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Enhancing the Performance and Durability of M35 Grade Concrete with Alccofine 1203

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Abstract: The construction industry faces pressures to reduce its environmental footprint, prompting the exploration of sustainable materials that maintain or enhance conventional concrete's performance. This study investigates Alccofine 1203, a high-performance micro-fine material, as a partial replacement for cement at increments of 5%, 10%, and 15%. Multiple concrete cubes were prepared and tested for compressive strength, flexural strength, workability, and durability. Fresh properties were evaluated using slump and flow tests, ensuring adequate workability, while long-term performance was assessed through durability tests, including permeability and chloride ion penetration. The results indicate that a 10% replacement of cement with Alccofine 1203 enhances the compressive strength and durability of concrete without compromising workability. Higher replacement percentages showed varied results, necessitating further investigation to optimize the mix design. This study highlights the potential of Alccofine 1203 as a sustainable alternative to traditional cement, offering significant implications for eco-friendly construction practices. This research contributes to the field by providing empirical data on Alccofine 1203's effects on concrete, supporting the development of more sustainable building materials. Future work will focus on refining mix proportions and exploring Alccofine's impact on other concrete properties such as shrinkage and creep.

Keywords: Alccofine 1203, Durability, Environmental impact in construction**,** Sustainable construction materials, Workability.

1 INTRODUCTION

Concrete, being the most widely used construction material worldwide, constantly undergoes innovations to improve its properties and sustainability. One such innovation is the incorporation of supplementary cementitious materials (SCMs) like Alccofine 1203, which have shown promising results in enhancing concrete performance while reducing environmental impact. This paper investigates the behaviour of M35 grade concrete when Alccofine 1203 is used as a partial replacement for cement. The construction industry faces challenges related to environmental sustainability, with concrete production being a significant contributor to carbon dioxide emissions. Traditional concrete, composed mainly of cement, aggregates, and water, requires large amounts of energy for its production and contributes to greenhouse gas emissions. To address these concerns, researchers have explored alternative materials and mix designs aimed at reducing cement content and improving concrete durability.

The motivation for this paper stems from the potential benefits offered by Alccofine 1203 in concrete mixtures. Alccofine 1203, possessing pozzolanic properties, is a high-performance micro-fine material that reacts with calcium hydroxide to form additional cementitious compounds, thereby enhancing the strength and durability of concrete. By partially replacing cement with Alccofine 1203, it is possible to achieve comparable or improved mechanical properties while reducing the carbon footprint of concrete production. The main goal of this paper is to investigate the results of incorporating Alccofine 1203 on the properties of concrete grade M35. Specific objectives include:

- Evaluating the properties of M35 concrete, both fresh and hardened mixes with varying percentages of Alccofine 1203.
- Assessing the flexural strength, compressive strength, and durability characteristics of Alccofine 1203-modified M35 concrete.
- Comparing the environmental impact of Alccofine1203-modified concrete with conventional M35 concrete through life cycle assessment studies.

The research methodology involves laboratory experimentation to prepare and test M35 concrete mixes with different proportions of Alccofine 1203. Standard procedures will be followed to assess the properties that are still fresh, like workability and setting time, and the properties that have hardened, like compressive strength, flexural strength, and durability against factors such as chloride ion penetration and sulfate attack. The microstructural analysis will be conducted using Scanning Electron Microscopy and X-ray Diffraction to understand the effects of Alccofine 1203 on the hydration products and pore structure of concrete.

The findings of this study will add to the corpus of information regarding the application of Alccofine 1203 within concrete technology, particularly in the context of M35-grade concrete. Understanding the performance of Alccofine 1203-modified concrete can lead to more sustainable construction practices by reducing cement consumption and lowering carbon emissions.

2 LITERATURE SURVEY

The studies reviewed focus on using Alccofine as an SCM to improve the mechanical properties, workability, and durability of concrete. Muthukumar and Sathyanarayanan (2023) explored Alccofine-1203 in 3D concrete printing (3DCP), showing that it enhances cement hydration and workability, with optimal performance at 6% replacement. This replacement improved the strength and durability of concrete mortar cubes, outperforming conventional concrete [1]. Similarly, Venkatesan et al. (2020) studied Alccofine as a partial cement replacement alongside iron powder in M30 concrete. Their results revealed significant improvements in compressive and tensile strength, along with better durability in sulphate and acid environments [2].

