%, 10%, 15%, and 20%, respectively. Notably, the highest CS was achieved at a 15% alccofine, gradually decreasing with higher percentages. Results have shown that as rebound hammer values increase, CS also tends to increase [16]. The CS and rebound hammer test show a difference of 15-20%, which closely results in accuracy. The reason behind the lesser rebound CS could be due to a weaker zone [17]. The comparison of rebound CS has been shown in Fig. 3.

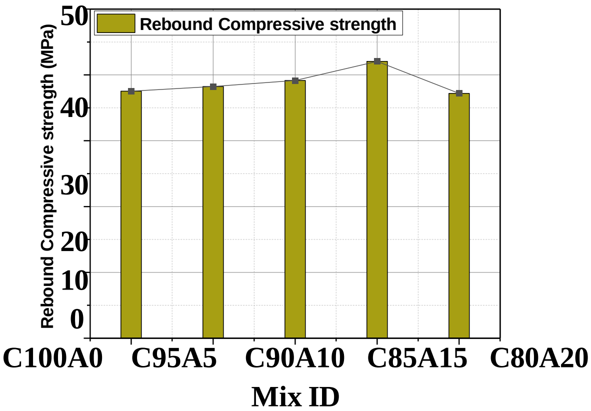

Fig. 3 Comparative plot of rebound compressive strength of various mixes

3.2 Ultrasonic pulse velocity

A non-destructive test called a UPV test measures the eminence of concrete by gauging the speed of an ultrasonic pulse as it travels through a specimen of concrete or a naturally occurring rock formation. While slow rates may indicate low-quality concrete with numerous voids, defects, or cracks, higher velocities indicate superior quality and consistency of the materials. The average UPV for the control mix (0% alccofine replacement) was recorded at 5,12 km/s. Subsequent replacements yielded UPV of 5.21, 5.32, 5.46, and 5.21 km/s for 5%, 10%, 15%, and 20%, respectively. Especially, the greater UPV was attained at a 15% alccofine, gradually decreasing with a surge in replacement. Every concrete mix's UPV values are more than 4.5 Km/s, depicting the robust concrete quality. The improved density and structural compactness with increasing alccofine content up to 15%. A maximum value of 5.46 km/sec at 28 days, likely due to increased porosity and weaker interparticle bonding. Fig. 4 depicts the comparison of UPV of various mixes.

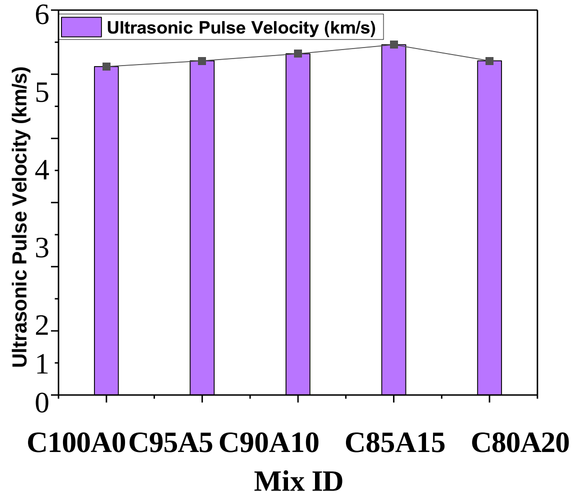

Fig. 4 Comparative plot of UPV of various mixes

3.3 Compressive strength

The experimental investigation aimed to assess the CS of concrete with varying percentages of cement replacement by alccofine, specifically at 0% to 20%. The average CS for the control mix (0% alccofine) was recorded at 50.18 N/mm². Subsequent substitutions yielded CSs of 53.805, 56.67, 60.76, and 52.56 N/mm² for 5%, 10%, 15%, and 20%, respectively. The peak CS was attained at a 15% replacement of cement with alccofine, gradually decreasing with surge in replacement. The increase in CS for each replacement percentage with respect to control mix was 3.625 N/mm², 6.48 N/mm², 10.58 N/mm², and 2.38 N/mm² for 5%, 10%, 15%, and 20%, respectively. The surge of 10.58 N/mm² in CS at the 15% signifies a noteworthy improvement compared to the control mix. Fig. 5 illustrates the failure patterns observed in all mixes. Fig. 6 illustrates comparative CS plots. This inclusive analysis offers insights into the influence of alccofine on the CS of concrete, highlighting the optimal replacement percentage and the corresponding improvements in performance. Table 4 presents experimental results.

				
0%	5%	10%	15%	20%

Fig. 5 Crack pattern of each replacement percentage

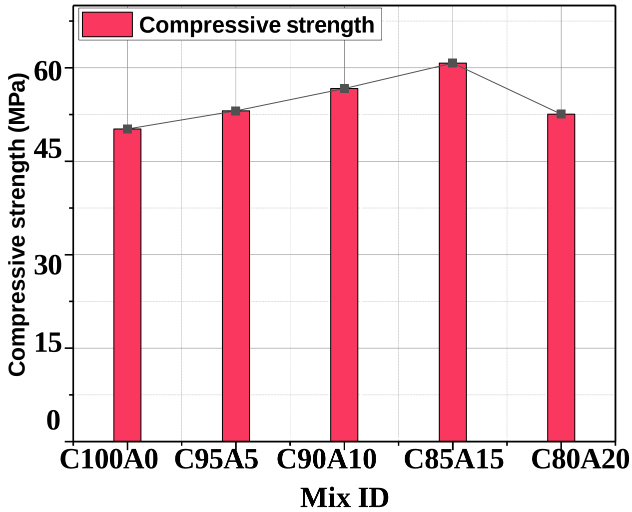

Fig. 6 Comparative plot of compressive strength of various mixes Table 4
Experimental test results

Mix ID	Rebound Hammer (MPa)	UPV (km/s)	Compressive Strength (MPa)
C100A0	37.53	5.12	50.18
C95A5	38.23	5.21	53.10
C90A10	39.15	5.32	56.67
C85A15	42.05	5.46	60.76
C80A20	37.19	5.21	52.56

4. CONCLUSION

a) The experimental findings specify that the optimal replacement percentage of cement with alccofine is attained at 15%, resulting in a CS of 60.76 N/mm² after 28 days curing period.

b) Rebound hammer strength follows a trend that is the same as compressive strength, with optimum values at 40% replacement of alccofine and then a reduction because of enhanced porosity at higher levels of replacement.

c) UPV values above 4.5 km/sec in all mixes indicate compact concrete with the highest compactness at 15% replacement of alccofine.

d) Alccofine, being highly pozzolanic, increases hydration and greatly improves compressive strength if used in optimum quantities with the replacement of cement.

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