Experimental Investigation on Mechanical Properties of Concrete Incorporating Alccofine and Polypropylene Fiber

Revathi B[1*], Saravanan J[2]

[1, *] Research Scholar, Department of Civil and Structural Engineering, Annamalai University, Chidambaram, Tamil Nadu, India.

[2] Professor, Department of Civil and Structural Engineering, Annamalai University, Chidambaram, Tamil Nadu, India.

ABSTRACT:

Objectives: To examine the mechanical properties of concrete incorporating alccofine as supplementary cementitious material and polypropylene fiber. **Methods:** In this study, two concrete grades, M30 and M60, were used. The alccofine was incorporated in the concrete at varying dosages of 12%, 14%, 16% & 18% to determine the optimum percentage. Using the optimum dosage, polypropylene fibers were added at volume fractions of 0.1%, 0.2%, 0.3% & 0.4%. The mechanical properties, such as compressive strength, Elastic modulus and flexural strength, were examined for all the concrete mixes. **Findings:** The incorporation of alccofine and polypropylene fiber results in improved mechanical properties. The results indicate the mix with 16% alccofine and 0.3% polypropylene fiber exhibits increased compressive strength compared to the control concrete. **Novelty:** The addition of alccofine improves workability, strength and reduces the permeability in concrete, whereas polypropylene fiber improves ductility and controls crack propagation. The concrete containing alccofine and polypropylene fiber enhances the compressive strength, Elastic modulus, flexural strength and durability of concrete.

Keywords: Alccofine, Polypropylene fiber, M sand, Compressive strength, Elastic modulus and Flexural strength.

1. INTRODUCTION

Concrete is one of the most extensively used building materials in the world, and it plays an important role in construction. Many waste materials like Fly Ash (FA), Ground Granulated Blast Furnace Slag (GGBS), Rice Husk Ash (RHA), Limestone Fines and Alccofine have been shown to exhibit pozzalonic properties; thus they have been used as alternative cementitious substances(1). Alccofine is a slag-based micro-fine mineral admixture used as a supplementary cementitious material for concrete and mortar. It is an eco-friendly material based on low-calcium silicate containing a high amount of glass content with high reactivity. It is a highly processed material made from ground-granulated blast-furnace slag which contains ultra-fine particles with a fineness of 12,000 cm^2/g that were produced in a controlled granulation process(2). The inclusion of Alccofine 1203 in concrete formulations not only enhances compressive strength but also improves the material's fluidity and overall workability. This admixture can be utilized in two primary ways: as a replacement for cement, which reduces the overall cement content and thereby lowers costs, and as an additive to enhance the desirable properties of high-strength concrete(3). The incorporation of polypropylene fiber enhanced the flexural strength of samples remarkably(4).

Narender and Meena(1) concluded that replacement of cement with combination of fly ash and alccofine resulted in the development of superior eco-friendly concrete. Sagar and Sivakumar(5) reported the uniaxial stress strain behaviour of alccofine based HSC and concluded that the mix with 10% alccofine exhibited highest Young’s modulus and energy absorption capacity compared to other mixes. Jamenraja and Ravichandran(6) concluded that the optimum dosage of alccofine and nano-silica with polypropylene fiber resulted in maximum compression and flexural strength.

2. METHODOLOGY

In this study, two different grades of concrete, M30 and M60, were developed to evaluate the combined effects of alccofine and polypropylene fibers on mechanical behaviour. The alccofine was incorporated in the M30 grade of concrete at varying dosages of 12%, 14%, 16% and 18% to determine the optimum percentage. The optimum dosage of alccofine has been kept the same for both M30 and M60 mixes. Additionally, polypropylene fibres were added at four different volume fractions: 0.1%, 0.2%, 0.3%, and 0.4%.

The nomenclature of each concrete specimen is given in the form of the variables (mix and material), and their respective content is mentioned as ‘x’. i.e. Mx-Ax-Px. Mx represents the mix grade of concrete. For instance, M1 and M2 represent M30 and M60 grades of concrete, respectively. Ax represents the percentage of alccofine replaced in the concrete. For example, the four varying dosages of alccofine (12%, 14%, 16% & 18%) are given as A1, A2, A3 and A4, respectively. Likewise, Px represents the polypropylene fiber content in the concrete. For instance, four different volume fractions of 0.1%, 0.2%, 0.3% & 0.4% are denoted as P1, P2, P3 and P4, respectively.