Harish et al. (2021) and Kumaar et al. (2023) further evaluated Alccofine's impact on high-performance concrete. Harish's team tested Alccofine in various grades of concrete (M30–M70), discovering that it reduced the heat of hydration and enhanced compressive, tensile, and flexural strengths [3]. Meanwhile, Kumaar's study on M30-grade concrete identified a 15% replacement level as optimal for compressive strength and improved resistance to acid, sulphate, and chloride ion penetration, resulting in a denser, more durable microstructure [4].

Other studies have explored innovative uses of Alccofine. Tiwari and Gangwar (2021) used Alccofine alongside crumb tyre rubber, finding that it mitigated strength loss caused by the rubber and improved the concrete's resistance in acid conditions [5]. Manju et al. (2023) examined a mix of Alccofine with machine-crushed animal bones as a partial aggregate replacement, noting enhanced mechanical and durability properties [6]. Sambangi et al. (2023) tested the combination of fly ash and Alccofine in M40 concrete, achieving a maximum compressive strength of 62.74 MPa with 15% fly ash and 15% Alccofine replacement [7].

Further research by Vivek et al. (2023) used Alccofine in hybrid fibre-reinforced self-compacting concrete (SCC), showing that a 15% replacement with Alccofine, combined with polypropylene and abaca fibres, produced a high-strength, durable concrete [8]. Reviews by Yadav and Samanta (2023) and Sai Srinath et al. (2021) highlighted the environmental benefits of Alccofine, emphasizing its ability to reduce CO_2 emissions and improve concrete properties. They concluded that 8–12% replacement provides optimal strength and durability [9, 10]. Nishanth et al. (2022) also tested Alccofine in a geopolymer concrete mix, showing its positive impact on workability and strength when combined with ground-granulated blast furnace slag (GGBFS) and fly ash [11]. Lastly, Rao et al. (2024) investigated the use of quartz powder and eggshell powder in cement replacement, though Alccofine was not a focus of this study [12].

3 MATERIALS USED

3.1 Fine Aggregate

Zone-II M-sand was used. The properties of normal sand are shown in Table 1.

Table 1. Properties of Fine Aggregate

Property	Value
Fineness modulus	2.98
Specific gravity	2.57
Bulk density	Loose state: 1.77 g/cc Compacted state: 2.00 g/cc

3.2 Coarse Aggregate

Coarse aggregate consists of gravel, crushed stone, or other materials ranging from 4.75 mm to 38 mm in size. It provides strength and stability to concrete, influencing its density and durability. To achieve the desired properties of concrete and guarantee the structural integrity of construction projects, coarse aggregate must be carefully chosen and graded.

3.3 Water

The concrete was mixed with potable fresh water—an organic substance devoid of acidity.

3.4 Admixture

Alccofine 1203 type is used. The properties of Alccofine 1203 are shown in Table 2.

Table 2. Properties of Alccofine 1203

Property - Chemical Composition	Value
SiO_2	45%
Al_2O_3	30%
CaO	8%
MgO	5%

3.5 Cement

The binding component of cement concrete is cement. At high temperatures, calcareous, siliceous, and aluminous materials are intimately mixed to create cement, which is then crushed into a fine powder called clinkers. The costliest component of concrete is cement, which comes in a range of forms. The chemical makeup, the manufacturing process, and the level of grinding fineness all affect the properties of cement. A chemical reaction occurs when cement and water are combined, causing the cement paste to first set and then harden into a mass that resembles stone. Cement can be broadly classified into two categories based on its chemical composition, setting, and hardening properties, i.e., portland cement, and special cement.

Portland cement is highly popular and gets its name from the fact that it shares many characteristics with a popular natural stone that is quarried in Portland, UK. Portland cement is recognized as having been discovered by Yorkshireman Joseph Aspdin. Cement is primarily composed of three ingredients: silica, alumina, and lime. Additionally, iron oxide, magnesia, sulfur trioxide, and alkalis in trace amounts are present in most cement. Cement is manufactured by burning to white heat an intimate mixture of the above ingredients and then grinding the resulting clinkers with gypsum to an extremely fine powder. The proportions of the various constituents in cement are presented in Table 3.

