

Effect on Mechanical Properties of Concrete using Alccofine and Synthetic Fibres

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Abstract

Several steps are being implemented to restrict carbon emissions, which harm the environment. Cement production plays an important role in carbon emissions, and there is a need to reduce its usage. Many researchers replaced the cement in concrete with various supplementary cementitious materials, and alccofine is one of the promising materials. Alccofine has been used in varying percentages of 10%, 20%, and 30% to replace the cement. Polypropylene fibres have been used in volume fractions of 0.1%, 0.2%, 0.3%, and 0.4% with alccofine concrete mix. The mechanical tests are carried out on the concrete specimens. The average 28-day compressive strength of concrete with 20% alccofine reaches the peak value of 39.94 N/mm², and the concrete mix with 20% alccofine and 0.2% PP fibres has maximum compressive strength and modulus of elasticity of about 43.55 MPa and 25155 MPa, which is greater than the control mix after 28 days of curing. The addition of alccofine and polypropylene improves the mechanical behavior of the concrete mix.

Keywords: Concrete, Alccofine, synthetic fibre, compression test, mechanical properties

. Introduction

India is the second-largest cement manufacturer in the world. In 2022, India produced 356 million tons of cement. Compared to 2021 production, it is 60 million tons increased. Still, India is a developing country, and the government concentrates on developing the infrastructure of our nation. So, in the upcoming years, the need for cement will increase. However, the major problem of cement manufacturing is CO₂ emission. To overcome this issue, research is going on alternate cement materials. Alccofine is one of the supplementary cementitious materials that can be used as an alternative material for cement [1]. Many research works are being carried out using alccofine, and some of them are discussed as follows:

The Self-Compacting Concrete (SCC) was developed through the addition of alccofine 1203 from 0-15% and 25% fly ash in the cement mixes. The developed concrete specimens are tested for their maximum compression and split tensile test, along with the Modulus of rupture. The analysis showed that the cement mix with 65% cement and 25% fly ash with 10% alccofine has higher

performance in comparison with the control mix, and it can be preferred for construction purposes [2]. The fly ash was used at 30% as a replacement material and developed the SCC by adding the alccofine 1203 at various proportions of 5% to 25% along with steel fibres at 1%. The developed SCC showed fresh properties with better flowability and compacting properties. The testing showed that the compressive, split tensile, and flexural strength of the specimen with 15% alccofine is better than other mixes in the study [3]. The alccofine-1203 is added as the replacement material for the cement mortar at various proportions of 5%, 10%, 15%, and 20%. The study is carried out to analyse the impact of alccofine on the compressive strength of cement mortar. The study revealed that the compressive strength of concrete with 10% alccofine is more than the control mix [4].

The two different concrete mixes were developed using the alccofine 1203 and silica fume, along with the GGBS. The alccofine and GGBS-based concrete mix exhibited higher compressive, split tensile, and flexural strength at 136.67 MPa, 15.20 MPa, and 31.88 MPa, respectively, which is better than the silica and GGBS-based concrete with 119.31 MPa,

13.26 MPa, and 27.82 MPa for compressive, tensile, and flexural strength, respectively [5]. The microstructural and mechanical properties of concrete developed with 20% fly ash and alccofine material. The study showed that the mix with 10% alccofine and 20% fly ash in the concrete mix showed maximum compression, flexural, and split tensile strength than other mixes used in the study [6]. The consistency, setting time, and compressive strength behavior of concrete with the ternary blend of fly ash, alccofine 1203, and GGBS were studied. The concrete prepared with the mix of alccofine-fly ash and alccofine-GGBS showed better setting time than the control mix. However, the addition of alccofine-fly ash provided better compressive strength in comparison with the control mix, whereas alccofine-GGBS showed a decrease in compressive strength [7].