In this study, M1A0 and M2A3 are considered as control concrete mixes for M30 and M60 grades, respectively.

3. Materials

3.1. Cement

The Ordinary Portland Cement 53 grade (Chettinad Cement), confirming to IS12269:2013, was used in this study. The physical properties are listed in Table 1.

Table 1. Physical properties of Cement

Characteristics	Values
Specific gravity	3.15
Initial setting time	30 min
Final setting time	600 min

3.2. Alccofine

The Alccofine 1203 used in this study was procured from Eaden Earth, Thiruvallur. The physical and chemical properties of alccofine are provided in Table 2 and 3, respectively.

Table 2. Physical properties of Alccofine

Characteristics	Values
Size	6μ
Specific gravity	2.7
Bulk density	700 kg/m^3

Table 3. Chemical properties of Alccofine

Chemical component	Composition %
CaO	30-34%
Sio_2	30-36%
Al_2O_3	18-25%
Fe_2O_3	1.8-3%
MgO	6-10%
SO_3	0.1-0.4%

3.3. Aggregate

Fine aggregate

Manufactured sand (M-sand) in accordance with IS 383:2016 is used as a fine aggregate in this study. The physical properties are shown in Table 4.

Table 4. Physical properties of Fine aggregate

Characteristics	Values
Specific gravity	2.6
Grading zone	II
Water absorption	1%
Fineness modulus	4.31

Coarse aggregate

Crushed angular coarse aggregate of size 20mm was used in this study. The physical properties are shown in Table 5.

Table 5. Physical properties of Coarse aggregate

Characteristics	Values
Specific gravity	2.8
Water absorption	0.5%
Fineness modulus	7.35

3.4. Superplasticizer

Polycarboxylic ether (PCE) based superplasticizer, which confirms to IS 9103:1999, is used in this study. The specific gravity of the PCE superplasticizer used is 1.10.

3.5. Polypropylene fiber

The polypropylene fiber of sizing 12mm was used in this investigation. The properties of polypropylene fiber are detailed in Table 6.

Table 6. Properties of Polypropylene fiber

Characteristics	Values
Appearance	White fibers
Specific gravity	0.91
Melting point	165ºC
Length	12mm

3.6. Mix Proportions

In this study, the mix proportions for M30 and M60 grades of concrete were proposed in accordance with IS 10262:2019, as listed in Table 7.

Table 7. Mix Proportion

Mix ID	Cement (kg/m³)	Fine agg (kg/m³)	Coarse agg (kg/m³)	Water (kg/m³)	SP (%)	PPF (%)	w/b ratio (kg/m³)
M1AxPx	378.70	678.71	1266.12	162.84	---	0.1-0.4	0.43
M2AxPx	447.02	634.41	1326.24	134.1	0.5	0.1-0.4	0.3

3.7. Sample preparation, casting and curing

A total of 14 mixes of concrete were prepared, and an average of three sample specimens were casted for each test. For the compressive strength test, a cube size of 150mm * 150mm * 150mm was used. For the elastic modulus test, a cylinder of size 150mm * 300mm was used. For the flexural strength test, a prism size of 100mm * 100mm * 500mm was used. The binder materials (cement and alccofine) are mixed to ensure they are well combined, and the PCE superplasticizer is added to water before the concrete preparation. The raw concrete materials are manually mixed by adding one material at a time, resulting in well-mixed concrete. All the specimen moulds are filled with three layers of compaction on concrete using a tamping rod. The cast specimens were kept undisturbed and demoulded after 24 hours.

4. EXPERIMENTAL INVESTIGATION

4.1. Testing

Figure 1. Test setup for: (a) Compression Strength Test and (b) Flexural Strength Test, and (c) Elastic modulus

The compressive strength test is performed in the compression testing machine, as shown in Figure 1(a). The flexural strength test was performed using a CBR testing machine. Figure 1(b) shows the test setup for flexure. The elastic modulus test was performed using a compression testing machine, along with a compressometer attached to the cylinder to evaluate the strain and deformation of the specimen. Figure 1(c) shows the test setup for the Elastic modulus.

