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RESEARCH ARTICLE

Microstructural and Durability Properties of Concrete Containing Alccofine and Zeolite Reinforced with Polypropylene Fibres

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Abstract

Objectives: To study the microstructural and durability properties of a polypropylene fibre reinforced concrete (PPFRC). **Methods:** In this research 10% and 15% of cement was replaced by natural zeolite and Alccofine and four different volume fractions of polypropylene fibre (0, 0.1, 0.2, 0.3 and 0.4 percent) were utilized to improve the strength and durability properties of concrete. Scanning Electron Microscope (SEM) was used to observe the crystal structure and that interfactial transition zone (ITZ). **Findings:** SEM Results indicates that fibres changes the microstructure, reduces $Ca(OH_2)$ through the secondary C-S-H gel formation and hence the voids get reduced Six concrete mixtures with water to binder ratio of 0.50 were cast. **Novelty**: Addition of polypropylene fibre has greatly improved the durability properties of concrete containing alccofine and zeolite.

Keywords: Alccofine; Compressive Strength; Durability; Elasticity Modulus; Zeolite; polypropylene fibre

1 Introduction

Concrete has been transported and used in construction projects all over the world on a regular schedule in excess of a billion tonnes. During the production of cement clinker, over a tonne of CO_2 was produced for every tonne of cement. Cement use must be reduced via the use of alternative materials in order to lower CO_2 emissions. With the aim of enhancing strength while minimising emissions and costs, by-products are used in place of cement in the construction industry. The mechanical and durability characteristics of concrete are the primary focus of this research.

Due to its harmful greenhouse gas emissions, the manufacture of cement clinker is both extremely expensive and environmentally harmful. This inspires us to investigate alternative cements for making concrete that are more environmentally friendly. Because they promote aggregate interlocking and improve workability, strength, and toughness, several industrial by-products, such as Alcofine, fly ash, silica fume, zeolite, GGBS, rice husk ash, and metakaolin, are consumed as binders instead of cement.

Furthermore, it reduces maintenance expenses and permeability. Fibres that are embedded in concrete provide an important benefit by preventing cracks from propagating. As a result, the ability of fibres to transfer stress keeps internal stress-induced microcracks in concrete from propagating.

In this investigation, cement was partially replaced with 15% alccofine and 10% zeolite to enhance the mechanical and durability properties of concrete. And also, polypropylene fibre was added in different volume fractions, such as 0.1%, 0.2%, 0.3%, and 0.4% (volume of concrete). Alccofine is a slag-based microfine mineral admixture. It is a highly processed material obtained from controlled granulation with a specific surface area of 12000 cm^2/g. Replacement of cement with alccofine improved mechanical properties such as compressive strength, flexural strength, modulus of elasticity, and durability properties by reducing the voids.

Zeolite is a mineral made up of aluminosilicate. Zeolite is a volcanic material containing hydrated aluminosilicates of alkali and alkalinity with a 3D frame structure. The replacement of cement with zeolite increased the strength and durability of concrete. It is highly resistant to corrosion. The introduction of fillers in concrete is attributed to increasing its strength. Because of their extreme fineness and high amorphous silicon dioxide content, alccofine and zeolite are highly reactive pozzolanic materials. The thickness of the transition phase in mortars and the degree of orientation of the CH crystals in them are influenced by the presence of fillers. By strengthening the cement paste-aggregate bond and generating a less porous and more homogenous microstructure in the interfacial zone, microfillers eliminate the weak links. As a result of the increased interfacial or bond strength, the mechanical characteristics and durability are enhanced.

Polypropylene fibres have a very high tensile strength of about 561.02 to 867.02 N/mm^2. It is a light fibre, and its density (0.91 g/cm3) is the lowest of all synthetic fibres. The thermal conductivity of PP fibre is lower than that of other fibres. Polypropylene is one of the cheapest and most abundantly available polymers. Fibre-reinforced concrete can be produced using conventional concrete practices, though there are obviously some important differences. The basic idea is to introduce a sufficient volume of uniformly dispersed fibres to achieve the desired improvements in mechanical behaviour while retaining sufficient workability in the fresh mix to permit proper mixing, placing, and finishing. The performance of the hardened concrete is enhanced more by fibres with a higher aspect ratio, since this improves the fibre-matrix bond.

1.1 Literature Review

In Ref. [(1)], Hua Zhanget al. (2019) studied the compressive impact dynamic behaviour and constitutive model of polypropylene fibre. The authors reported that a maximum compressive strength of 18.6% and a maximum flexural strength of 23.1% were attained through 0.3% PP fibre with 10% rice husk and nanoalumina.

In Ref. [(2)], Eisaet al. (2020) examined the improvement of the flexural toughness behaviour of RC beams using micro/nano silica and steel fibres. The authors observed that significant improvements have been made in the physical properties and the static behaviour of RC beams by replacing cement with 10% MS and 1% NS in the presence of a 2% volume fraction of steel fibres.

In Ref. [(3)], Sakthivelet al. (2020) conducted research on experimental assessment over theoretical prediction and analytical studies on the flexure behaviour of RC beams with recycled coarse aggregate. The authors suggested that RC beams reinforced with crimped and hooked steel fibres exhibited higher flexural toughness, improved ductility, and reduced crack width and spacing when compared to non-fibrous beams.

In Ref. [(4)], BodeVenkata Kavyateja et al. 2020 studied the effectiveness of alccofine and fly ash on the mechanical properties of ternary blended self-compacting concrete. The authors suggested the combination of fly ash and Alccofine as a replacement for cement, which leads to eco-friendly and sustainable concrete.

In Ref. [(5)], Raghul Raj Kundanati et al. 2020 conducted an experimental study on the mechanical properties of alccofine based high-grade concrete. The authors observed that replacing cement with Alccofine showed improvements in flexural and compressive strength along with increased workability and fluidity.

In Ref. [(6)], Farnoosh Jokar et al. 2019 studied the experimental investigation of the mechanical properties of crumbed rubber concrete containing natural zeolite. The authors reported that adding both crumb rubber and zeolite to concrete decreased the density of the concrete.