Table 3. Components of Portland Cement

Component	Percentage
Lime (CaO)	60 to 67%
Silica (SiO_2)	17 to 25%
Alumina (Al_2O_3)	3 to 8%
Iron oxide (Fe_2O_3)	0.5 to 6%
Magnesia (MgO)	0.1 to 4%
Sulphur trioxide (SO_3)	1 to 2.75%
Alkalis (Soda and Potash)	0.5

4 TESTS CONDUCTED ON AGGREGATES

4.1 Sieve Analysis

A technique called sieve analysis, also known as a gradation test, is frequently employed in civil engineering to evaluate the particle size distribution, or gradation, of granular materials. The size distribution often has a significant impact on how well a material functions when used. Depending on the precise technique, sieve analysis can be carried out on any kind of inorganic or organic granular material, including sand, crushed rock, clays, granite, feldspar, coal, and soil. It can also be applied to a wide range of manufactured powders, grains, and seeds down to a minimum size. Since particle sizing is straightforward, this is likely the most used technique.

4.2 Fineness Modulus

The Fineness Modulus (FM) is employed to ascertain the degree of uniformity of the aggregate gradation. The modulus is typically used to determine the aggregate's fineness or coarseness. It is an empirical measure of the aggregate's fineness. A higher fineness modulus value indicates that the aggregate is coarser, while a lower value suggests that it is finer. Table 4 presents the Fineness Modulus for different types of sand. Sand with a fineness modulus greater than 3.2 is typically not utilized to produce high-quality concrete.

Table 4. Fineness Modulus

Fine Aggregate	Fineness Modulus
Fine sand	2.2-2.6
Medium sand	2.6-2.9
Coarse sand	2.9-3.2

4.3 Bulk Density

Knowing the spaces that exist between aggregate particles is crucial when working with aggregates because it helps us determine whether to fill them with cement paste or finer aggregate.

The density is equal to mass divided by volume. Using this law, the density of aggregates can be determined by multiplying the aggregate volume by the void volume, resulting in a new number known as the bulk density.

4.3.1 Specific Gravity

One way to gauge the strength or quality of a material is to look at its specific gravity. Stone identification is aided by the specific gravity test.

4.3.2 Bulking of Sand

When dry sand encounters moisture, a thin film is formed around the particles, causing them to separate from each other. This results in an increase in the volume of sand, a phenomenon known as bulking of sand. The particles in dry sand separate from one another when they encounter moisture, and a thin film gets formed around them. The volume of sand increases as a result. This process is referred to as the bulking of sand. Table 5 presents the bulking of sand properties; Table 6 presents the physical properties of fine aggregate. Sieve analysis of fine aggregate and recycled coarse aggregate are given in Table 7 and Table 8 respectively. The physical properties of coarse aggregate are given in Table 9.

Table 5. Bulking of Sand Properties

S. No.	Property	Value
1	Specific gravity	2.94
2	The fineness of cement by sieving	2%
3	Normal consistency	30
4	Initial setting time	168 min
5	Final setting time	284 min

Table 6. Physical Properties of Fine Aggregate (M-sand)

S. No.	Property	Value
1	Grading of sand	Zone II as per IS 383
2	Specific gravity	2.57
3	Bulk density	Loose state - 1.77 g/cc Compacted state - 2.00 g/cc
4	Fineness modulus	2.80

Table 7. Sieve Analysis of Fine Aggregate (M-sand)
(Weight of sample taken = 1000 g)

S. No.	IS Sieve	Weight Retained (g)	% Weight retained	Cumulative % Weight retained	% Passing
1	10 mm	0	0	0	100
2	4.75 mm	2.1	0.21	0.21	99.79
3	2.36 mm	126.5	12.65	12.86	87.14
4	1.18 mm	240	24	36.86	63.14
5	600 µm	238.2	23.82	60.68	39.32
6	300 µm	266	26.6	87.28	12.72
7	150 µm	127.2	12.72	100	100
Fineness modulus = 2.98					