The Geopolymer concrete was developed using alccofine 1203 and high silica husk ash to study the effectiveness in terms of compressive strength and split tensile strength. The experimental results showed that the presence of alccofine 1203 improved the compression and split tensile performance of concrete in comparison with the control mix [8]. The cement was partially replaced in the concrete mix with alccofine 1203 and GGBS. The study is conducted in two phases. Firstly, the concrete mix is prepared with GGBS and cement, in which the GGBS is varied from 0 to 40%. The result showed that the concrete mix with 20% GGBS showed better compressive strength. The second phase involves the addition of alccofine at 8%, 10%, 12%, and 14% in the concrete mix of cement-20% GGBS. The final analysis showed that the ternary blend of concrete with 72% cement-20% GGBS-8% Alccofine showed better compressive strength than other concrete mixes developed in the study [9]. The concrete was developed by adding alccofine 1203 and steel fibres and testing its compressive strength. The study showed that a 10% addition of alccofine improved the compressive strength among the steel fibre-based concrete mixes [10]. The strength of the concrete was developed and investigated through the addition of alccofine at 0%, 5%, 10%, and 15%. The mechanical properties

of the materials are tested at different curing times (1 day, 2, 7, 28 days). It was observed that the alccofine at 10% provided better compressive, flexural, and split tensile strength than other mixes at different stages of curing [11]. The usage of alccofine at 15% in the concrete mix can improve the performance of the concrete, and it is also economical [12].

From the literature study, it is observed that concrete is strong in compression, but its tensile strength is just one-tenth of its compressive strength. Though the addition of steel reinforcements increases the tensile strength of the concrete, some of the microcracks are unavoidable. These microcracks lead to the corrosion of steel rods and weaken the strength of the concrete. The addition of polypropylene synthetic fibers will arrest the microcracks. By considering the above two problems, an effort has been made in this study to find out the compressive strength, modulus of rupture and modulus of elasticity of the replacement of cement with alccofine with varying percentages of polypropylene in the concrete mix of cement and alccofine.

2. Materials and Methods

2.1. Cement

This investigation used an ordinary Portland Cement of grade 53 conforming to IS 12269:2013. The obtained cement has a specific gravity of about 3.15. The initial setting time of the cement is about 56 minutes, whereas the final setting time is about 383 minutes.

2.2. Coarse Aggregate

The coarse aggregate used was crushed granite of a maximum particle size of 20mm and conforming to IS 383:2016. The coarse aggregate is in angular shape with a specific gravity of 2.83 and water absorption of 0.8.

2.3. Fine Aggregate

River sand was used in this study as per the standards of IS 383:2016. The sieve analysis test was conducted to determine the Zone. The values obtained are mentioned in Table 1.

Table 1 Sieve Analysis of Fine Aggregate

S.No	Sieve size	Weight of Fine aggregate retained	Cumulative Weight of Fine aggregate retained	Cumulative Percentage of Fine aggregate retained	Percentage of Passing
1	4.75 mm	16	16	1.6	98.4
2	2.36 mm	18	34	3.4	96.6
3	1.18 mm	158	192	19.2	80.8
4	600 μ	322	514	51.4	48.6
5	300 μ	419	933	93.3	6.7
6	150 μ	53	986	98.6	1.4
7	75 μ	12	918	99.8	0.2
8	Pan	2	1000	-	-

2.4. Super Plasticizer

The Conplast SP430 is a chloride-free sulfonated naphthalene polymer admixture that is used as a super-plasticizer. This plasticizer disperses the water instantly in the concrete mix.

2.5. Alccofine

Alccofine is produced from GGBS in completely controlled conditions with special types of equipment/instruments to obtain optimized particle size distribution with unique properties. The properties of Alccofine 1203 are given in Table 2.

Table 2 Properties of Alccofine

Chemical Properties	Ingredients in Percentage
Sio2	35.6%
Al2O3	21.4%
Fe2O3	1.3%
Cao	33.6%
SO2	0.12%
MgO	7.98%

2.6. Polypropylene Fibre

Commercially available Recron 3S fibres were used in this study. The fibres are compatible with all admixtures used in concrete, which conform to ASTM C1116. The properties of polypropylene fibres are given in Table 3.

