ISSN 2348 – 7968

Performance of Concrete with Metakaolin and Recron Fibre

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Abstract

Concrete a major building material which is versatile and can be used for all types of structures in construction industry throughout the world. Use Metakaolin as admixture improves the mechanical properties of concrete and improves the durability aspects and use of Recron fiber controls the cracking of concrete. This study is carried out to understand the performance of concrete with the addition of Metakaolin and Recron -3s. Recron fiber is used in different percentages (0.5%, 1%, 1.5% &2%) to the weight of concrete along with a constant percentage (5%) of Metakaolin for the production of this modified concrete. Various strength parameters like compressive strength, split tensile strength and flexural strength of modified concrete are studied and presented in this paper.

Keywords: *Metakaolin, Rcron fibre, mechanical properties of concrete*

1. Introduction

Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking[1]. The presence of micro cracks at the mortar-aggregate interface is responsible for the inherent weakness of plain concrete. Because of the poor tensile strength, cracks propagate with the application of load, leading to brittle fracture of concrete. Fibre in the cement based matrix acts as cracks arrester which restricts the growth of flows in the matrix, preventing these from enlarging under load, into cracks, which eventually cause failure. Also the supplementary cementitious material and additives such as ground granulated blast furnace slag (GGBS), pulverized fly ash, silica fume, metakaolin, etc have been successfully used to enhance the properties of concrete[2].

Production of cement results in a lot of environmental pollution as it involves the emission of CO_2 gas. Supplementary cementitious materials (SCM) are finely ground solid materials that are used to replace a portion of the cement in a concrete mixture[2].Various types of pozzolanic materials that improve cement properties have been used in cement industry for a long time. Metakaolin is a dehydroxylated aluminium silicate. It is an amorphous non crystallized material, constituted of lamellar particles. Metakaolin is a supplementary cementing material which is produced from carefully calcining kaolin clay between 600^0 and 800^oC to make it reactive[3]. Metakaolin is composed mainly of alumina and silica phases, which can vary by approximately 10% and 8% respectively depending on the kaolin source. Metakaolin has the general form $Al_2O_3.SiO_2$. When blended with Portland cement in appropriate amounts, typically below 10%, it will enhance the strength and durability of the concrete. Metakaolin also makes concrete greener because Metakaolin production does not produce chemical CO_2 as opposed to cement (de-carbonating limestone) and also requires lower temperatures to produce (800 as opposed to 1450^o C). From the recent research works using Metakaolin[3], it is evident that it is a very effective pozzolanic material and it effectively enhances the strength parameters of concrete.

Recron-3s is a polypropylene monofilament, discrete, discontinuous short fibre that can be used in concrete to control and arrest cracks. Recron 3s fibre reduces rebound splattering of concrete and shotcrete[4]. This reduces wastage of mortar and speeds up the space of work. They reduce bleeding so solids in the concrete don't settle as much, and they increase the tensile strength. More importantly it saves a great deal of labour employed for the job. The gains are higher when plastering is in progress at higher floors, ceilings and outside surfaces of the buildings.

Replacement of Portland cement by Metakaolin and addition of Recron fibre on weight basis seems to be very suitable for Indian construction industry due to abundant availability of Recron fibre and Metakaolin at cheap cost.

2. Materials and Their Properties

2.1 Cement

Cement is the most important constituent in a concrete mixture. The function of cement is first, to bind the sand and the coarse aggregates together and second, to fill the voids in between sand and coarse aggregates particles to form a compact mass. For the present work, Ordinary Portland cement (OPC) of 53 Grade confirming to IS 12269 was used. The brand of cement used was Dalmia superoof cement. The use of high grade cement offers 10 to 20% savings in cement consumption in addition to high strength. The various laboratory tests for cement are specific gravity, standard consistency, fineness, initial setting time and final setting time.