In Ref. [(7)], Y. Li, C. Qiao, et al. examined green concrete with ground granulated blast furnace slag activated by desulfurization gypsum and electric arc furnace reducing slag. The authors reported that TGA and XRD results have shown negligible amounts of Ca (OH) 2 and Mg (OH) 2, which are useful for the strength of green concrete. Etringite, amorphous CSH, and hydrotalcite are produced during the hydration of the ternary products. It has been observed from the XRD and SEM results that this is more helpful to achieving good strength in green concrete. Green concrete (GGBS-DG-EAFRS) has been studied for the recycling of industrial solid waste, reducing the cost of materials, and enhancing the sustainability of concrete.

In Ref.[8], K. Ashwini et al. (2021) studied the effect of addition on the compressive strength of cement mortar cubes. The authors observed that early-age strengths were obtained for all the combinations, but 10% alccofine yielded more strength than other dosages.

In Ref.[9], B. Sankar et al. (2022) studied the experimental and statistical investigation of alccofine-based ternary blended high-performance concrete. The authors reported that higher replacement levels of alcoofine (more than 10%) led to a decrease in strength due to the dilution effect. Denser particle packing reduces water absorption in ternary mixes.

In Ref.[10], Dheyaaldin MH et al. (2021) studied the performance of fibre-reinforced alkali-activated mortar with or without nanosilica and nanoalumina. The authors observed that between the polypropylene fibre, aggregates, and cementitious materials, both the porosity and the pore size decreased with increasing fibre content.

In Ref.[11], Abdulkareem M et al. (2022) reviewed the durability of propylene fibre-reinforced concrete. The authors reported that the incorporation of polypropylene fibres at various rates into the concrete can limit the development of cracks by forming a bond bridge, modifying the pore network, and thus enhancing durability. However, some researchers reported that this enhancement can be fulfilled with a certain rate of added fibres, which, if exceeded, will have opposite effects.

In Ref.[12], Prithviraj et al. (2022) examined the assessment of the strength and durability properties of self-compacting concrete comprising alccofine. The authors reported that an increase in the replacement percentage of alccofine in the SCC mix considerably reduced water absorption capacity, voids, and sorptivity due to the presence of rich fineness, which leads to fewer pores and higher density in the concrete. The authors also observed that mechanical properties gradually increased for the mixes C5-A10 to C5-A30 and decreased further. The increase in strength is due to the increased total specific surface area, denser particle packing, and high pozzolanic reactivity that resulted in an enhanced hydration process. The occurrence of a higher amount of calcium, silica, and alumina in alccofine is one reason for the enhancement of compressive strength.

1.2 Research Gap

The current study is focused on reducing the amount of cement used in concrete production. The use of by-products also prevents waste disposal and storage, which have significant environmental consequences and also ensure sustainability. As a whole, the current study aims to produce sustainable concrete using industrial waste (alccofine and zeolite). There hasn't been much study done on the use of polypropylene fibres in ternary-blend concrete. In light of this, the current study aims to test the mechanical and durability properties of ternary blended concrete by adding polypropylene fibres. The objective of the present investigation is to know the microstructural and durability properties of concrete when the cement is partially replaced by alccofine and zeolite (15% and 10%, respectively). And also, polypropylene fibres were added to the concrete in different volume fractions (0.1%, 0.2%, 0.3%, and 0.4%). The results have been compared with conventional concrete.

2 Methodology

The properties of the cement used are provided in Table 1. A combination of river sand (55%) and M. sand (45%) with a specific gravity of 2.67 and conforming (IS 383:1970) to grading zone III was used as fine aggregate. The properties of the fine aggregate used are provided in Table 2. The grain size distribution curve graph is shown in Figure 1. Crushed granite with a maximum particle size of 20mm was used as coarse aggregate. The properties of the coarse aggregate used are provided in Table 3. Potable water was used for preparing the concrete and curing the specimens. Polypropylene fibre (Recron 3s fibres) was used in this study, conforming to ASTM C1116. The properties of polypropylene fibre are presented in Table 4. A cement content of 262.5 kg/m^3, 52.5 kg/m^3 of alccofine, 35 kg/m^3 of zeolite, and 378 kg/m^3 of fine aggregate (river sand), 309 kg/m^3 of fine aggregate (manufactured sand), 747 kg/m3 of 20mm coarse aggregate, and 498 kg/m^3 of 12mm coarse aggregate, with a 0.5 water/binder ratio, was used in this study and according to IS 10262:2019. The properties of alccofine are presented in Table 5. The properties of zeolite are presented in Table 6. Conplast SP430, a sulphonated naphthalene formaldehyde-based superplasticizer, was used, and it conforms to ASTMC494. The properties of SP 430 used are provided in Table 7.

Table 1. Properties of Cement

Property	Test value
Cement Consistency	33%
Specific Gravity	3.14
Initial Setting Time	55 minutes
Final Setting Time	380 minutes

Table 2. Properties of Fine Aggregate

Property	Test value
Specific gravity	2.67
Grading zone	III

Table 3. Properties of Coarse Aggregate

Property	Test Value
Specific gravity	2.72
Water Absorption (%)	0.72
Shape	Angular

Table 4. Properties of Fibres

Property	Value
Specific gravity	0.91
Aspect Ratio(L/D)	300
Tensile strength (MPa)	480
Young's Modulus(GPa)	5