Table 8. Sieve Analysis of Recycled Coarse Aggregate

S. No.	Property	Value
1	Specific gravity	2.74
2	Bulk density	Loose state - 1.77 g/cc Compacted state - 2.00 g/cc
3	Fineness modulus	6.62
4	Water absorption 1. 20mm	1.02%

Table 9. Physical properties of Coarse Aggregate

S. No.	Property	Value
1	Specific gravity	2.82
2	Bulk density	Loose state - 1.45 g/cc Compacted state - 1.60 g/cc
3	Fineness modulus	6.62
4	Water absorption (20mm)	0.81%
5	Water absorption (10mm)	0.78%

4.4 Water Cement Ratio

The ratio of the weight of cement to the volume of water used in the concrete mix is termed the water-cement ratio. Experiments show that there is nearly a fixed amount of water (optimum) that provides maximum strength for a given proportion of ingredients in a concrete mix. A slight change in the amount of water used results in a much larger variation in the concrete's strength. If less water is used, the resulting concrete will be relatively dry, challenging to install, and may have compaction issues.

4.5 Alccofine 1203 Description

Alccofine 1203 is a highly reactive supplementary cementitious material that significantly enhances concrete's microstructural properties. Derived from specific minerals through calcination and ultrafine grinding, it is exceptionally fine and rich in silica. This contributes to its pozzolanic and latent hydraulic properties. In concrete, when Portland cement hydrates, Alccofine 1203 reacts with the calcium hydroxide to produce more calcium silicate hydrate (C-S-H), the primary phase that imparts strength. This reaction boosts concrete's strength, durability, and resistance to aggressive environments, reduces permeability, and improves workability and finishability. It is especially effective in high-performance concrete applications, offering reduced chloride permeability and increased corrosion resistance. A sample of Alcoffine 1203 is shown in Fig. 1.

Fig. 1 Alccofine - 1203

4.6 Casting of Specimens

In the casting process, concrete is typically poured into a mold with a hollow cavity in the desired shape, and the mold is then left to solidify. A metal base plate with a smooth surface is included with every mold. The base plate is ideally fastened to the mold with screws or springs and is sized to support the mold during filling without leaking. To ensure that no water escapes during the filling process, lubricating oil is thinly coated on the joints between the sections of the mold when it is assembled for use. A similar coating is applied between the base plate and the mold's bottom contact surface. To prevent concrete from adhering, the interior surface of the assembled mold must also be thinly coated with oil. In this research, various mold sizes, including prism, cylinder, and cubes, are cast.

The test specimens' compressive strength, split tensile strength, and flexural strength were assessed in the current study. Mixtures were made for the design mix M35. Portland Pozzolana Cement (PPC) was the type of cement used. Crushed stone that passed through an IS 20 mm sieve and was retained on an IS 10 mm sieve, as well as recycled aggregates that passed through an IS 20 mm sieve and were retained on an IS 10 mm sieve, were used as the coarse aggregate. The M-sand fine aggregate, which complies with IS 383-1970 zone II, was utilized. The mold is set up on an even surface. Vibrating the well-mixed concrete in the mold with a table vibrator fills the mold. Using a trowel, extra concrete was removed, and the top surface was smoothed and levelled following IS: 516-1959.

Fig. 2 Casting Preparation

The composition of the different mixes is summarized in Table 10, detailing the percentage of cement and Alccofine 1203 used. The control concrete mix (CC) contains 100% cement, while M1, M2, and M3 replace portions of cement with Alccofine 1203 at 5%, 10%, and 15%, respectively. This variation in Alccofine 1203 content allows for the evaluation of its effect on the mechanical properties of concrete, such as compressive strength, split tensile strength, and flexural strength.