Table 3. Properties of Polypropylene Fibres

S.NO	PROPERTY	VALUE
1	Length	12 mm

2	Shape	Triangular
3	Effective diameter	40 micron
4	Specific Gravity	0.91
5	Tensile Strength	4 Gpa
6	Elongation	90%
7	Elasticity Modulus	4000 Mpa
8	Alkaline Stability	Very Good

2.7. Experimental Investigation

The compressive strength of the concrete is usually obtained by testing concrete cubes using a compression testing machine, according to IS 516-5919. The dimensions of the cubes are 150mm x 150mm x 150mm. The compressive strength for different Alccofine dosages 10% (A10), 20% (A20), and 30% (A30) in concrete cubes was determined along with the control mix (CM). From the obtained compression test results, the mix with the maximum compression value is selected and the polypropylene fibres are added at 0.1% (P1), 0.2% (P2), 0.3% (P3), and 0.4% (P4), respectively, and the corresponding compressive strength is determined. Similarly, the test specimen for the split tensile test

is prepared in the form of cylinders with a diameter of 150mm and with length of 300mm. The specimens are prepared for mix configuration of cement-Alccofine and cement-alccofine-polypropylene (CAP) as in the compressive test. The modulus of elasticity test is conducted based on ASTM C469 with the cylindrical specimen of size 150x300 mm. Finally, the flexural test is conducted on the specimens with a size of 100x100x500 mm conforming to the recommendations of IS 516-1964. The specimens are prepared based on the mix configurations, as in the compressive and split tensile tests. All the test specimens are tested after 28 days of curing in water. Figure 1 shows the schematic diagram for the experimentation work.

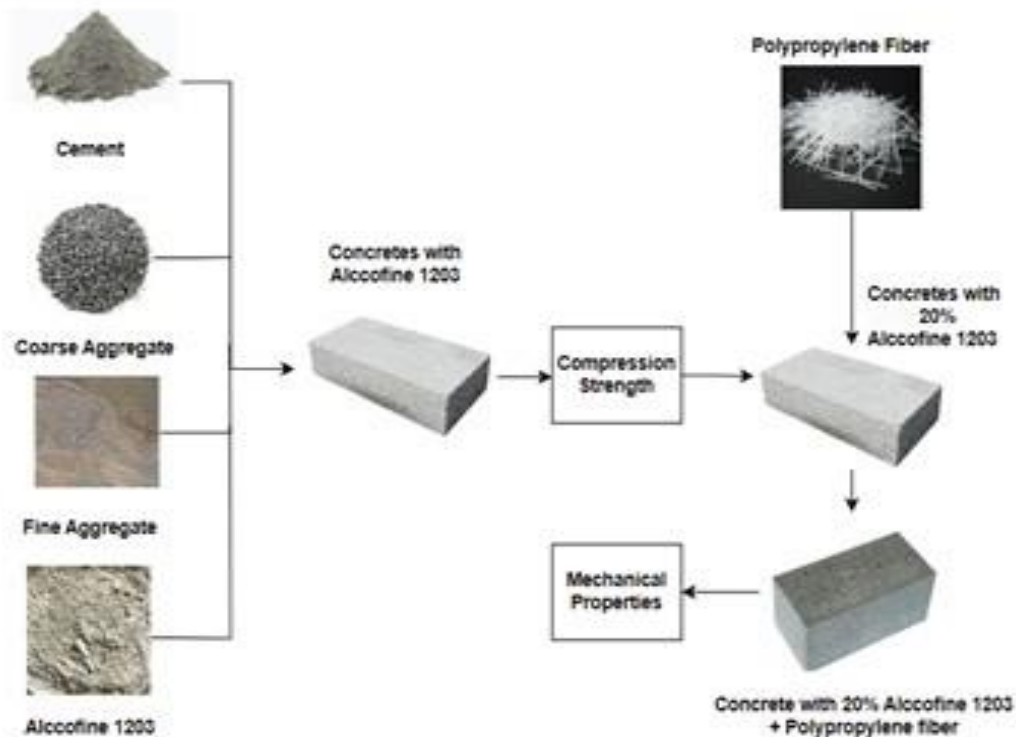


Figure 1. Experimental schematic diagram

For testing the concrete mixes, the specimens are prepared according to the standards. For each of the three tests, 18 specimens with different alccofine mix configurations are prepared. Concrete is produced as the control mix with cement, fine aggregate, and coarse aggregate in the ratio of 1:1.88:2.87. For the alccofine-added concrete mix, the cement content is replaced by