Table 5. Properties of Alccofine

Property	Value
Specific surface area (m^2/g)	12
Specific gravity	2.94

Table 6. Properties of Zeolite

Property	Value
Specific gravity	2.66
Specific surface area (m^2/g)	19.2

Table 7. Properties of Superplasticizer

Property	Value
Appearance	Brown Liquid
Specific Gravity	1.18

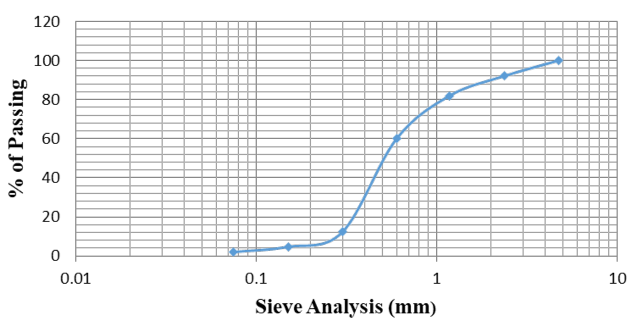


Fig 1. Grain Size Distribution Curve

2.1 Test Specimens and Methods

Cube specimens of size 150 mm x 150 mm x 150 mm were cast and tested as per ASTM C642-97. The test set-up for water absorption is shown in Figure 5. Cube specimens of size 150 mm x 150 mm x 150 mm were cast and tested as per ASTM C642-97. Cylinder specimens of size 100 mm X 50 mm were cast and tested as per ASTM C1585-04. The test setup for sorptivity is shown in Figure 6. Cube specimens of size 150 mm x 150 mm x 150 mm were cast and tested as per ASTM C1012. Details of control specimens are presented in Table 8. Nomenclature of all specimens are presented in Table 9.

Table 8. Details of Control Specimens

Experiment	Specimen	Size (mm)
Water Absorption Test (ASTM C642-97)	Cube	150x150x150
Porosity Test (ASTM C642-97)	Cube	150x150x150
Sorptivity Test (ASTM C1585-04)	Cylinder	100x50
Acid Resistance Test (ASTM C1012)	Cube	150x150x150

Table 9. Nomenclature of Specimens

Test specimen	Description
CC	Control specimen
AZ0	15% Alccofine + 10% Zeolite
AZ1	15% Alccofine + 10% Zeolite + 0.1% PP fibres
AZ2	15% Alccofine + 10% Zeolite + 0.2% PP fibres
AZ3	15% Alccofine + 10% Zeolite + 0.3% PP fibres
AZ4	15% Alccofine + 10% Zeolite + 0.4% PP fibres

2.2 Water Absorption and Porosity

A total of 18 cubes of size 150mmx150mmx150mm (CC, AZ0, AZ1, AZ2, AZ3, and AZ4) were tested for water absorption as per ASTM C642-97. Each value represents the average results of three specimens in the same group. The specimen was immersed, cooled, and dried, and the mass was determined. Two consecutive values of the mass of the surface-dried specimen at intervals of 24 h show a rise in mass of less than 0.5% of the larger value. The water absorption was determined by using the formula.

$$water\ absorption\ (\%) = \left(2 - \frac{1}{1}\right) * 100$$

1 = Mass of dried specimen, 2 = Mass of specimen after 48 hrs. The porosity test was carried out as per ASTM C642-97. The specimens were placed in a receptacle, immersed in water, and boiled for 5 hours. The specimen mass was determined after removing the moisture. The soaked, boiled, and surface-dried mass was found (3), as was the apparent mass of the sample after boiling (4). The porosity was determined by using the formula

$Volume\ of\ permeable\ voids\,(\%) = (\frac{3-1}{3-4}) * 100$

2.3 Sorptivity

A total of 18 specimens of 100 mm diameter and 50 mm diameter were tested for capillary rise of water as per ASTM C1585-04. Each value represents the average result of three specimens in the same group. The test set-up is shown in Figure 2. Measure the initial mass of the specimen. Place the specimen at the bottom of the pan, and fill the pan with water up to 3mm. Start the timing device and record the measurements every hour. The readings were taken up to 6 hours. The sorptivity is determined by using the formula Where, I= the absorption(mm), m= mass changes at time (t), a= area of the specimens (mm^2), d= Density of water (g/mm^3) $I = m/(\frac{a}{d})$

2.4 Acid Resistance

A total of 18 cubes of size 150×150×150mm were tested for acid resistance as per ASTM C1012. Each value represents the average result of three specimens in the same group. The initial mass of all the specimens was measured. The specimens were

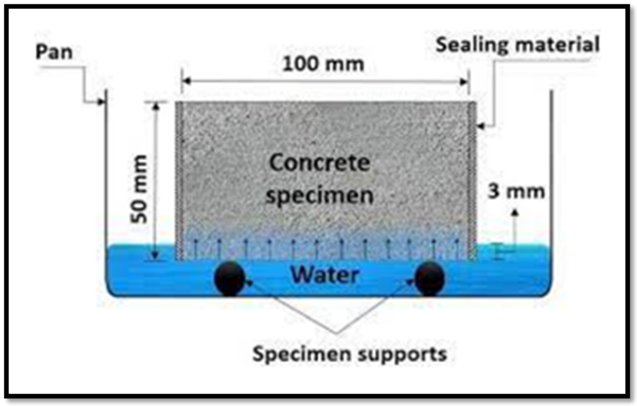


Fig 2. Test Set up for Sorptivity

kept immersed in a 5% H_2SO_4 solution. After 28 days, the specimens were taken out, surface dried, and their masses determined. All the specimens were tested in compression to assess the loss in strength.

3 Microstructural Study

Sample Preparation for Microscopic Study

An SEM test was carried out to observe the microstructures of the samples. The SEM specimen pieces were cut off at 10 mm X 10 mm X 5 mm from the different samples.

3.1 SEM Analysis and Results

The characteristic micromorphology images of non-fibre concrete and PPFRC specimens observed using SEM are shown in Figures 3, 4 and 5. The SEM images of all the specimens were obtained at 50 kx magnification. From the SEM images, CH is found as a major compound formed from the hydrolysis process of calcium and silicates with a crystalline structure. Specimen M0% shows that voids are filled by microfillers, and it created a structure denser than the specimen CC, as shown in Figure 6. Based on SEM analysis, it seems that fibre forms a network to resist the growth of CH crystalline, reduce the voids, and make the interfacial transition zone of PPFRC much denser than that of control concrete, as shown in Figure 7 -M0.4%. The SEM analysis clearly indicates that fibre performs the networking effect to hold concrete particles together, which also provides resistance to spalling.