Table 10. Composition of Concrete Mixes

Specimen	Cement (%)	ALCCOFINE 1203 (%)
CC	100	0
M1	95	5
M2	90	10
M3	85	15

5 EXPERIMENTAL RESULTS

This section presents the results of the experimental work. The compressive strength, split tensile strength, flexural strength, and resistance to acid attack of the concrete are evaluated. Concrete specimens with a mix design of M35 grade were cast and cured in water. Their compressive strength, split tensile strength, and flexural strength are measured at intervals of 7, 14, and 28 days using a compression testing machine. The compressive strengths of different specimens are given at 7, 14, and 21 days of the period in Table 11, Table 12, and Table 13 respectively. Fig. 3 shows the average compressive strengths of the different specimens.

Table 11. Compressive Strength of Concrete at 7 Days under normal curing

S. No.	Specimen	Compressive strength (N/mm^2)			
		Trail-1	Trail-2	Trail-3	Average
1	CC	24	23.5	24.5	24.00
2	M1	23.1	23.7	24	23.6
3	M2	25	24	24.5	24.50
4	M3	23	22.7	21.65	22.45

Table 12. Compressive Strength of Concrete at 14 Days under normal curing

S. No.	Specimen	Compressive strength (N/mm^2)			
		Trail-1	Trail-2	Trail-3	Average
1	CC	33.5	34.25	34.1	33.95
2	M1	32.54	31.76	33.25	32.52
3	M2	35.67	36.2	34.68	35.52
4	M3	33.83	34.63	34.76	34.41

Table 13. Compressive Strength of Concrete at 28 Days under normal curing

S. No.	Specimen	Compressive strength (N/mm^2)			
		Trail-1	Trail-2	Trail-3	Average
1	CC	39.65	41	37.84	39.50
2	M1	38	39.75	37.46	38.40
3	M2	40.1	43	42.61	41.90
4	M3	38	39.33	40	39.11

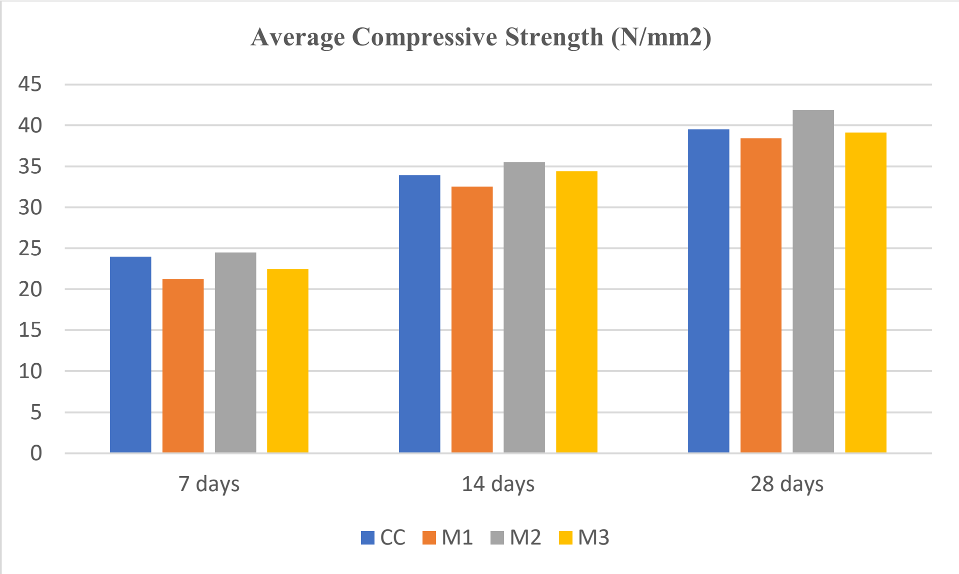

Fig. 3 Average Compression Strength

The split tensile strength is calculated for each specimen at 7, 14, and 21 days. The average values by considering three trials are given in Table 14. The values are plotted in Fig. 4. Similarly, Flexural strength values are given in Table 15 and are plotted in Fig. 5.