Table 1: Properties of Cement

SL NO	PROPERTIES	TEST RESULT
1	Grade	53
2	Specific Gravity	3.14
3	Standard Consistency (%)	30
4	Fineness (%)	3
5	Initial setting time(min)	80

2.2 Coarse Aggregate and Fine Aggregate

Manufactured sand having specific gravity 2.56 was used as fine aggregate. Sieve analysis helps to determine the particle size distribution of the course and fine aggregates. This is done by sieving the aggregates as per IS: 2386 (part I)-1963. Locally available crushed granite stone aggregates have been used as coarse aggregate. Table-2 gives the physical properties of the coarse and fine aggregates.

Table 2: Properties of Fine Aggregate and Coarse Aggregate

Sl No	Properties	Fine Aggregate	Coarse Aggregate
1	Specific Gravity	2.56	2.67
2	Fineness Modulus	2.79	2.34

2. 3 Water

Water is the most important ingredient of concrete. It actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Potable water is generally considered satisfactory for mixing concrete. For the present study, clean drinking water available in the college water supply system was used for the casting as well as the curing of the test specimens. The quality of water was found to satisfy the requirements of IS: 456 – 2000[10]

2. 4. Super Plasticizer

To keep the water-cement ratio as low as possible and hence to obtain a given degree of workability, chemical admixtures such as super plasticizer was used. Super plasticizers help to reduce the water content, thereby effectively controlling the water-cement ratio to achieve the design strength. The super plasticizer used in this study was Master Rheobuild 1125. It is a high-range, retarding, super plasticizing admixture for concrete. It is a sulphonated naphthalene polymer based super plasticizer having slump retaining capabilities. It shall comply with IS: 9103 and shall be of type G when tested to ASTM C-494. The optimum dosage of super plasticizer has been fixed based on a number of trials wherein the dosage was increased from 0.5% to 1.2% by weight of cement. Based on the results, it has been decided to use a constant super plasticizer dosage of 1% by weight of cement for casting the various specimens. The properties are listed below in table 3[10].

Table 3: Physical Properties of Super plasticizer

Appearance	Dark Brown free flowing liquid
Density	1.24±0.02 at 25^0C
pH	≥6
Chloride ion content	<0.2%
Dosage limit	0.5 – 1.2% by weight of cement

2.5 Metakaolin

Metakaolin obtained from Ashapura Mine chem. Ltd, Trivandrum was used for the present investigation. The specific gravity of the metakaolin sample was 2.5.

2.6 Recron Fibre

Recron fibres are manufactured by Apollo fibres limited, PO Cohal, Hoshiyarpur, Punjab, India an associate company of Reliance Industry Limited (RIL). The material was obtained from royal marketing & distributors, Cochin. The specific gravity of the Recron fibre was 1.34.[4]

Table 4: Properties Of Recron Fibre

Properties	Values
Colour	Brilliant White
Specific gravity	Polyester 1.34 Polypropylene 0.91
Length	3 – 24 mm
Tensile strength	1000 – 1079 N/mm^2

3. Experimental Work and Tests

3.1 Mix Design:

Concrete mix of grade M 30 was designed using IS 10262 code procedure[9]. The aggregates used in the mix design were under saturated surface dry conditions. The quantity of materials needed listed below.

Table 5 : Mix Proportions for 1 m^3

Component	Quantity
Coarse aggregate	1252 kg
Fine aggregate	647 kg
Cement	360 kg
Water	144 kg
Superplasticizer	1% of cement weight

Table 6: Mix Designation

Mix Designation	Metakaolin (%)	Recron Fibre(%)
NC	0	0
MR 0	5	0.0
MR 0.20	5	0.20
MR 0.25	5	0.25
MR 0.30	5	0.30
MR 0.35	5	0.35
MR0.40	5	0.40

3.2 Slump Test

Slump test to find the workability was carried out in a standard slump cone of 200 mm bottom diameter and 100 mm top diameter with a height of 300 mm. The results show that compared to the normal concrete, all investigated Recron fibre mixtures had high slump values and acceptable workability. Metakaolin has extremely high surface area, which results in increase in water demand to maintain consistency.