4.2. Results & Discussion

4.2.1. Compressive Strength

The compressive strength results of all mixes are graphically presented in Figure 2 and presented in Table 8. The compressive strength of M1A0 obtained was 39.56N/mm^2, which is a conventional mix. The compressive strength values of 40.57, 41.07, 41.81 and 39.8N/mm^2 were achieved for M1A1, M1A2, M1A3 and M1A4, respectively. Since the mix M1A3 has achieved a maximum compressive strength of 41.81N/mm^2 compared to the control concrete, it is selected as the optimum percentage of alccofine. The mix with polypropylene fiber, i.e. M1A3P1, M1A3P2, M1A3P3 and M1A3P4, has gained 42.31, 42.84, 43.83 and 38.76N/mm^2. The higher compressive strength of the mix with polypropylene was achieved in M1A3P3. The control mix for the M2 group is M2A3, which has achieved compressive strength of 64.04N/mm^2. The polypropylene incorporated mix has attained strength values of 64.72, 65.18, 67.9 and 63.56N/mm^2, for mixes M2A3P1, M2A3P2, M2A3P3 and M2A3P4, respectively. M2A3P3 has gained higher compressive strength in the group 2 mixes.

Table 8. Mechanical strength properties

Mix ID	Compressive strength (N/mm^2)	Elastic modulus x10^4(N/mm^2)	Flexural strength (N/mm^2)
M1A0	39.56	3.25	6.73
M1A1	40.57	3.31	6.84
M1A2	41.07	3.35	7.13
M1A3	41.81	3.58	7.71
M1A4	39.8	3.22	6.58
M1A3P1	42.31	3.59	7.76
M1A3P2	42.84	3.63	7.81
M1A3P3	43.83	3.68	7.86
M1A3P4	38.76	3.13	6.45
M2A3	64.04	4.11	8.17
M2A3P1	64.72	4.19	8.21
M2A3P2	65.18	4.25	8.29
M2A3P3	67.9	4.52	8.37
M2A3P4	63.56	4.01	7.65