35kg, 70kg, and 105kg. For the alccofine-polypropylene (AP) concrete mix, the cement content is further replaced from 0.03 to 0.12 kg. A total of 36 specimens are prepared for compression, split tensile, and flexural strength. The prepared specimen and the compression test for the concrete are shown in Figure 2



Figure 2. Specimen for Compression Test



3. Results and Discussion

3.1. Compressive strength

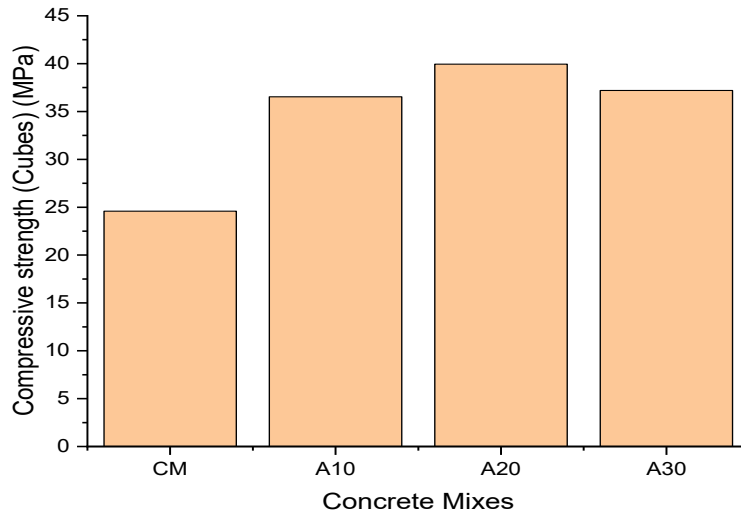


Figure 3. Compressive strength of cubical concrete specimens with Alccofine

The average 28-day compressive strength of conventional concrete is 24.59 N/mm². The average 28-day compressive strength was escalated to 36.54 N/mm² with the incorporation of 10% of alccofine, respectively, which is 48.60% more than that of the control mix. The average 28-day compressive strength of concrete with 20% and 30% alccofine reaches the peak value of 39.94 N/mm² and 37.2 N/mm², which is 62.44% and 51.28% better than the control mix. For 28 days of curing, the alccofine-based concrete showed an improvement in compressive strength over the control mix, as shown in Figure 3. However, the compressive strength of concrete decreased by 30% of alccofine after 28 days of curing due to the excessive expansion of concrete with microcracks

[6]. It is observed that Alccofine with 20% replacement gave a better compressive strength.

The compressive strength of a concrete mix with alccofine-polypropylene fibres is analysed. The compressive test showed that the concrete mix with 20% alccofine and 0.2% PP fibres has a maximum compressive strength of about 43.55 MPa, which is greater than the control mix by 77.09% after 28 days of curing. The compressive strength for all the concrete mixes is higher than the control mix; however, in the concrete mix with the addition of 0.3% and 0.4% PP fibre, there is a downward trend that resulted from micro-cracks [6] and created a larger interfacial transition zone in concrete [13]. The compression strength for the control mix and the other mixes is given in Figure 4.