Table 14. Split Tensile Strength

Average Split Tensile Strength (N/mm2)			
	7 days	**14 days**	**21 days**
M1	1.13	1.98	2.25
M2	1.273	1.84	2.65
M3	1.556	1.98	2.44

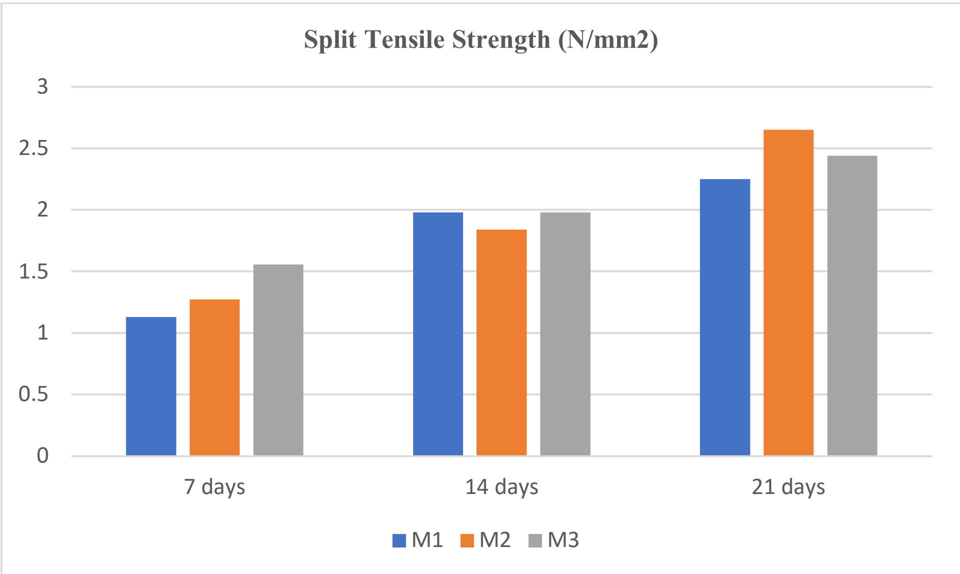

Fig. 4 Average Split Tensile Strength

Table 15 Flexural Strength

Average Flexural Strength(N/mm2)			
	7 days	14 days	21 days
M1	4.4	5.8	8.2
M2	4.4	5.1	7.6
M3	4.5	5.9	6.1

