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Effect of metakaolin on compressive strength of concrete by normal & accelerated curing

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Abstract: Concrete is widely used construction materials. However, the production of Portland cement releases large amount of CO2 (carbon dioxide), a greenhouse gas. One ton of Portland cement clinker production releases approximately one ton of CO2 and other gases. Environmental issues are playing essential role in the sustainable development of concrete industry. Metakaolin is mainly used as a mineral admixture in cement and concrete. Compared to silica fume and fly ash, metakaolin has a very high reactivity level. Previous studies have shown that metakaolin can increase the mechanical strength of concrete to varying degrees, depending mainly on the replacement rate of metakaolin, the water/binder ratio, and the age at testing Remarkably, metakaolin has a positive effect on reducing drying shrinkage and improving durability.

Keywords: Compressive Strength, metakaolin, Normal curing, Accelerated curing.

I. INTRODUCTION

Mineral admixtures such as supplementary cementitious materials are an indispensable part of modern concrete. The use of high activity admixtures such as slag and low-activity or inert admixtures such as limestone powder effectively reduces energy and resource consumption by decreasing the amount of cement used in the concrete production process and ensures the green and sustainable development of the concrete industries. More importantly, the use of admixtures reduces the dependence of modern concrete strength on cement strength, improves the rheological properties of the mixture, and increases the durability of concrete structures.

The compressive strength of cement concrete obtained after 28 days of moist curing is considered for quality of concrete in construction works. To get this strength for good quality control one has to wait for 28days. In order to get high early strength and also to reduce time for economical quality control, accelerated curing is used. In this method of curing the temperature of water is increased, which results in increase in concrete temperature and rate of development of strength accelerates which will be more comparing to normal moist curing.

▪ What is Accelerated Curing Test?
• Usually, the concrete specimen shall be tested after completion of 28 days of concrete curing activity.
• The accelerated curing test is a method of curing concrete specimens to attain its yield strength quickly. So, we can know the 28 days of compressive strength of concrete within a day.

▪ Why do we need it?
• Most of the time, knowing the concrete strength earlier helps avoid dangerous accidents and saves a life.
• This Accelerated curing method is mostly used in the precast construction industry, where the formwork needs to be removed at the earliest for productivity.
• To reduce the waiting period of formwork removal and to save cost eventually.

▪ How do you accelerate the curing of concrete?
• The acceleration concrete curing can be done by following methods,
• Warm water method
• Boiling water method

▪ Apparatus required
1. Curing Tank
2. Clock
3. Compression Testing Machine
4. Weighing Machine
5. Cube Mould

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- IS code for Accelerated Curing Tank

The specification of the accelerated curing tank has been mentioned in IS code 9013- 1978. The curing tank should be made of corrosion-resistant material.

- Chemical Composition of Metakaolin:

Chemical Composition(%)	MK(%)
SiO2	50.62
Al2O3	45.7
Fe2O3	0.31
CaO	0.2
Mgo	0.32
Na2+K2O	0.32

- Physical properties of metakaolin:

Metakaolin is a de-hydroxylated form of the clay mineral kaolinite . Here are some of its physical properties:

- Metakaolin is an aluminosilicate material that contains varying amounts of alumina (40%–45%) and silica (50%–55%). It is usually a white powder that consists of particles with a diameter of approximately 2µm, which makes it finer than Portland cement2.
- It is a pozzolanic material that can be used in concrete as an admixture.
- High reactivity metakaolin reacts with slaked lime at room temperature in the presence of moisture, resulting in slow hardening cement with great strength.
- Replacing Portland cement with 8–20% (by weight) metakaolin produces a concrete mix that exhibits favorable engineering properties, including the filler effect, the acceleration of OPC hydration, and the pozzolanic reaction.
- Metakaolin in concrete tends to reduce the size of pores which consequently leads to obtaining more strength, higher density, and more resistance to acid. Furthermore, metakaolin improves concrete resistance to alkali silicate reactions and sulphate attack.