Table 7: Workability

Mix designation	Metakaolin %	Recron fibre%	Slump (mm)
NC	0	0.00	80
MR 0	5	0.00	70
MR0.20	5	0.20	80
MR 0.25	5	0.25	100
MR0.30	5	0.30	105
MR0.35	5	0.35	110
MR0.40	5	0.40	110

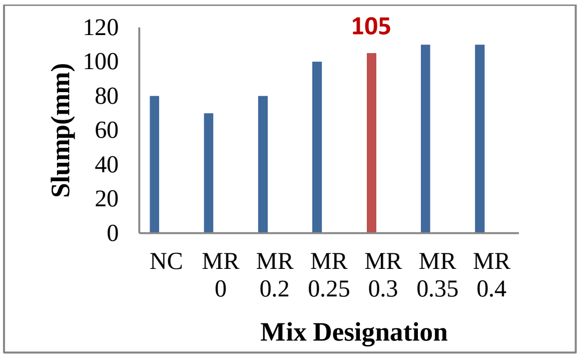

Figure 2: Workability

4. Results and Discussions

4.1 Hardened Properties of Concrete

4.1.1 Compressive Strength

The compressive strength tests were conducted on concrete cube specimens of size 150mm. The cubes were tested after curing periods of 7 and 28 days. The results obtained for cube compressive strengths for the different mixes at 7 day and 28 day are shown in Table.

Table 8: 7th And 28th Day Compression Test Results

Mix designation	Metakaolin	Recron fibre	Cube compressive strength in N/mm2 (7 days)	Cube compressive strength in N/mm2 (28days)
NC	0	0.00	22.00	33.84
MR 0	5	0.00	24.44	37.80
MR0.20	5	0.20	26.70	41.10
MR 0.25	5	0.25	28.14	43.30
MR0.30	5	0.30	29.70	45.63
MR0.35	5	0.35	28.04	43.15
MR0.40	5	0.40	26.43	40.67

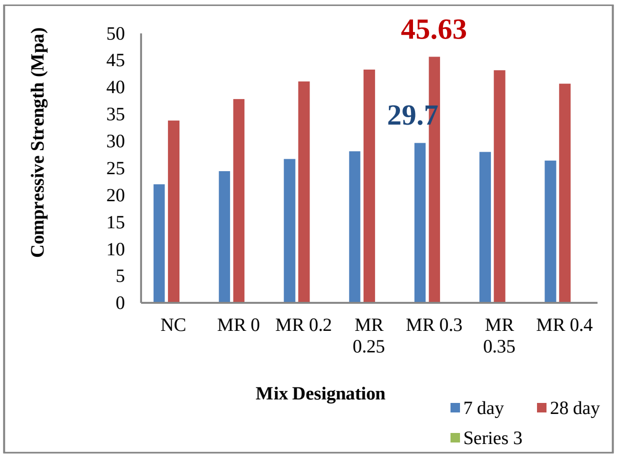

Figure 3: Comparison of 7 & 28 Day Compressive Strength

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 5, May 2016.
www.ijiset.com
ISSN 2348 – 7968

At both 7 and 28 days, compressive strength increased up to 0.3% of RF with 5% cement replacement and after that it decreased. i.e. optimum replacement is 5% metakaolin and 0.3% recron fibre. The compressive strength of RF concrete is 1.35 times greater than normal concrete.The silica content of pozzolans reacts with free lime released during the hydration of cement and forms additional calcium silicate hydrate (CSH) as new hydration products, which improved the compressive strength of concrete.