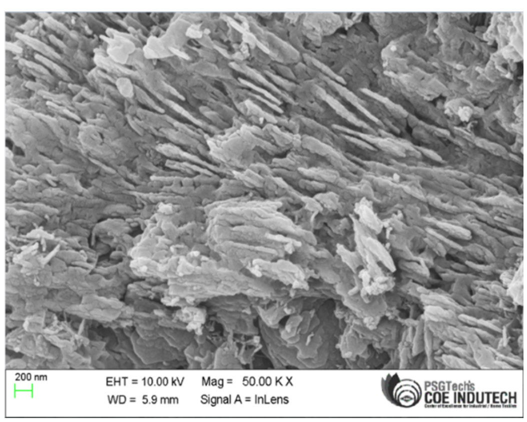


Fig 3. SEM Images-CC

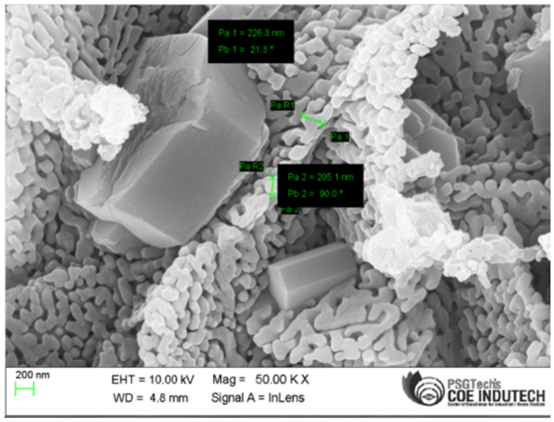


Fig 4. SEM Images-M0.4%

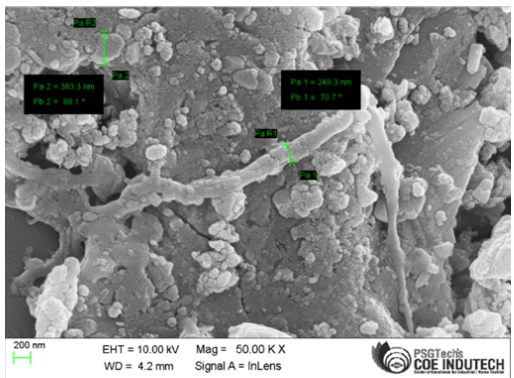


Fig 5. SEM Images-M0.4%

3.2 EDX Analysis

The energy of X-rays emitted from a specimen was measured by an energy dispersive X-ray spectrometer. The EDX analysis for each sample is shown in Figures 6, 7 and 8. The sample images were obtained at 115x magnification. The quantification of the atomic percentage of elements present in each binder is presented in Tables 10–12. To quantify C-S-H gel formation in each mix binder, the atomic Ca/Si ratio was calculated using the atomic percentages of Ca and Si obtained from the EDS analysis. Based on the results of the Ca/Si ratio, the control mix had a Ca/Si ratio of 0.76, whereas specimens M0% and M0.4% have ratios of 0.51 and 0.24 with respect to 0% and 0.4% PPF, 15% alccofine, and 10% zeolite replacement levels, respectively. Compared to all mixes, M0.4%, which has a low atomic Ca/Si ratio of 0.24, exhibits higher compressive strength, whereas the control mix has a high Ca/Si ratio of 0.81 and shows lower compressive strength. Based on the results, it can be concluded that a lower Ca/Si ratio leads to better C-S-H gel formation, thereby increasing the compressive strength. Similarly, a higher Ca/Si ratio leads to lower C-S-H gel formation and hence lower compressive strength.

Table 10. Atomic Percentage of Specimen-CC

Element	Series	Unn.C (Wt.%)	Norm.C (Wt.%)	Atom.C (at.%)	Error	(3 Sigma) (Wt.%)
Oxygen	K-Series	11.28	40.52	59.21		4.81
Sodium	K-Series	0.49	1.78	1.81		0.19
Magnesium	K-Series	0.07	0.26	0.25		0.1
Aluminium	K-Series	1.03	3.69	3.2		0.23
Silicon	K-Series	6.07	21.82	18.17		0.86
Potassium	K-Series	0.09	0.33	0.19		0.09
Calcium	K-Series	6.65	23.91	13.95		0.67

Continued on next page

Table 10 continued

Iron	K-Series	2.17	7.69	3.22		0.28
	Total:	**27.83**	**100**	**100**		

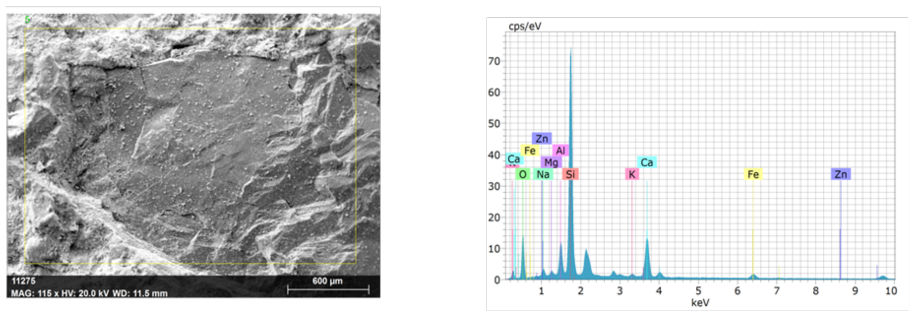


Fig 6. EDX Analysis of samples A.CC (without fillers and fibres)

Table 11. Atomic Percentage of Specimen-M0%

Element	**Series**	**Unn.C (Wt.%)**	**Norm.C (Wt.%)**	**Atom.C (at.%)**	**Error**	**(3 Sigma) (Wt.%)**
Oxygen	K-Series	12.06	37.49	53.86		5.16
Sodium	K-Series	0.46	1.43	1.43		0.18
Magnesium	K-Series	0.05	0.16	0.15		0.09
Aluminium	K-Series	1.7	5.28	4.5		0.33
Silicon	K-Series	11.62	36.12	26.56		1.57
Potassium	K-Series	0.07	0.22	0.13		0.09
Calcium	K-Series	4.86	15.11	8.66		0.52
Iron	K-Series	1.26	3.91	1.61		0.21
Zinc	K-Series	0.09	0.27	0.09		0.11
	Total:	**32.16**	**100**	**100**		