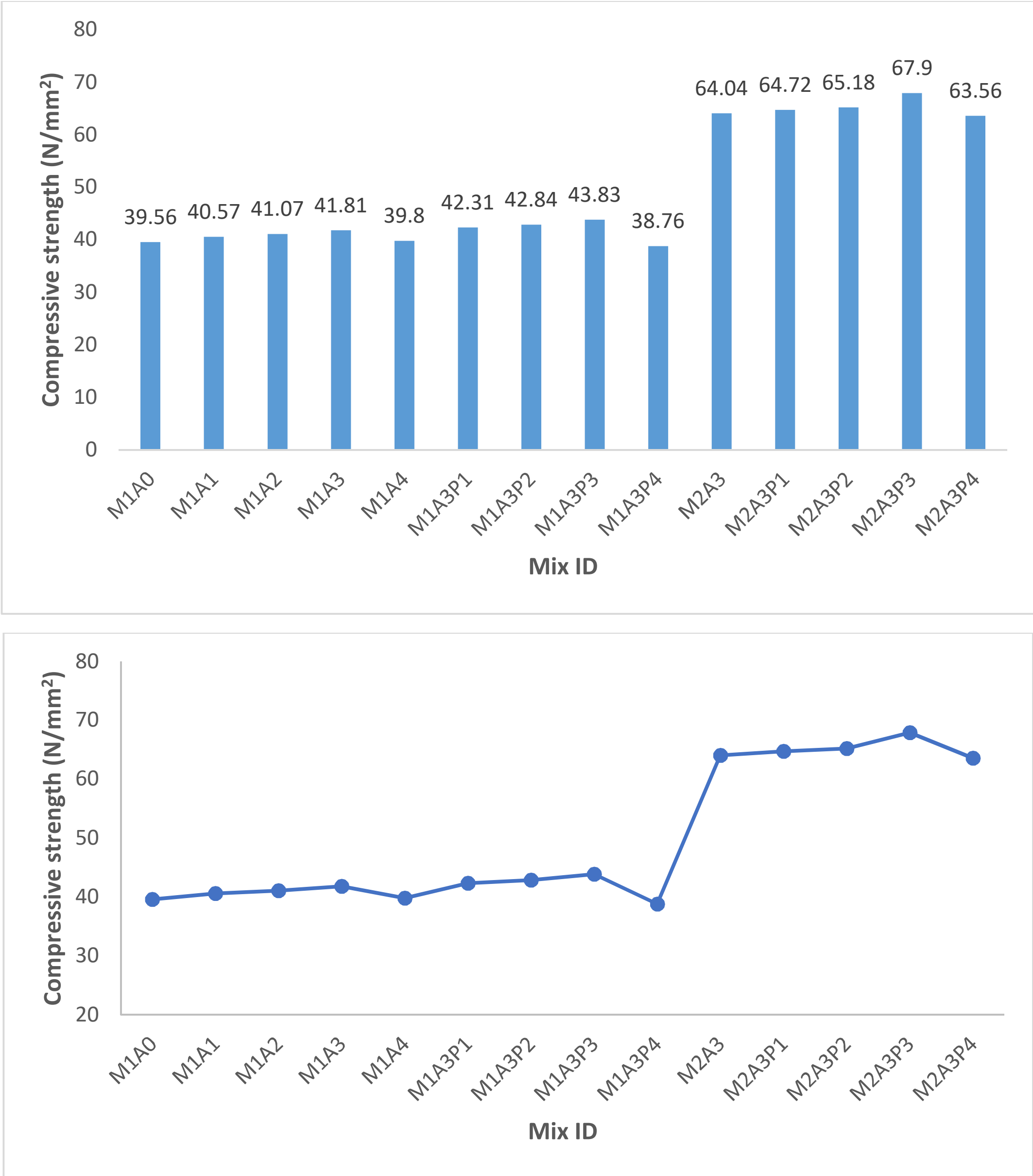


Figure 2. Compressive strength test value

4.2.2. Elasticity Modulus

The elasticity modulus test results are presented in Figure 3. The test values of mixes M1A0, M1A1, M1A2, M1A3 and M1A4 are 3.25, 3.31, 3.35, 3.58 and 3.22x10^4N/mm², respectively. The mix 1 group with polypropylene fiber shows values of 3.59, 3.63, 3.68 and 3.13x10^4N/mm² for M1A3P1, M1A3P2, M1A3P3 and M1A3P4, respectively. For the Mix 2 group, the values obtained are 4.11, 4.19, 4.25, 4.52 and 4.01x10^4N/mm² for M2A3, M2A3P1, M2A3P2, M2A3P3 and M2A3P4, respectively.

