©2022 International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies

ISSN 2228-9860 eISSN 1906-9642 CODEN: ITJEA8

TuEngr Group

International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies

http://TuEngr.com

A Study on Fibre Reinforced Concrete Involving Nano-Alumina and Zeolite

Sala Gayathri[1*], K.Suguna[1], P.N.Raghunath[1]

Dept. of Civil and Structural Engineering, Annamalai University, Annamalainagar, INDIA.
**Corresponding Author(Email: sala.gayathri @gmail.com).*

Paper ID: 13A9C

Volume 13 Issue 9

Received 08 February 2022
Received in revised form 08 June 2022
Accepted 15 June 2022
Available online 22 June 2022

Keywords:
Compressive Strength; Mechanical Properties; Modulus of Elasticity; Modulus of Rupture; Nano-Alumina; Polypropylene Fibres; Split Tensile Strength; Zeolite.

Abstract

The paper presents the results of a research study carried out on ternary blended concrete containing Nano Alumina (NA), Zeolite and Polypropylene fibres (PPF). The optimum combination of Nano Alumina and Zeolite has been arrived at using standard procedures from the point of view of mobility and strength. The optimum combination has been found to be 1% Nano Alumina and 10% Zeolite. Polypropylene fibre has been added in different volume fractions (0.1, 0.2 & 0.3%) to examine its impact on the mechanical properties of concrete involving Nano alumina, Zeolite. Compressive Strength, indirect tensile strength, flexural strength and elastic modulus for the above concrete mixture have been found using appropriate specimens such as cube, cylinder and prism following the standard test protocols. The results indicated that the addition of 0.3% polypropylene fibres increased compressive strength by 19.33%, increased split tensile strength by 66.26%, increased flexural strength by 26.15%, and increased modulus elasticity by 16.13%.

Disciplinary: Civil Engineering (Material & Technology).

Cite This Article:

Gayathri, S., Suguna, K. , Raghunath, P. N. (2022). A Study on Fibre Reinforced Concrete Involving Nano-Alumina and Zeolite. *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies, 13*(9), 13A9C, 1-11. http://TUENGR.COM/V13/13A9C.pdf DOI: 10.14456/ITJEMAST.2022.171

1 Introduction

The growth of infrastructure always shows an uptrend all over the world. It is an indicator of the economic growth of a country. Concrete still remains a strong player in civil engineering constructions. All out efforts are being made to enhance the performance of concrete as it has to be utilized under a variety of environmental conditions (Gaayathri et al., 2022). To accomplish this task, various replacement materials are being tried out. Zeolite shows promise in this direction. Zeolite is rich in hydrated aluminosilicate and much finer than other pozzolanic materials. Cement replacement with 15% zeolite exhibited maximum mechanical and durability properties and did not demand too much superplasticizer (Najimi, 2012). Concrete with 10% Portland cement replacement with zeolite gave a 26% increase in compressive strength (Emam, 2017). The mix containing 0.7 fractions of PPF increased the tensile and flexural strength by 39% and 10%. (Ramezanianpour, 2013). Concrete with a 0.3% volume fraction of polypropylene fibres reduced water absorption by 59.21% (Afroughsabet- 2015). The combination of zeolite and PP fibres increased compressive and tensile strength by 44% and 22% (Dabbaghi-2021). The mix containing 1.5% of nano alumina exhibited a 27% increase in compressive strength (Ibadur Rahman-2020, niloofar Salemi-2013). The inclusion of 1% NA in the concrete improved compressive strength by 33.14% (Jaishankar-2017)

2 Test Programme

2.1 Concrete Mix

Mix design has been done as per IS 10262:2019 for ternary blended concrete incorporating Zeolite, Nano-Alumina and Polypropylene fibres. Table 1 presents the mix details used in the testing program. The mix details, details of test specimens and nomenclature of specimens are mentioned in Tables 1, 2 and 3.