4.2.2 Cylinder Split Tensile Strength

The split tensile strength was conducted on the compression testing machine using cylinders of 300 mm height and 150 mm diameter. Results obtained are reported in Table

Table 9: Split Tensile Strength

Mix designation	Metakaolin %	Recron fibre %	Split Tensile Strength. N/mm2
NC	0	0.00	2.74
MR 0	5	0.00	3.02
MR0.20	5	0.20	3.32
MR 0.25	5	0.25	3.64
MR0.30	5	0.30	4.60
MR0.35	5	0.35	4.27
MR0.40	5	0.40	3.97

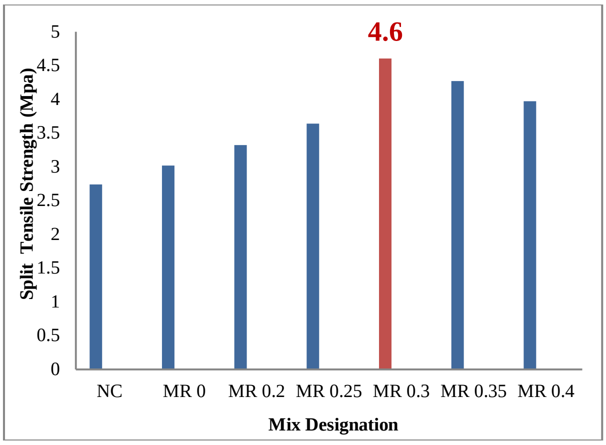

Figure 4: Split Tensile Strength

Optimum split tensile strength is obtained for MR 0.3, i.e. 0.3% recron fibre and 5% metakaolin. The split tensile strength is increased by 40.43 % in comparison to normal concrete.

4.2.3 Flexural Strength

The flexural strength was conducted on the universal testing machine using beams of 100mm x 100mm x 500mm. Results obtained are reported in Table10. It is found that there is 13.77 % increase in flexural strength

Table.10. Flexural strength

Mix Designation	Metakaolin %	Recron Fibre %	Flexural strength N/mm2
NC	0	0.00	4.07
MR 0	5	0.00	4.30
MR0.20	5	0.20	4.48
MR 0.25	5	0.25	4.60
MR0.30	5	0.30	4.72
MR0.35	5	0.35	4.60
MR0.40	5	0.40	4.46

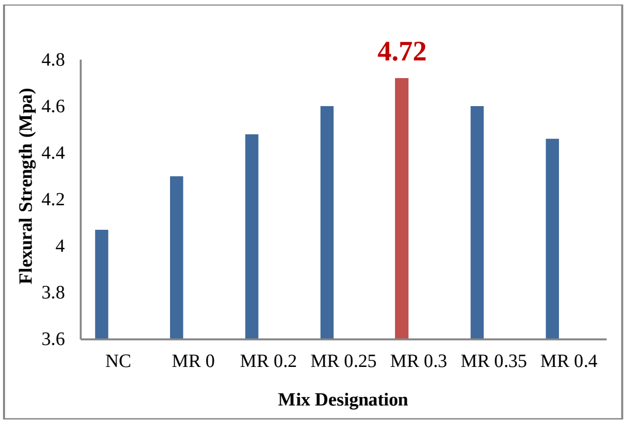

Figure 5: Variation In Flexural Strength

5. Conclusions

Based on the present study the following conclusions can be drawn:-

1. Wet density of fibre reinforced Metakaolin concrete goes on increasing with increase in % of fibre and with increase in % of Metakoalin the fresh matrix becomes dry.
2. Addition of Metakaolin results in reduction in temperature of fresh concrete. i.e. hydration reaction slows down due to addition of Metakoalin.
3. As The workability of the modified concrete increases with increase in recron fibre percentage when Metakaolin percentage is kept constant. So use of superplasticizer is not essential.
4. The replacement of cement with Metakaolin and addition of Recron fibre increases the compressive strength by 25.83%, flexural strength by 13.77% and splitting tensile strength by 40.43% up to 0.3% and then decreases.
5. Maximum compressive strength, flexural strength and splitting tensile strength occur at 5% Metakaolin and 0.3% Recron fibre.
6. The ultimate load carrying capacity of FRC concrete is about 1.13 times that of conventional concrete.

ISSN 2348 – 7968

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