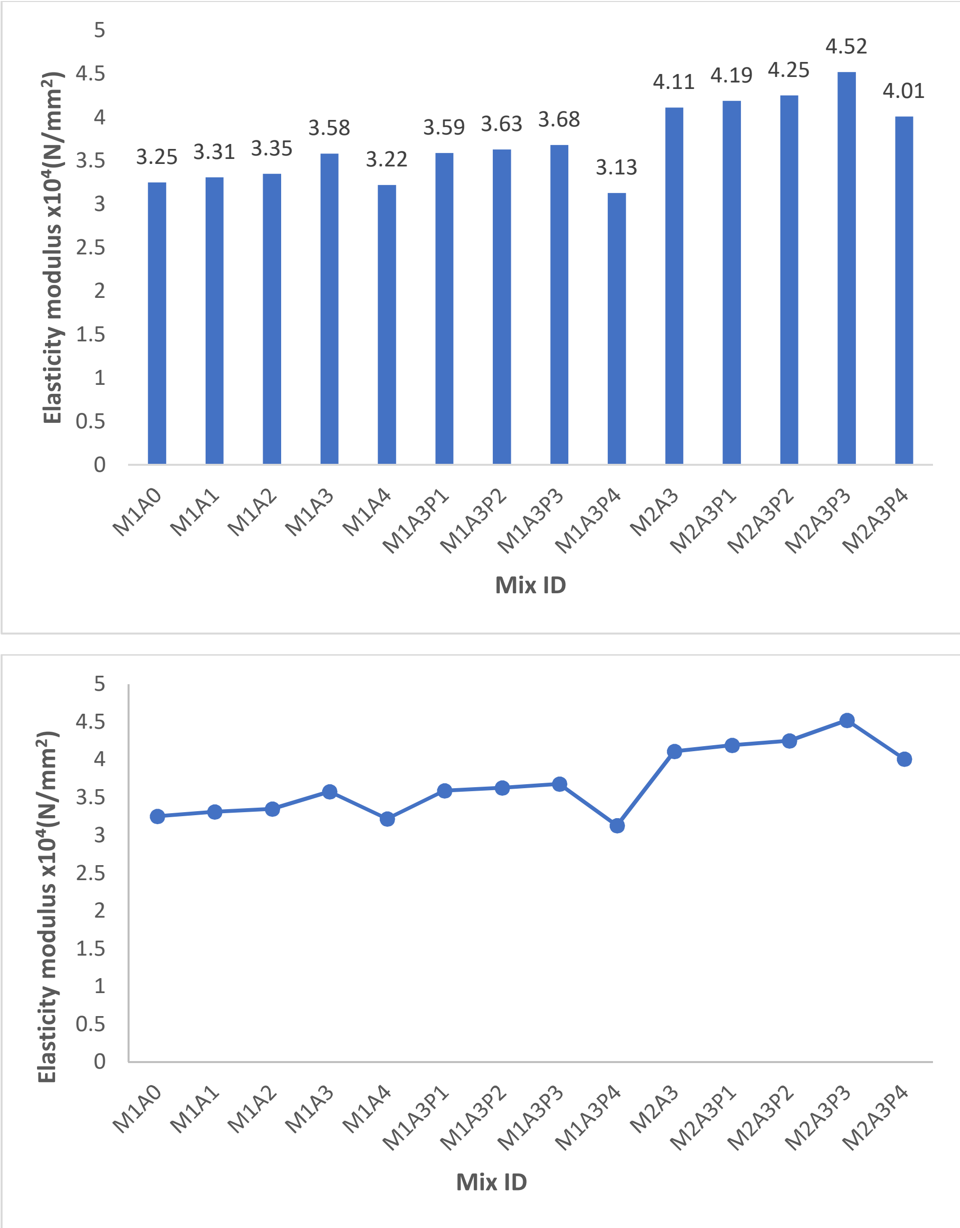
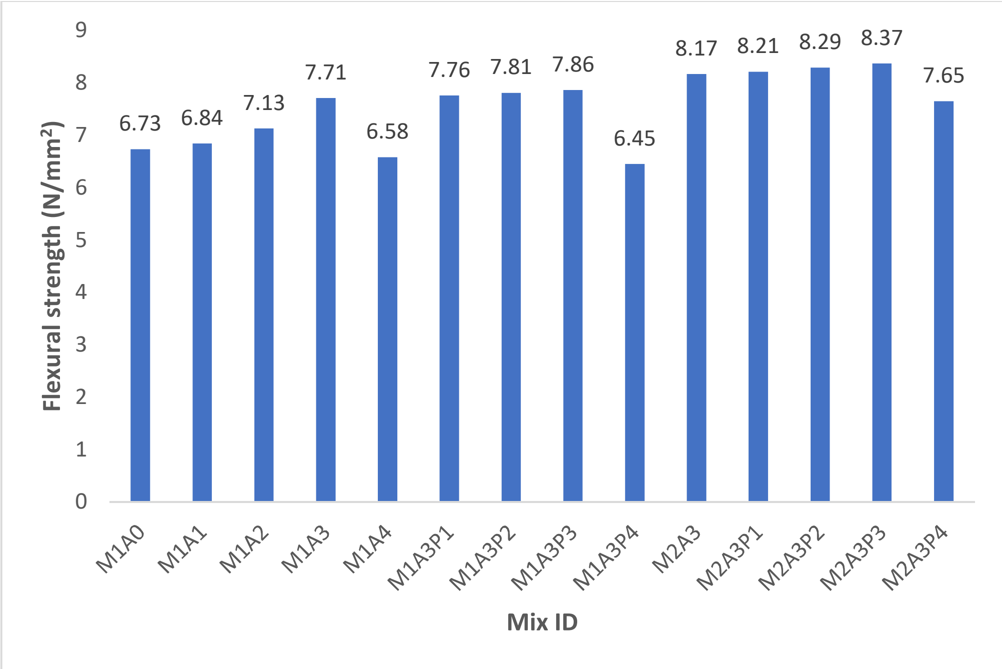