Table 1: Mix Details

Details	CC	Z	ZA	ZAP-1	ZAP-2	ZAP-3
Cement (Kg/m^3)	387	348.3	344.43	344.43	344.43	344.43
FA (Kg/m^3)	654	654	654	654	654	654
CA (Kg/m^3)	1219	1219	1219	1219	1219	1219
Zeolite (Kg/m^3)	-	38.70	38.70	38.70	38.70	38.70
Nano-Alumina (Kg/m^3)	-	-	3.87	3.87	3.87	3.87
PPF (%)	-	-	-	0.1%	0.2%	0.3%
Water (L/m^3)	187	187	187	187	187	187

Table 2: Details of Tests Specimens

Sl. No.	Test	Specimen Type	Size (mm)	No. of Specimens
1	Compressive Strength Test	Cubes	150 X150	18
2	Compressive Strength Test	Cylinders	150 X 300	18
3	Split Tensile Strength Test	Cylinders	150 X 300	18
4	Elasticity Modulus Test	Cylinders	150 X 300	18
5	Flexural Strength Test	Prisms	100 X 100 X 500	18

Table 3: Nomenclature of Specimens

Specimens	Description
CC	Conventional Concrete
Z	Specimen with 10% Zeolite
ZA	Specimen with 10% Zeolite and 1% Nano- alumina
ZAP-1	Specimen with 10% Zeolite , 1% Nano- alumina and 0.1% Polypropylene Fibre
ZAP-2	Specimen with 10% Zeolite , 1% Nano- alumina and 0.2% Polypropylene Fibre
ZAP-3	Specimen with 10% Zeolite , 1% Nano- alumina and 0.3% Polypropylene Fibre

2.2 Materials

2.2.1 Cement

Ordinary Portland cement (OPC) 53 grade conforming to IS 12269:2013 was used for the experimental work. The properties of cement are presented in table 4.

Table 4: Properties of Cement

Property	Value
Specific Gravity	3.15
Grade	53 grade

2.2.2 Aggregates

Natural river sand with a specific gravity of 2.61 is used as a fine aggregate. The coarse aggregate used was crushed granite of maximum particle sizes 20mm and 12 mm conforming to IS 383:2016. The properties of aggregates are presented in Table 5.

Table 5: Properties of Aggregates

Aggregate	Specific Gravity	Zone/ Shape
Fine Aggregate	2.61	Zone-III
Coarse Aggregate	2.80	Angular shape

2.2.3 Zeolite (Z) and Nano-Alumina (NA)

Zeolite (Figure 1) and nano-alumina (Figure 2) used in the investigation were procured from Astrra chemical, Chennai. The properties of the materials used are presented in Table 6.

Table 6: Properties of Nano-Alumina and Zeolite

Material	Specific Gravity	Specific Surface area (m^2/g)
Nano Alumina	1.2	300
Zeolite	2.6	19.20

Figure 1: Zeolite

Figure 2: Nano-Alumina

2.2.4 Polypropylene Fibres

Commercially available polypropylene fibres (Figure 3) were used in this study which conforms to ASTM C1116. The properties of PP fibres are presented in Table 7.

Table 7: Properties of Polypropylene Fibres

Properties	Test data
Dia. (D), mm	0.04
Length (l), mm	12
Aspect Ratio	300
Shape	Triangular
Tensile strength	4MPa
Specific gravity	0.910
Elasticity Modulus	400 MPa

Figure 3: Polypropylene Fibres

2.2.5 Super Plasticizer

Conplast 430 (ASTM C494) was used as a water-reducing admixture in this experimental work. The optimum dosage of Conplast SP430 (Figure 4) to meet the specific requirements of mixes is determined by trial mixes. The properties of SP are presented in Table 8.

Table 8: Properties of SP

Properties	Value
Colour	Brown
Form	Liquid
Specific gravity	1.26 at 25 Degree C

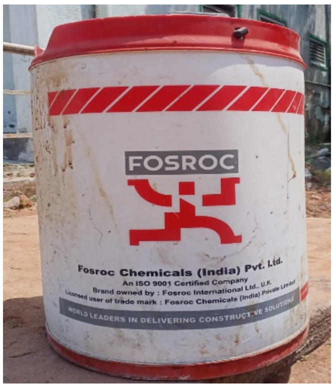

Figure 4: Super Plasticizer

2.2.6 Preparation of Specimens

The ingredients were first mixed in a dry state and then fibres were added in smaller quantities to avoid balling of fibres. The water plus Super plasticizer was added slowly and mixed thoroughly to avoid the formation of clustering. The specimens were cast in steel moulds and vibrated using a vibrating table. All the specimens were de-moulded after 24 hours of casting and then cured for 28-days before being tested.

