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Experimental Studies on Concrete containing Metakaolin as mineral admixture

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Abstract.

It is known that regular concrete isn't very strong when it comes to pulling or stretching forces. Lately, stronger concrete has become a good choice for many projects because it deals with both strength and durability. To make regular concrete better while keeping its main properties, people use natural materials like metakaolin instead of some cement. This research is all about using metakaolin in concrete and checking how it acts when it's fresh and after it hardens.

The main goal of this study is to see how metakaolin affects concrete. We tested different mixes by replacing 10%, 15%, and 20% of cement with metakaolin. We made four sets of concrete with different mixtures and tested their strength using standard cubes, cylinders, and prisms. We checked their strength after 7 and 28 days, as well as their flexibility and elasticity after 28 days.

When we used more metakaolin in the concrete, we noticed a big change in how it behaved. The concrete became more fluid (we call this "slump") and took longer to set. We compared the results of these tests with regular concrete to see if using metakaolin is better for the environment and helps with sustainable development.

Keywords: High performance concrete, early age strength, durability.

1. Introduction

Metakaolin is like an extra ingredient for cement that follows specific rules for good quality. It's not made from leftover industrial stuff or entirely natural things. Instead, it's carefully created from minerals found in nature, especially for making cement. We heat a natural clay called kaolin to pretty high temperatures (650 to 900ºC) in a process called calcination. This

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changes the kaolin, removing certain parts and creating a special, reactive material that's great for cement. When we mix metakaolin with cement, it can make concrete stronger and more durable. It affects how well the concrete can handle pressure, how water moves through it, its resistance to chemicals, and how it changes size when it dries. Metakaolin particles are smaller than cement but bigger than something called silica fume. People usually replace some of the cement with metakaolin, usually around 5% to 20%. The fact that metakaolin is white makes it useful for matching colors and using it in architectural projects. That's why more and more people are using metakaolin to make good and strong concrete.

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2. Design/Methods/Modelling

Materials:

Cement: Ordinary Portland cement of 53 grades conforming to IS-12269-1987, with fineness and specific gravity values of 97% and 3.15, respectively.

Fine aggregate: Natural River sand passing through a 4.75 mm IS sieve, with specific gravity and fineness modulus values of 2.61 and 2.57.

Coarse aggregate: Crushed granite of 20 mm down and 12.5 mm retained, with specific gravity and fineness modulus values of 2.66 and 7.66.

Metakaolin: A mineral admixture conforming to class-N pozzolan specifications, sourced from Mumbai (Maharashtra).

Super Plasticiser: A melamine-based formaldehyde super plasticiser used in the concrete mix.

Mix Proportion:

The mix design followed the DOE method, adopting a mix proportion of 1:1.27:1.58 by weight of constituents. This choice was influenced by the quantitative relationship between compressive strength and various desirable characteristics and properties of concrete. Compression testing was performed on three cubes of size 150mmX150mm using a 2000 KN capacity machine, as per IS 516:1959, and the compressive strength results are illustrated in Fig 1.

Flexural Strength:

This test aimed to determine the maximum load-carrying capacity of beam specimens. Prisms were tested under a digital UTM of 200 KN capacity, following IS 516:1959. All beams underwent symmetrical loading under two-point loading conditions, with an overall test zone

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length of 400mm and load applied through two rollers mounted at the third points of the supporting span.

Modulus of Elasticity:

Extensometers were affixed at the ends or on opposite sides of the specimen, parallel to its axis, ensuring symmetrical gauge points. The extensometer was placed with the recording points at the same end. The specimen, centered accurately, was subjected to a continuous load at a rate of 140 kg/sq cm/min until an average stress of (C + 5) kg/sq cm was reached. Here, C represents one-third of the average compressive strength of the cubes, rounded to the nearest 5 kg/sq cm. Readings were taken at constant intervals.

Water Absorption:

Water absorption of different specimens was determined by measuring the increase in weight of oven-dry specimens when immersed in water. The weight increase for each sample was recorded at regular intervals.

3. Results and Discussion

According to Figure 1.0, it was noted that the M2 mix achieved the highest compressive strength after 7 days of curing compared to the other mixes. Similarly, the M2 mix demonstrated the maximum compressive strength after 28 days compared to the other mixes. At the 28-day mark, the M2 mix exhibited a higher flexural strength than the MO mix (control mix). The incorporation of Metakaolin contributed to the enhancement of properties. As depicted in Figure 3, the modulus of elasticity at the age of 28 days was higher for the M0 mix. Regarding water absorption, the M0 mix showed the minimum percentage of water absorbed.