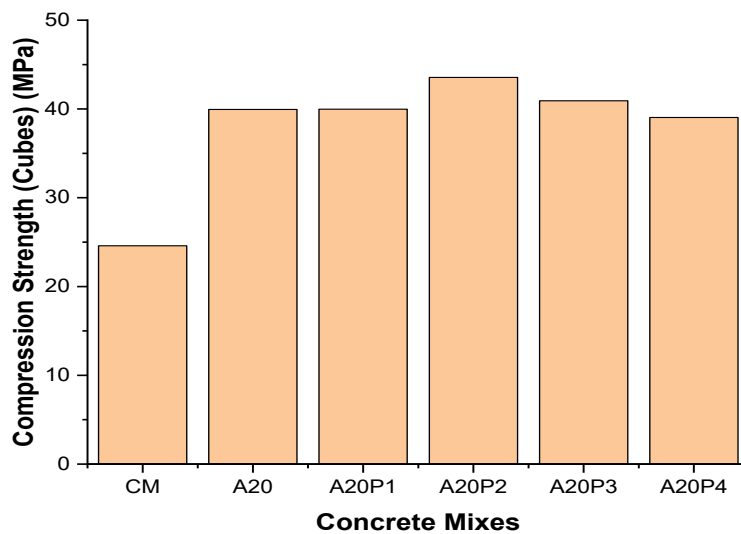


Figure 4. Compressive strength of cubical concrete specimens with Alccofine-PP fibres

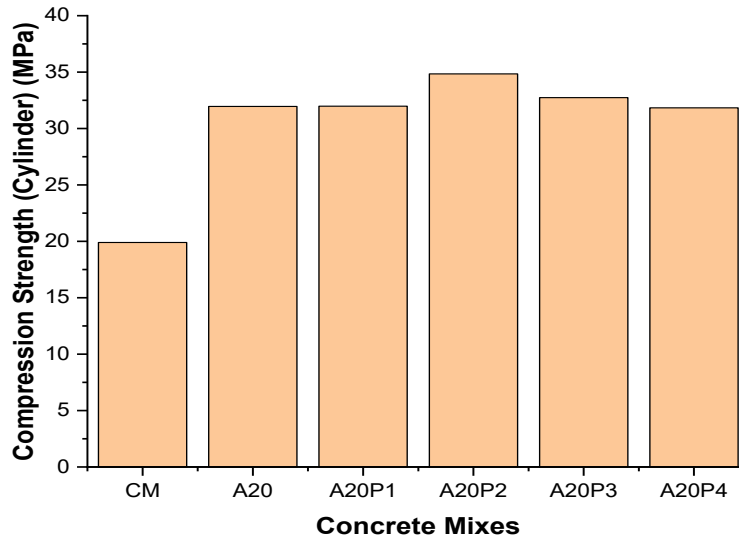


Figure 5. Compressive strength of cylindrical concrete specimens with Alccofine-PP fibres

The compressive strength of the concrete can be determined using the cylindrical specimens after 28 days of curing. The concrete specimens with 20% alccofine and 0.2% PP fibres showed a maximum compressive strength of 34.84 MPa, which is 75.06% higher than the control concrete. The concrete specimens with PP fibres showed more compressive strength than the control concrete. The strong adhesion between the fibres and the cement matrix provided the concrete mix with better strength. At higher fibre percentages, the bonding between the cement matrix and PP fibres is observed to be improper due to poor dispersion [14]. The compressive strength of the cylindrical specimens is given in Figure 5.

3.2. Modulus of Elasticity

All the alccofine-PP fibre-based concrete has a higher modulus of elasticity in comparison with the control mix. The maximum modulus of elasticity is observed for the specimen with the concrete mix of 20% alccofine and 0.2% PP fibre, which is about 25155 MPa respectively after 28 days of curing. When the PP fibre is increased above 0.2%, the Modulus of Elasticity decreases. Above 0.2% of PPf addition, the specimens show lesser stiffness, and the MoE decreases gradually; similar results are observed in Bhagwat et al. (2023) and Mahdi et al. (2024). Figure 6 shows the modulus of elasticity for the concrete specimens.