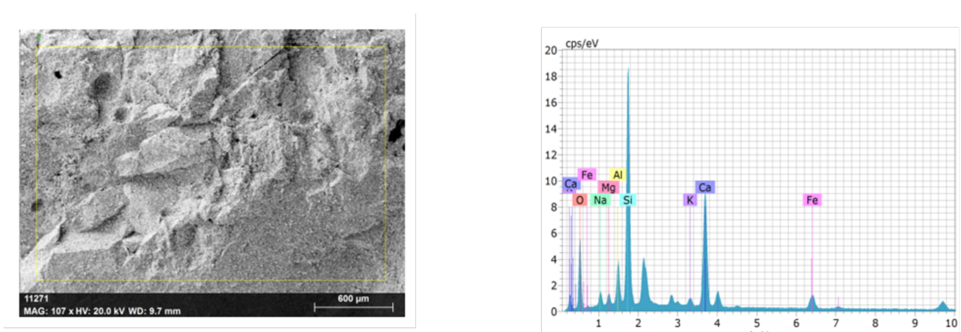


Fig 7. EDX Analysis of samples B.M0% (Al15%+Z10%+0%PP)

3.3 XRD Analysis

The XRD analysis was performed using an X-ray diffractometer. It is a tool for material characterization and identification of the phase composition of elements and the crystal structure of particles present in a material. Portlandite, calcite, and quartz are

Table 12. Atomic Percentage of Specimen-M0.4%

Element	Series	Unn.C (Wt.%)	Norm.C (Wt.%)	Atom.C (at.%)	Error	(3 Sigma) (Wt.%)
Oxygen	K-Series	6.43	32.59	48.26		2.88
Silicon	K-Series	6.31	31.99	26.98		0.89
Aluminium	K-Series	2.47	12.53	11		0.44
Calcium	K-Series	2.2	11.13	6.58		0.28
Iron	K-Series	1.36	6.87	2.91		0.21
Sodium	K-Series	0.67	3.38	3.48		0.22
Potassium	K-Series	0.07	0.37	0.22		0.09
Titanium	K-Series	0.23	1.16	0.57		0.11
	Total:	**19.74**	**100**	**100**		

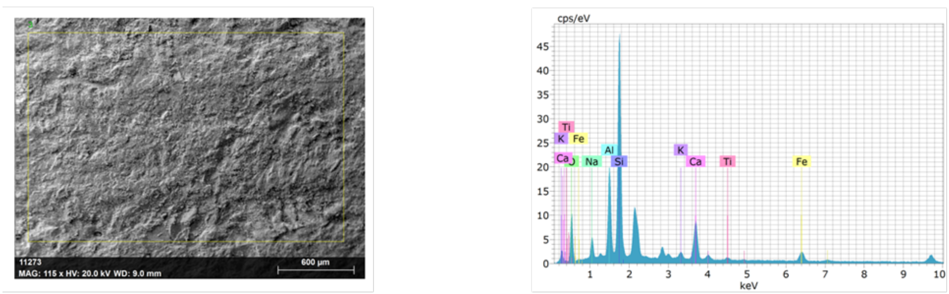


Fig 8. EDX Analysis of samples C.M0.4% (Al15%+Z10%+0.4%PP)

the major minerals identified in mixes. Test results show that both $Ca(CO)_3$ and $Ca(OH)_2$ have not changed significantly after adding fibres and also show that fibres could not participate in any chemical reactions. The formation of CSH was greater in ternary blended concrete (alccofine + zeolite) due to $Ca(OH)_2$ being converted to secondary CSH and therefore enhancing the strength of the concrete. From XRD, it was observed that this improved the formation of calcium silicate hydrate and calcium silicate aluminium hydrate in concrete. The identified minerals with their quantifications are presented in Figures 9, 10 and 11.