2.3 Test Methods

The experimental research was carried out in two stages. In the first stage, cement was partially replaced by different proportions of zeolite and nano alumina to find the optimum combination. In the second stage, Polypropylene fibres in varying volume fractions (0.1, 0.2 & 0.3%) were added to concrete with the optimum dosage of zeolite and nano-alumina. Mechanical tests were conducted.

2.3.1 Compressive Strength of Cubes and Cylinders

Cubes and cylinders were cast and tested in a standard manner in a 1000 kN capacity compression testing machine. A total of 18 Cubes and 18 cylinders were tested as per IS516: 2004 (Reaffirmed). Concrete Cubes of size 150X150X150mm and Cylinder Specimens of size 150 X 300mm were tested. The test set-up with the appropriate instrumentation experiment is shown in Figures 5 and 6.

Figure 5: Cube Compressive Strength Test

Figure 6: Cylinders Compressive Strength Test

2.3.2 Split Tensile Test

A total of 18 Concrete cylinder Specimens of size 150 X 300mm were cast and tested as per IS 516: 2004 (Reaffirmed) for split tensile strength. The experimental setup is shown in Figure 7

Figure 7: Split Tensile Strength Test

2.3.3 Flexural Strength

A total of 18 Concrete prisms Specimens of size 100 x 100x 500 mm were cast and tested as per IS 516: 2004 (Reaffirmed) for flexural strength. Figure 8 shows the experimental setup.

Figure 8: Flexural Strength Test

2.3.4 Modulus of Elasticity

A total number of 18 cylinders of size 150x300 mm were tested as per IS 516: 2004 (Reaffirmed) in a standard Compression Testing Machine. The experimental setup is shown in Figure 9.

Figure 9: Modulus of Elasticity Test

3 Results and Discussion

3.1 Compressive Strength of Cube

The cube compressive strength results are presented in Table 9. The specimens Z, ZA, ZAP-1, ZAP-2 and ZAP-3 exhibited an increase in compressive strength of 4.84%, 7.73%, 15.21%, 19.33% and 17.62% respectively compared to the CC specimen. The specimens ZA, ZAP-1, ZAP-2 and ZAP-3 showed an increase up to 2.76%, 9.89%, 13.82% and 10.86% with respect to specimen Z. The specimens ZAP-1, ZAP-2 and ZAP-3 showed an increase up to 6.22%, 9.66% and 9.17% with respect to specimen ZA. The effect of PP fibre on compressive strength is presented in Figure 10.

Table 9: Cube Compressive Strength

S.No.	Specimens	Compressive Strength (N/mm2)
1	CC	39.04
2	Z	40.93
3	ZA	42.06
4	ZAP-1	44.98
5	ZAP-2	46.59
6	ZAP-3	45.92