TABLE: 1 TYPES OF CONCRETE MIX

Mix	OPC	METAKAOLIN
MO	100%	-
M1	90%	10%
M2	85%	15%
M3	80%	20%

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TABLE: 2 MECHANICAL PROPERTIES

Mix Designation	Compressive Strength (7 days) Mpa	Compressive Strength (28days) Mpa
MO	40	49.3
M1	44.30	53.3
M2	50.8	65.43
M3	41.9	53.42

TABLE: 3 DURABILITY PROPERTIES

Mix ID	% of water absorbed
MO	1.16
M1	1.41
M2	1.39
M3	1.43

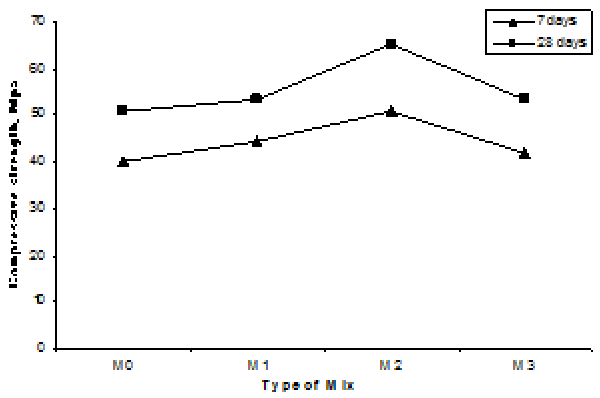

Fig 1.0 Compressive Strength for 7 & 28 days

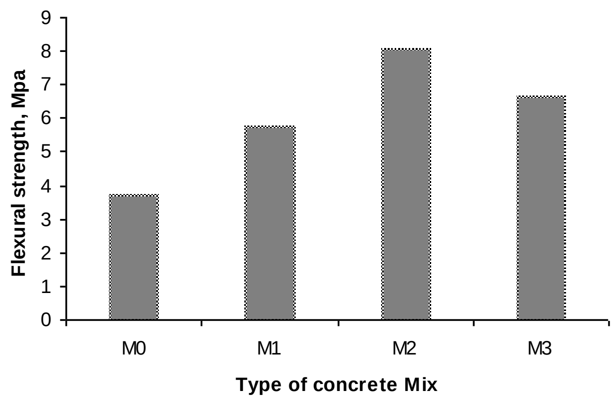

Fig 2.0 Flexural Strength for 28 days

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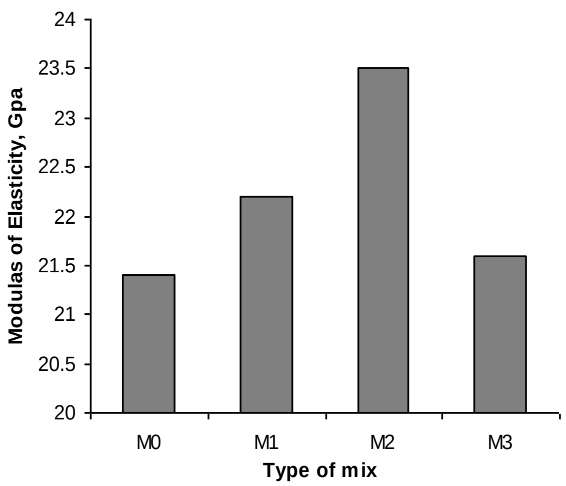

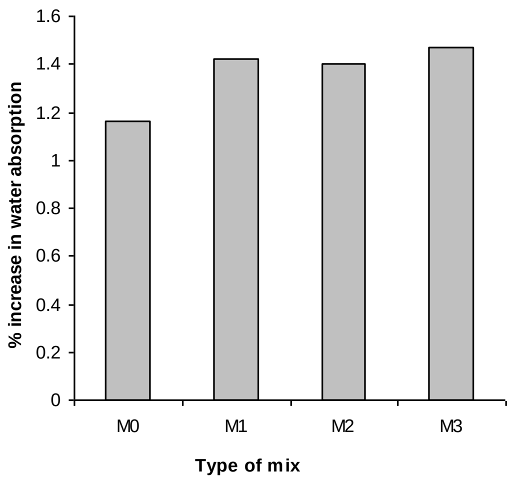

Fig 3.0 Modulus of Elasticity for 28 days

Fig 4.0 water absorption for 28 days

4. Conclusions

The improvement in compressive strength ranges from 10.75% to 27% across all metakaolin concrete mixes when compared to the control concrete. The compressive strength at 28 days for the M2 mix surpasses that of the other two mixes. The flexural strength of the M2 mix at 28 days outperforms that of the other two mixes. The modulus of elasticity for the M2 mix at 28 days is higher than that of the other two mixes. Water absorption is higher for all mixes when compared to the control mix. Among the mixes, the 15% replacement of metakaolin in concrete yields the maximum results at 28 days of curing.

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