Figure 3. Elasticity Modulus test

4.2.3. Flexural Strength

The flexural strength test results are provided in a graphical representation in Figure 4. The test values of mixes M1A0, M1A1, M1A2, M1A3 and M1A4 are 6.73, 6.84, 7.13, 7.71 and 6.58N/mm², respectively. The mix containing polypropylene fibers in the Mix 1 group shows values of 7.76, 7.81, 7.86 and 6.45N/mm² for M1A3P1, M1A3P2, M1A3P3 and M1A3P4, respectively. For the Mix 2 group, the flexural strength values achieved are 8.17, 8.21, 8.29, 8.37 and 7.65N/mm² for M2A3, M2A3P1, M2A3P2, M2A3P3 and M2A3P4, respectively. The maximum flexural strength for the Mix1 and Mix2 groups was recorded in M1A3P3 and M2A3P3, respectively.



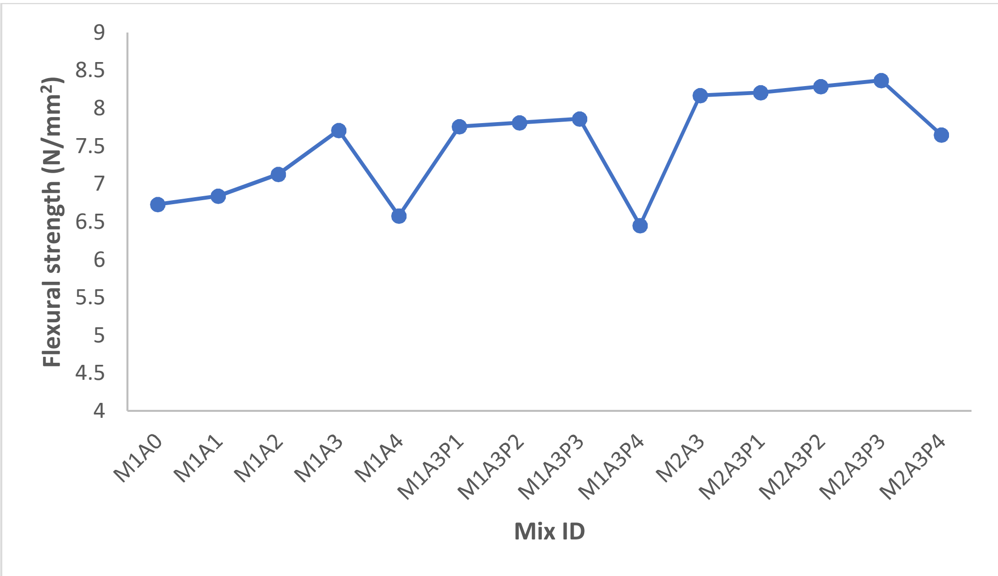


Figure 4. Flexural strength test results

5. CONCLUSIONS

Based on the experimental investigation, the mechanical properties of concrete incorporating alccofine as supplementary cementitious material and polypropylene fiber are examined. The following conclusions are drawn based on the results.

1. The incorporation of alccofine and polypropylene fiber has enhanced the mechanical properties.
2. The compressive strength of alccofine was optimized at 16%, beyond that, i.e. at 18% replacement, the mechanical properties decreased.

3. Maximum compressive strength of 43.83 and 67.8N/mm² was observed at M1A3P3 and M2A3P3.
4. Addition of polypropylene fiber has increased the strength, and there is a strength reduction beyond 0.3% polypropylene fiber.
5. M1A3P3 and M2A3P3 show better mechanical performance compared to all other mixes.

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