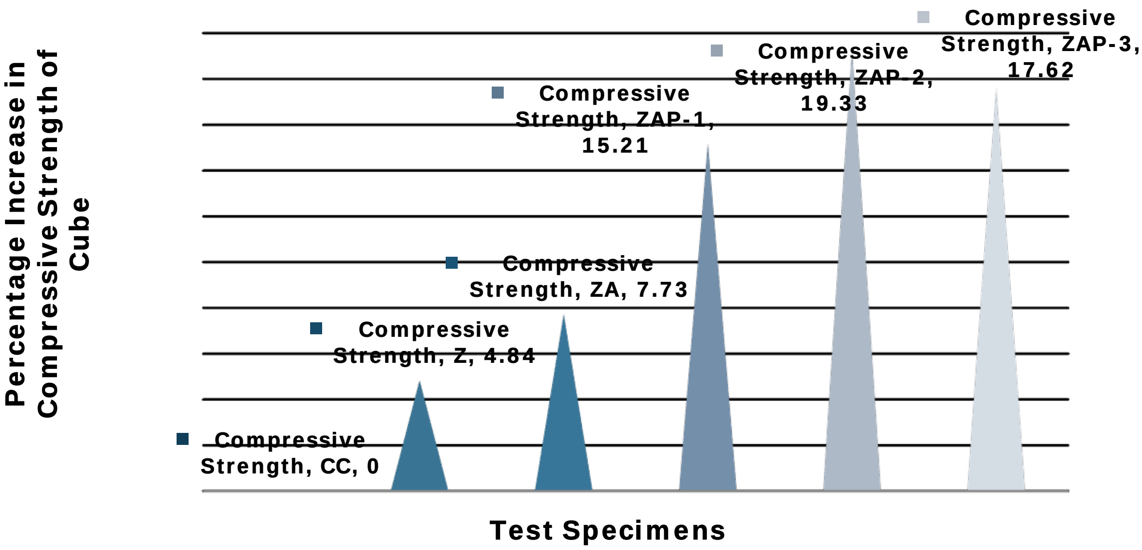

Figure 10: Effect of PP Fibre on Cube Compressive Strength

3.2 Compressive Strength of Cylinder

The cylinder compressive strength test results are presented in Table 10. The specimens Z, ZA, ZAP-1 and ZAP-2 exhibited an increase in compressive strength of 3.36%, 9.09% 15.2% and 18.12% respectively compared to the CC specimen. The specimens ZA, ZAP-1 and ZAP-2 showed an increase up to 5.42%, 11.32% and 14.15% with respect to specimen Z. The specimens ZAP-1 and ZAP-2 showed an increase up to 5.59% and 8.27% with respect to specimen ZA. The effect of PP fibre on cylinder compressive strength is presented in Figure 11.

Table 10: Cylinder Compressive Strength

S. No.	Specimens	Compressive Strength (N/mm2)
1	CC	30.45
2	Z	31.51
3	ZA	33.22
4	ZAP-1	35.08
5	ZAP-2	35.97
6	ZAP-3	35.39

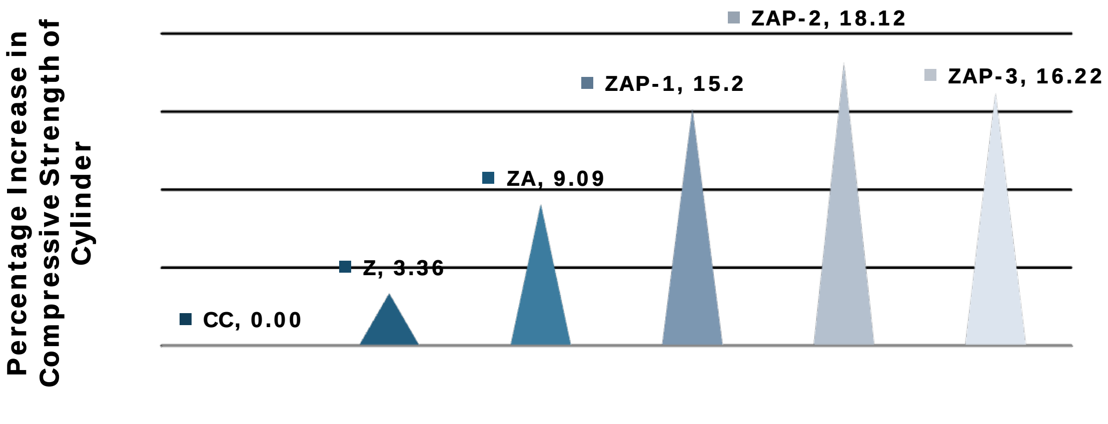

Figure 11: Effect of PP Fibre on Cylinder Compressive Strength

3.2.1 Failure Mode

Cubes were tested in a standard manner in a 1000 kN capacity compression testing machine. Figure 15 shows the failure modes of cubes tested under axial compression. In the early stages, cracks were formed on the surface only. The specimens incorporated with Polypropylene fibre exhibit fewer cracks and no spalling compared to the CC specimen. This is because of the fibre interlocking mechanisms.