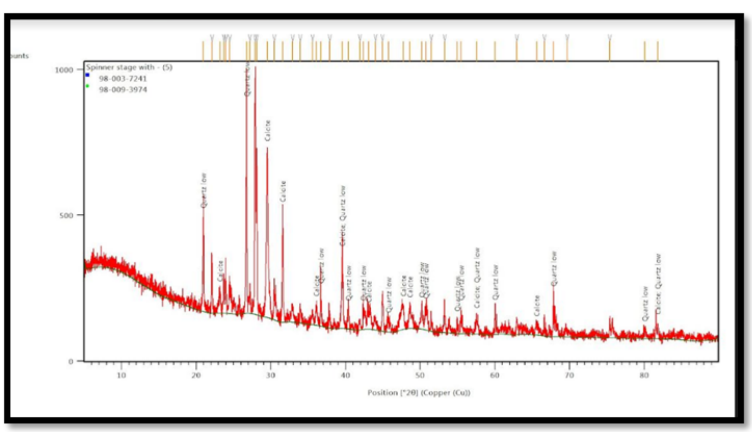


Fig 9. XRD Image-CC

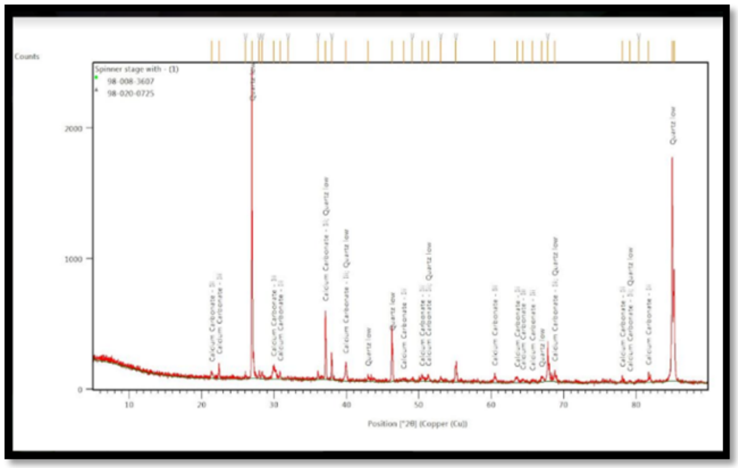


Fig 10. XRD Images-M0%

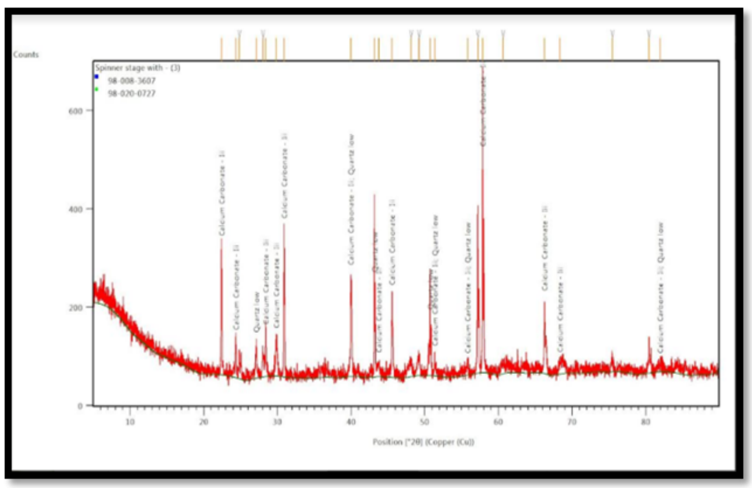


Fig 11. XRD Images-M0.4%

4 Results and Discussion

4.1 Water Absorption

The effect of fibres on water absorption is shown in Fig. 12. Specimen CC, AZ0, AZ1, AZ2, AZ3, and AZ4 showed a decrease of 0.37, 0.34%, 0.29%, 0.25%, 0.18%, and 0.30% in water absorption when compared to before immersion. The test results indicated a decrease in water absorption with an increasing fibre volume fraction. Similar results were observed in other researchers' works, such as In Ref[12], (Prithvi Raj et al., 2022), an increase in the substitute percentage of alccofine in the SCC mix considerably reduced water absorption due to the presence of rich fineness, which leads to fewer pores and higher density in the concrete. In Ref[13], Gayathri K.K. et al. (2022), the addition of 0.1%, 0.2%, and 0.3% fibre volume fraction resulted in a decreasing trend in the absorption of water. This tendency may be due to uniform fibre dispersion. A slight increase in absorption was seen for the concrete with a 0.4% volume fraction of fibres. This may be due to the agglomeration of fibres. In Ref[14] (Swetha et al., 2022), the reduction in water absorption may be due to the densification of the transition zone caused by the inclusion of zeolite, nanosilica, and steel fibres in isolation or in combination. In Ref[15], Meenatchi K et al. (2022), the test results indicated a decrease in water absorption with an increasing fibre volume fraction.

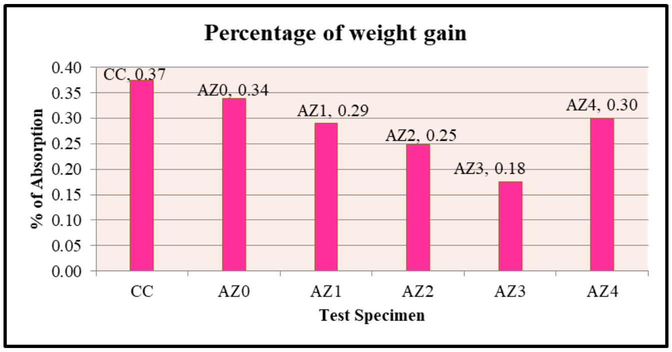


Fig 12. Effect of Fibres on Water Absorption

4.2 Porosity

The test result indicated a decrease in the volume of permeable voids with an increasing fibre volume fraction in the concrete. Specimens AZ0, AZ1, AZ2, AZ3, and AZ4 showed a decrease of 1.13%, 0.98%, 0.89%, 0.86%, 0.80%, and 1.02% when compared to specimens This may be attributed to good bonding between the PP fibres, aggregates, and cement matrix. The inclusion of polypropylene fibres in concrete enhanced the pore-blocking effect. The effect of fibres on porosity is shown in Figure 13. Similar effects were observed in previous works, such as In Ref[13], Gayathri K.K. et al. (2022), An increase in porosity was observed with a 0.4% volume fraction of PP fibres owing to the collation of fibres. In Ref[16], Jamen Raja MCK et al., 2023. The test results showed that as the fibre volume percentage increased, water absorption decreased. In Ref.[14], Swetha et al. (2022), the refinement of the pore structure caused by the fibre addition would have resulted in a decrease in porosity. The maximum reduction in 42.78% of voids has been experienced with concrete containing 1% nanosilica, 10% zeolite, and a 1.0% volume fraction of steel fibres. In Ref[17] (Meenatchi K et al., 2023), the inclusion of polypropylene fibres in concrete enhanced the pore-blocking effect.