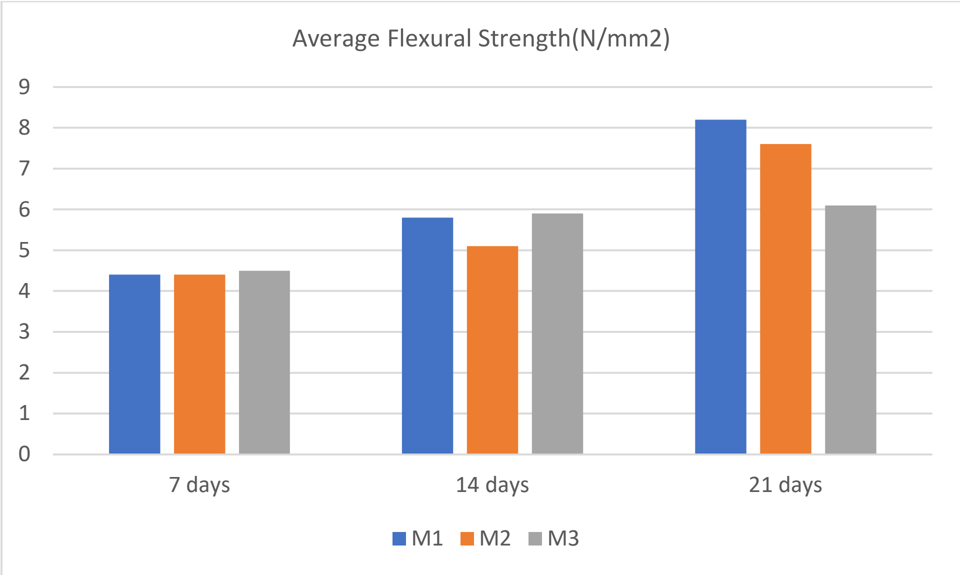

Fig. 5 Average Flexural Strength

After proper water curing for 28 days, the specimens were subjected to concentrations of 0.1% and 0.3% of diluted sulfuric acid. Periodically, the acid's strength was measured, and any lost acid was added back in. The results of the acid attack tests on the specimens exposed to both 0.1% and 0.3% diluted sulfuric acid after 28 days of water curing are summarized in Tables 16 and 17. The data indicate that the weight reduction of the concrete specimens varied with the concentration of sulfuric acid and the age of the samples. For the specimens subjected to 0.1% H_2SO_4, weight reductions ranged from 0.88% to 2.97%, with the compressive strength at 56 days showing values between 33.00 N/mm² and 41.50 N/mm². In contrast, the specimens exposed to 0.3% H_2SO_4 exhibited greater weight loss, ranging from 0.77% to 4.16%, and compressive strength values decreased to a minimum of 31.00 N/mm² at 56 days. The observed decrease in compressive strength and the higher weight loss under the more concentrated acid solution suggest that the chemical resistance of the concrete diminishes with increased acid exposure. Overall, the results emphasize the impact of sulfuric acid concentration on the durability and structural integrity of concrete, highlighting the importance of selecting appropriate materials and mix designs for environments prone to acidic conditions.

Table 16. Acid attack with a concrete of 0.1% H_2S0_4

Age (days)	Specimen	Weight of cube before immersion (g)	Weight of cube after removal from the acid tank (0.1% of H_2SO_4) (g)	Weight reduction (%)	Compressive strength (N/mm²)
14	M1	2632	2605	1.03	34.5
	M2	2622	2599	0.88	34.00
	M3	2672	2631	1.53	34.50
28	M1	2672	2636	1.35	41.50
	M2	2798	2736	2.22	39.50
	M3	2684	2614	2.61	38.00
42	M1	2634	2588	1.75	36.00
	M2	2666	2600	2.48	37.00
	M3	2732	2665	2.45	35.00
56	M1	2676	2600	2.84	35.00
	M2	2738	2674	2.34	33.50
	M3	2622	2544	2.97	33.00

Table 17. Acid attack with a concrete of 0.3% H_2S0_4

Age (days)	Specimen	Weight of cube before immersion (g)	Weight of cube after removal from the acid tank (0.3% of H_2SO_4) (g)	Weight reduction (%)	Compressive strength (N/mm^2)
14	M1	2718	2685	1.21	39.50
	M2	2730	2709	0.77	40.00
	M3	2656	2611	1.69	39.00
28	M1	2618	2586	1.22	38.00
	M2	2716	2656	2.21	37.00
	M3	2718	2654	2.35	36.50
42	M1	2718	2600	2.40	35.00
	M2	2664	2604	2.54	36.00
	M3	2672	2615	2.79	34.00
56	M1	2676	2588	3.29	34.00
	M2	2738	2624	4.16	32.50
	M3	2622	2569	2.02	31.00

6 CONCLUSIONS

The experimental investigations conducted on M35 grade concrete incorporating Alccofine 1203 have yielded significant insights into its mechanical properties and durability. The study conclusively demonstrated that the M2 mix, which includes a 10% replacement of cement with Alccofine 1203, consistently exhibited superior compressive strength across all testing periods. Notably, the M2 mix achieved the highest compressive strength at 28 days, reflecting a substantial improvement over the control mix. Additionally, the inclusion of Alccofine 1203 positively influenced the split tensile and flexural strengths of the concrete. The consistent performance of the M2 mix across these parameters highlights its effectiveness in enhancing the mechanical properties of concrete, making it a promising choice for applications requiring high strength and durability. The durability assessments further revealed that all mixes, including the control, exhibited reasonable resistance to acid attacks, although higher concentrations of sulfuric acid had a detrimental effect on compressive strength over time. These findings affirm the potential of Alccofine 1203 as a valuable supplementary cementitious material in concrete formulations. The incorporation of Alccofine 1203 not only enhances the mechanical properties of M35-grade concrete but also contributes to its durability. The results advocate for its use in construction practices, especially in environments prone to acid exposure, thereby ensuring longer-lasting structural integrity.

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ETHICS STATEMENT

This study did not involve human or animal subjects and, therefore, did not require ethical approval.

STATEMENT OF CONFLICT OF INTERESTS

The authors declare no conflicts of interest related to this study.

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