CC Z ZA ZAP-1 ZAP-2 ZAP- 3

Figure 12: Failure Pattern of Cube Specimens

3.3 Split Tensile Test

The split tensile strength test results are presented in Table 10. The specimens Z, ZA, ZAP-1, ZAP-2 and ZAP-3 exhibited an increase in flexural strength of 13.85%, 28.31%, 47.28%, 56.02 % and 66.26% respectively compared to the CC specimen. The specimens ZA, ZAP-1, ZAP-2 and ZAP-3 showed an increase up to 12.39%, 29.36%, 37.03% and 46.29% with respect to specimen Z. The specimens ZAP-1, ZAP-2 and ZAP-3 showed an increase up to 14.78%, 21.59% and 29.81% with respect to specimen ZA. The effect of PP fibre on split tensile strength is presented in Figure 13.

Table 10: Split Tensile Strength Test Results

S.No.	Specimens	Split Tensile strength (N/mm^2)
1	CC	3.32
2	Z	3.78
3	ZA	4.26
4	ZAP-1	4.89
5	ZAP-2	5.18
6	ZAP-3	5.53

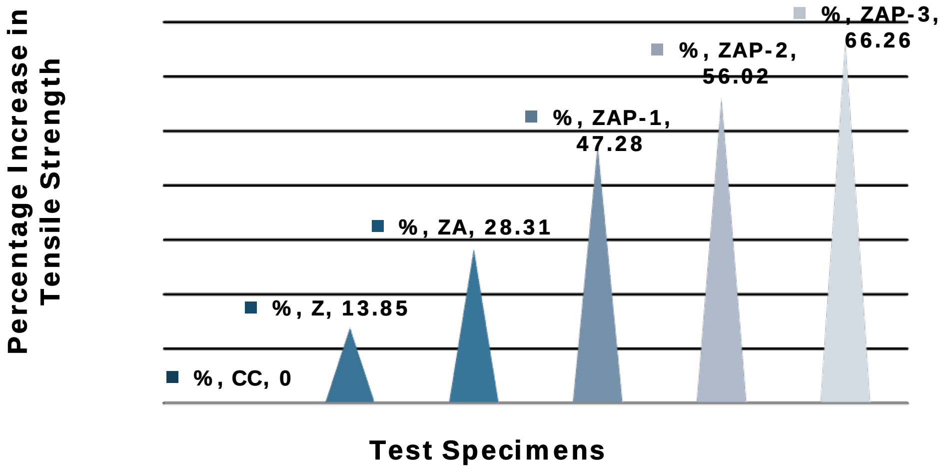

Figure 13: Effect of PP Fibre on Split Tensile Strength

3.3.1 Failure Pattern

The cylinder specimens were tested in a compression testing machine of 1000 kN capacity. The failure patterns of cylinder specimens are shown in Figure 14. In the early stages, a major macro crack was observed over the height of the cylinder. With the increase in axial compressive stress, more longitudinal cracks formed. With the inclusion of the PP Fibres the failure pattern of the cylinder changed, polypropylene fibres caused a confinement mechanism preventing the tendency of concrete to crack and spall.

Figure 14: Failure Pattern of Cylinder Specimens

3.4 Flexural Strength

The flexural strength test results are presented in Table 11. The specimens Z, ZA, ZAP-1, ZAP-2 and ZAP-3 exhibited an increase in flexural strength of 9.2%, 15.38%, 18.46%, 21.53% and 26.15% respectively compared to the CC specimen. The specimens ZA, ZAP-1, ZAP-2 and ZAP-3 showed an increase up to 5.63%, 8.45%, 11.26% and 25.35% with respect to specimen Z. The specimens ZAP-1, ZAP-2 and ZAP-3 showed an increase up to 2.66%, 5.33% and 18.6% with respect to specimen ZA. The effect of PP fibres on flexural strength is shown in Figure 15.