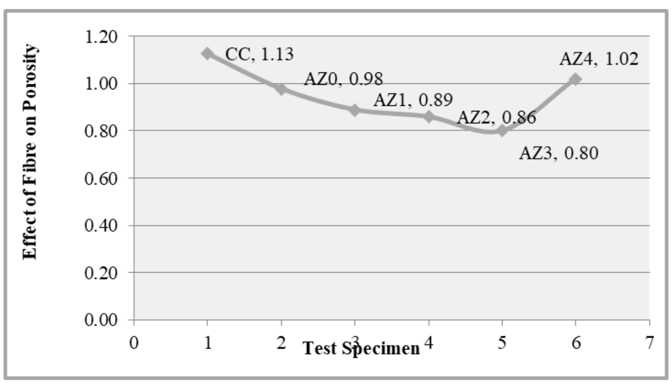


Fig 13. Effect of Polypropylene Fibres on Porosity

4.3 Sorptivity

Sorptivity is the capacity to absorb water through capillary rise in the hardened concrete. Sorptivity depends on the porosity of the concrete. The polypropylene fibre fills the pores and reduces absorption. Concrete with a 0.3% volume fraction of PP fibres and 15% alcofine and 10% zeolite shows a reduced sorptivity result compared to other concrete mixes. The sorptivity coefficient is reduced for fibre concrete when compared to control concrete. This may be attributed to the impact of fibres filling pores, which leads to a lack of inner connectivity in pores. The sorptivity graph is shown in Figure 14. In Ref[13], Gayathri K.K. et al. (2022), the bridging action of fibres would have facilitated the reduction in sorptivity. An increase in porosity was observed with a 0.4% volume fraction of PP fibres owing to the bundling of fibres. In Ref[16], Jamen Raja et al. (2023) found that when compared to control concrete, fibre concrete has a lower sorptivity coefficient. The use of PP fibres resulted in a considerable decrease in capillary pores and internal pore connectivity. In Ref[12], (Prithvi Raj et al., 2022), it can be observed that incorporation of an increased percentage of alccofine reduced the sorptivity.

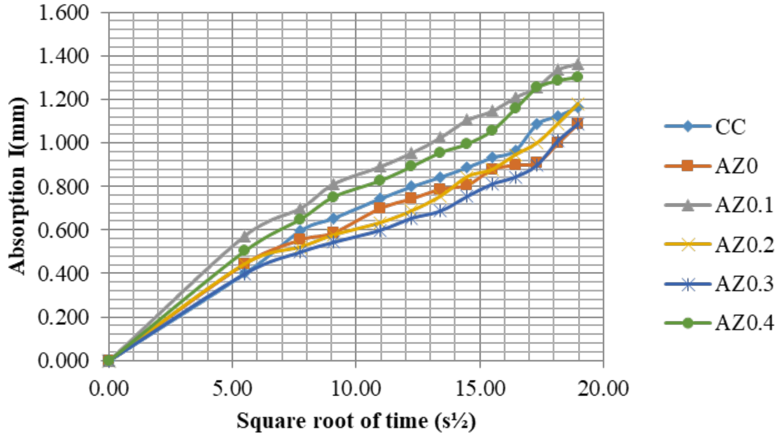
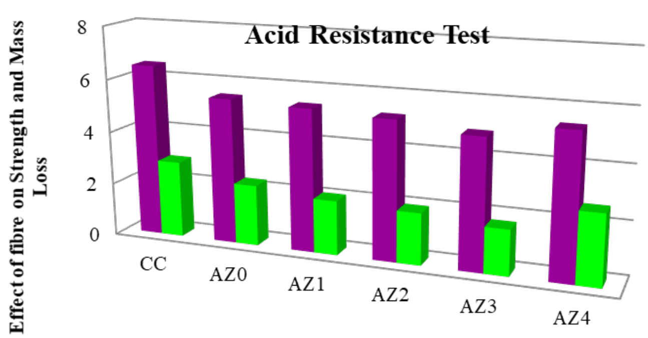


Fig 14. Sorptivity

4.4 Acid Resistance

The percentage of strength loss is shown in Figure 15. The specimens AZ1, AZ2, AZ3, and AZ4 showed an increase of 10.6%, 12.82%, 13.09%, 15.52%, 16.39%, and 14.68% when compared to the strength of normal curing. The comparison of compressive strength is shown in **Fig 19**. The test result showed an increase in the compressive strength of the specimen with an increasing percentage of the volume fraction of PP fibres in the concrete. Similar results were observed in other researchers' works, such as in Ref.[13], Gayathri K.K. et al. (2022). The addition of 0.1%, 0.2%, and 0.3% fibre volume fraction resulted in a decreasing trend of weight and strength loss. This may be because of a reduction in voids as a result of uniform fibre dispersion. A slight increase in weight and strength loss was noticed for the concrete with a 0.4% volume fraction of fibres. This may probably be due to the balling of fibres. In Ref[16], (Jamen Raja MCK et al., 2023), the weight loss in specimens made with fibre was less compared with specimens without fibre. This may be attributed to the inclusion of fibre in concrete. In Ref[17], (Meenatchi K et al., 2023), fibres provide a strong bond between the cementitious material and aggregate matrix. The specimens CC, AZ1, AZ2, AZ3, and AZ4 showed a decrease of 2.88%, 2.29%, 2.04%, 1.94%, 1.71%, and 2.64% in weight loss when compared to the CC. The test results indicated that polypropylene fibres create a stronger interfacial transition zone and reduce the spalling effect of concrete.



	CC	AZ0	AZ1	AZ2	AZ3	AZ4
Strength Loss	6.5	5.47	5.36	5.22	4.89	5.37
Mass Loss	2.88	2.29	2.04	1.94	1.71	2.64

Fig 15. Effect of Polypropylene Fibres on Acid Resistance

5 Conclusions

The focus of this study is on the influence of polypropylene fibre and drawn the following conclusion based on experimental results:

1. SEM observations indicate that the formation of additional C-S-H gel increased and voids were reduced when compared to the control mix. In EDS analysis, compared to the control concrete specimen, M0.4% shows lower Ca/Si ratios, signifying strength development.
2. From XRD analysis, a higher amount of Portlandite, Calcite, and Quartz was present in the M0.4% specimen, indicating a higher strength development when compared to control concrete.
3. Based on experimental results, specimen AZ3 showed a minimum of 0.18% water absorption when compared to control concrete. This diminution may be due to the incorporation of fibres in ternary blended concrete, which exhibits the tendency for uniform dispersion of fibres. In the porosity test, specimen AZ3 showed a 0.80% reduction in voids when compared to conventional concrete. The introduction of fillers in concrete considerably reduced water absorption due to the presence of rich fineness, which leads to fewer pores and higher density in the concrete.
4. Concrete with a 0.3% volume fraction of PP fibres and 15% alccofine with 10% zeolite shows a reduced sorptivity result compared to other concrete mixes. The sorptivity coefficient is reduced for fibre concrete when compared to control concrete.
5. AZ3 specimens show a minimum of 4.89% strength loss and 1.71% mass loss when compared to conventional concrete. Specimens made with fibre show minimum loss compared to specimens without fibre. This may be attributed to the introduction of polypropylene fibres in concrete, which provide good bonding between the cementitious material. Based on experimental results fillers (alccofine, zeolite) and polypropylene fibres are highly resistant to acid attack.
6. Industrial waste materials can be used to make concrete in an environmentally friendly and sustainable manner. The durability properties were also enhanced when the proper ratio of polypropylene fibre to fillers (alccofine, zeolite) was used.