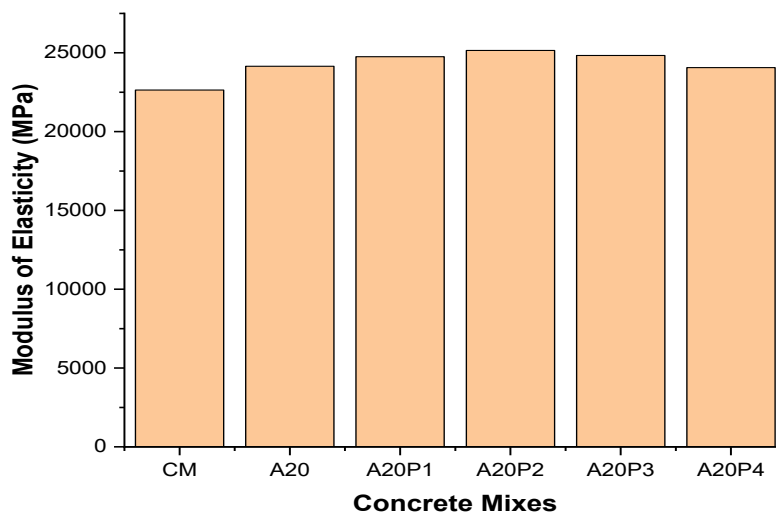


Figure 6. Modulus of Elasticity for concrete specimens with Alccofine-PP fibres

3.3. Modulus of Rupture

The Modulus of Rupture of the different concrete mixes showed that the concrete with alccofine-polypropylene fibres is better than the control mix, as shown in Figure 7. The maximum Modulus of Rupture is observed for 20% alccofine-0.4% PP fibre

with a strength of 8.17 MPa after 28 days of curing. The fibre addition in the concrete mix improved the modulus of rupture for the concrete specimens, mainly due to the interfacial bonding that exists among the concrete and fibres that enables the transmission of load to the fibers (Malek et al., 2020).

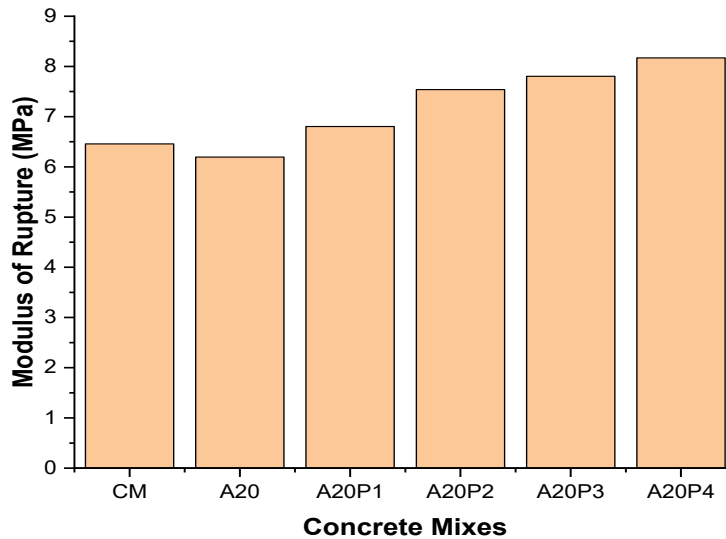


Figure 7. Modulus of Rupture for concrete specimens with Alccofine-PP fibres

4.

Conclusion

The current study involved the usage of alccofine 1203 and polypropylene fibres as the replacement material for cement in the concrete. The alccofine is varied at three different proportions (10%, 20%, and 30%) in the concrete mix, and the cubical test specimen is prepared for carrying out the compression test. Based on the compression test, the mix with 20% alccofine showed better strength than the other two mixes. The mix proportions of cement-20% alccofine are added with the PP fibres at four different proportions (0.1%, 0.2%, 0.3 %, and 0.4%). The mechanical behavior of the concrete mixes is studied in accordance with the relevant standards. The experimental results showed that the A20P2 concrete mix provided better mechanical performance than the other concrete mixes. A maximum compressive strength of 43.55 MPa and elastic modulus of 25155 MPa are obtained with A20P2 concrete mix, which is 75.06% and 11.11% higher than the control concrete. The addition of alccofine and polypropylene improves the mechanical behavior of the concrete mix.

Future work may involve durability tests to study the performance of concrete using different acids on the developed concrete mixes.

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