Table 11: Flexural Strength Test Results

S.No.	Specimens	Flexural Strength (N/mm^2)
1	CC	6.5
2	Z	7.1
3	ZA	7.5
4	ZAP-1	7.7
5	ZAP-2	7.9
6	ZAP-3	8.2

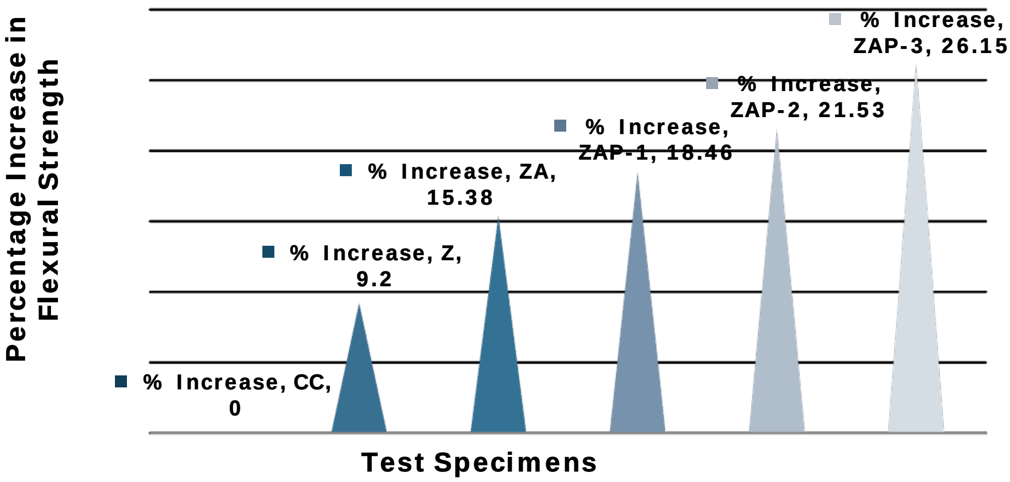

Figure 15: Effect of PP Fibre on Flexural Strength

3.4.1 Failure Mode

The prism specimens were tested in a loading frame under four-point bending. The failure patterns of prism specimens are shown in Figure 16. In all the specimens, a major crack initiated at the bottom fibre of the mid-span section propagated vertically upward with increasing loads. It has been observed that the crack size decreased with increasing fibre contents.

Figure 16: Failure Pattern of Prism Specimens

3.5 Modulus of Elasticity

The specimens Z, ZA, ZAP-1, ZAP-2 and ZAP-3 exhibited an increase in modulus of elasticity of 4.32%, 10.39%, 12.21%, 13.56% and 16.13% respectively compared to the CC specimen. The specimens ZA, ZAP-1, ZAP-2 and ZAP-3 showed an increase up to 5.81%, 7.56%, 8.85% and 11.31% with respect to specimen Z. The specimens ZAP-1, ZAP-2 and ZAP-3 showed an increase up to 1.62%, 2.82% and 5.111% with respect to specimen ZA. The effect of polypropylene fibres on the modulus of elasticity is presented in Figure 17.