References

1) Zhang H, Wang L, Bai L, Addae M, Neupane A. Research on the impact response and model of hybrid basalt-macro synthetic polypropylene fiber reinforced concrete. *Construction and Building Materials*. 2019;204:303–316. Available from: https://doi.org/10.1016/j.conbuildmat.2019.01.201.
2) Eisa AS, Shehab HK, El-Awady KA, Nawar MT. Improving the flexural toughness behavior of R.C beams using micro/nano silica and steel fibers. *Advances in Concrete Construction*. 2021;11(1):45–58. Available from: https://doi.org/10.12989/acc.2021.11.1.045.
3) Sakthivel SK, Saravanan J. Experimental Assessment over Theoretical Prediction & Analytical Studies on Flexure Behavior of RC Beams with Recycled Coarse Aggregate. *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies*. 2022;13(3):1–11. Available from: http://TuEngr.com/V13/13A3I.pdf.
4) Kavyateja BV, Gurujawahar JG, Sashidhar C. Effectiveness of Alccofine and Fly ash on Mechanical Properties of Ternary Blended Self Compacting Concrete. *Material Today: Proceedings*. 2020;33(Part 1):73–79. Available from: https://doi.org/10.1016/j.matpr.2020.03.152.
5) Kumar SR, Samanta AK, Roy DKS. An Experimental Study on the mechanical properties of alccofine based high grade concrete. *International Journal of Multidisciplinary Research and Development*. 2015;2(10):218–224. Available from: https://www.allsubjectjournal.com/assets/archives/2015/vol2issue10/21.1.pdf.
6) Jokar F, Khorram M, Karimi G, Hataf N. Experimental investigation of mechanical properties of crumbed rubber concrete containing natural zeolite. *Construction and Building Materials*. 2019;208:651–658. Available from: https://doi.org/10.1016/j.conbuildmat.2019.03.063.
7) Li Y, Qiao C, Ni W. Green concrete with ground granulated blast-furnace slag activated by desulfurization gypsum and electric arc furnace reducing slag. *Journal of Cleaner Production*. 2020;269:122212. Available from: https://doi.org/10.1016/j.jclepro.2020.122212.
8) Ashwini K, Rao PS. Evaluation of correlation between compressive and splitting tensile strength of concrete using alccofine and nano silica. *IOP Conference Series: Materials Science and Engineering*. 2021;1091:1–7. Available from: https://iopscience.iop.org/article/10.1088/1757-899X/1091/1/012056/pdf.
9) Sankar B, Ramadoss P. Experimental and Statistical Investigations on Alccofine Based Ternary Blended High-performance Concrete. *International Journal of Engineering*. 2022;35(8):1629–1640. Available from: https://www.ije.ir/article_150147.html.
10) Dheyaaldin MH, Mosaberpanah MA, Alzeebaree R. Performance of Fiber-Reinforced Alkali-Activated Mortar with/without Nano Silica and Nano Alumina. *Sustainability*. 2021;14(5):1–24. Available from: https://doi.org/10.3390/su14052527.
11) Abdulkareem OM, Alshahwany RB, Mousa AA. Durability of polypropylene fiber reinforced concrete: Literatures review. *Electronic Journal of Structural Engineering*. 2022;22(01):14–28. Available from: https://doi.org/10.56748/ejse.2225701.
12) Prithiviraj C, Saravanan J, Kumar DR, Murali G, Vatin NI, Swaminathan P. Assessment of Strength and Durability Properties of Self-Compacting Concrete Comprising Alccofine. *Sustainability*. 2022;14(10):1–19. Available from: https://doi.org/10.3390/su14105895.
13) Gaayathri KK, Suguna K, Raghunath PN. A Study on Material Properties of Structural Light Weight Concrete with Micro-reinforcement. *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies*. 2022;13(6):1–11. Available from: https://tuengr.com/A13/13A6/13A6U.html.
14) Swetha A, K S, N RP. Strength and Durability Studies on Steel Fiber Reinforced Ternary Blended Concrete Containing Nano Silica and Zeolite. *Civil Engineering and Architecture*. 2022;10(6):2306–2321. Available from: https://www.hrpub.org/journals/article_info.php?aid=12384.

15) Meenatchi K, Suguna K, Raghunath PN. Strength and Durability Study on Polypropylene Fibre Reinforced Ternary Blended Concrete Containing Alccofine and Zeolite. *Mathematical Statistician and Engineering Applications*. 2022;71(4):7661–7674. Available from: https://doi.org/10.17762/msea.v71i4.1382.
16) Jamenraja MCK, Ravichandran K. Experimental Investigation of Mechanical and Durability Properties of Concrete Containing Nano Silica, Alccofine and Polypropylene Fibers. *Indian Journal Of Science And Technology*. 2023;16(19):1395–1407. Available from: https://doi.org/10.17485/IJST/v16i19.2431.
17) Meenatchi K, Suguna K, Raghunath PN. Performance Evaluation of Fibre Reinforced Concrete Containing Alccofine and Zeolite. *Indian Journal Of Science And Technology*. 2023;16(17):1309–1322. Available from: https://doi.org/10.17485/IJST/v16i17.2346.