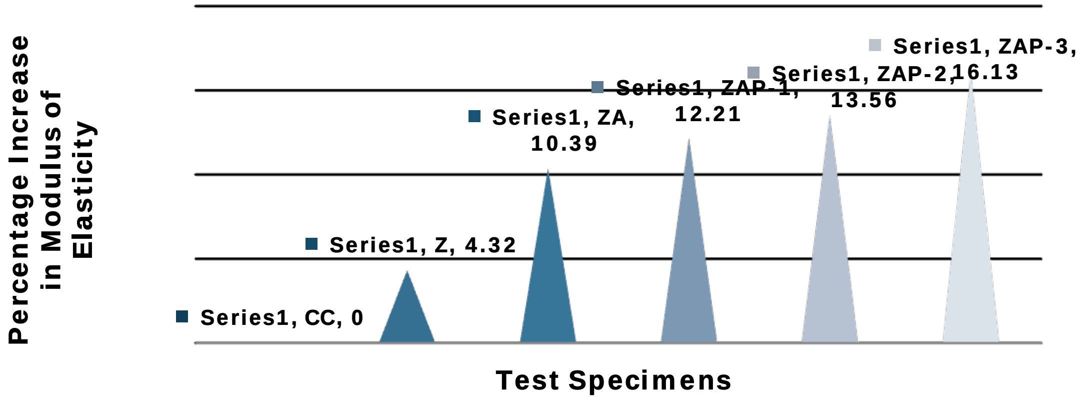

Figure 17: Effect of Polypropylene Fibres on Modulus of Elasticity

3.5.1 Failure Mode

The failure pattern of polypropylene fibre-based concrete cylinder specimens is shown in Figure 22. A macro-crack was observed over the height of the concrete cylinders in the early stage. With the increase in axial compressive stress, more longitudinal cracks were observed. With the inclusion of PP fibres, the failure pattern of specimens changed and increase crack density due to the interlocking mechanism of fibres.

Figure 18: Failure Pattern of Cylinder Specimens.

4 Conclusion

For this study, the ternary blended concrete showed a maximum 19.33% increase in compressive strength with the inclusion of a 0.2% volume fraction of polypropylene fibre.

The flexural strength, split tensile strength and modulus of elasticity increased by 26.15%, 66.26% and 16.13% with the inclusion of a 0.3% volume fraction of Polypropylene fibres.

Incorporating polypropylene fibres is very effective in improving the mechanical properties of ternary blended concrete.

5 Availability of Data and Material

Data can be made available by contacting the corresponding author.

6 References

Afroughsabet V, Ozbakkaloglu T. Mechanical and durability properties of high-strength concrete containing steel and polypropylene fibers. Construction and building materials. 2015;94:73-82.

Dabbaghi F, Sadeghi-Nik A, Libre NA, Nasrollahpour S. Characterizing fiber reinforced concrete incorporating zeolite and metakaolin as natural pozzolans. Structures, 2021;34:2617-2627.

Emam E, Yehia S. Performance of concrete containing zeolite as supplementary cementitious material. International research journal of engineering and technology. 2017;4(12):1619-25.

Gaayathri, KK, Suguna, K, and 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):13A6U,1-11. http://TUENGR.COM/V13/13A6U.pdf DOI: 10.14456/ITJEMAST.2022.126

Ibadur Rahman, Nirendera Dev (2020). Nano Alumina-Based High Strength Concrete. International Journal of Innovative Technology and Exploring Engineering. 9(4).

Jaishankar P, Karthikeyan C. Characteristics of cement concrete with nano alumina particles. In IOP conference series: earth and environmental science. 2017;80(1): 012005.

Najimi M, Sobhani J, Ahmadi B, Shekarchi M. An experimental study on durability properties of concrete containing zeolite as a highly reactive natural pozzolan. Construction and building materials. 2012 Oct 1;35:1023-33.

Ramezanianpour AA, Esmaeili M, Ghahari SA, Najafi MH. Laboratory study on the effect of polypropylene fiber on durability, and physical and mechanical characteristics of concrete for application in sleepers. Construction and Building Materials. 2013 Jul 1;44:411-8.

Salemi N, Behfarnia K. Effect of nano-particles on the durability of fiber-reinforced concrete pavement. Construction and Building Materials. 2013;48:934-41.

Sala Gayathri is a student in the Department of Civil and Structural Engineering, Annamalai University, Chidambaram. She got her Master's from JNTUH, Hyderabad, Telangana. Her research is based on the use of Micro and Nano filler in Combination as Partial Replacement of Cement in Polypropylene fiber Reinforced Concrete.

Dr. K. Suguna is a Professor in the Department of Civil and Structural Engineering, Annamalai University, Chidambaram. She got her Master's and PhD degrees in Structural Engineering, from Annamalai University, Chidambaram. Her research interest includes Alternative Materials for the Construction and Rehabilitation of Structures.

Dr. P. N. Raghunath is a Professor in the Department of Civil and Structural Engineering, Annamalai University, Chidambaram. he got his Master's and PhD degrees in Structural Engineering, Annamalai University, Chidambaram. His research interest includes Polymer and Fiber Composites.