II. MATERIALS AND METHODOLOGY

MATERIAL PROPERTIES:

1.Cement

Cement consists of four major compounds tricalcium silicate (C3S), dicalcium silicate (C2S), tricalcium aluminates (C3A) & tetra calcium aluminoferrite (C4AF). Tricalcium silicate (C3A) and dicalcium silicate (C2S) are the most important compound responsible for strength. Together they constitute 70 to 80 percent of cement. The average C3S content in modern cement is about 45 percent and that of c2s is about 25 percent.

During the course of reaction of C3S and C2A with water, calcium silicate hydrate (C-S-H) and calcium hydroxide (Ca(oH)2) are formed. Calcium silicate hydrates are the most important products and determines the good properties of concrete. C3S readily reacts with water and produces more heat of hydration. It is responsible for early strength of concrete. C2S hydrates rather slowly produces less heat of hydration.

It is responsible for later strength of concrete. The c3a portion of cement hydrates more rapidly, thereby reducing the workability of fresh concrete. Regarding particle size distribution, it may be noted that finer particles hydrate faster than coarser particles and hence contribute more to early age strength concrete; however, at the same time, the faster the rate of hydration may lead to quicker loss of workability due to rapid and large release of heat of hydration.

After reviewing all above requirements, ordinary portland cement (OPC) of 53 grades cement confirming to IS: 12269-1987 is used for this experimental investigation throughout. The cement is tested as per IS: 4031-1988.

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TABLE I: PROPERTIES OF CEMENT

Sr.No.	Description of Test	IS References	Result	IS Req.
1	Fineness of cement	IS 269-1976	1.00%	<10 %
2	Standard consistency of cement	IS 4031-1988	30.5%	26-33%
3	Setting time of cement: (is 12269-1987)	IS 269-1976		
	A) initial setting time		165 min	<30 min
	B) final setting time		275min	>600 min

2.Fine aggregate (sand)

Concrete is an assemblage of individual pieces of aggregate bound together by cementing material, its properties are based primarily on the quality of cement paste. This strength is dependant also on the bond between the cement paste and aggregate. If either the strength of the paste or the bond between the paste and aggregate is low, a concrete of poor quality will be obtained irrespective of strength of the aggregate, for making strong concrete, strong aggregate is an essential requirement. By and large naturally available mineral aggregate are strong enough for making normal strength concrete. Locally available sand, from "Pravara River", is used as fine aggregate, it confirm IS 383-1970.

TABLE II: PROPERTIES OF F.A.

Sr. No.	Description of test	IS References	Result	IS Requirement
1.	Fineness modulus	IS 2386 (part I)	3.97	2-4%
2.	Moisture content	IS 2386 (part IV)	2.55%	< 3%
3.	Specific gravity	IS 2386 (part III)	2.67%	2.5-3%
4.	Water absorption	IS 2386 (part III)	2.5	< 3%

3. Coarse aggregate

The nominal maximum size of coarse aggregate should as large as possible within the specified limits but in no case greater than one fourth of the minimum thickness of the member, provided that the concrete can be placed without difficulty so as to surround all reinforcement thoroughly and fill the corners of the form. Locally available crushed stone with 20mm & 12.5mm size aggregates confirming to IS 383:1970 are used.

TABLE III: PROPERTIES OF C.A

Sr. No.	Description of test	Result	IS Requirement
1.	Fineness modulus of coarse aggregates		
	20mm	7.739	6.75-8
	12.5mm	2.67	1.9-3.4
2.	Specific gravity		
	20mm	2.88	2.5-3
	12.5mm	2.78	2.5-3
3.	Water absorption		
	20mm	1.5	<2%
	12.5mm	1.75	<2%

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4. Metakaolin

Metakaolin used in this project work, Metakaolin is formed by exposing calcining kaolin to high temperature and typically contains 40-45% aluminium oxide(Al_2O_3) and 50-55% silicon oxide(SiO_2).

Metakaolin is a highly reactive pozzolana formed by the calcinations of kaolinite (China clay). It has to be processed in a burning process like cement, although the temperature of production is between 700 and 900 °C.

III. EXPERIMENTAL WORK

The performance of concrete is influenced by a proper mixing and good practice of mixing can lead to better performance and quality of the concrete. In the present study, total 72 cubes of M30 grade standard concrete cubes of size 150x150x150 mm were casted for determining the compressive strength for required number of days.

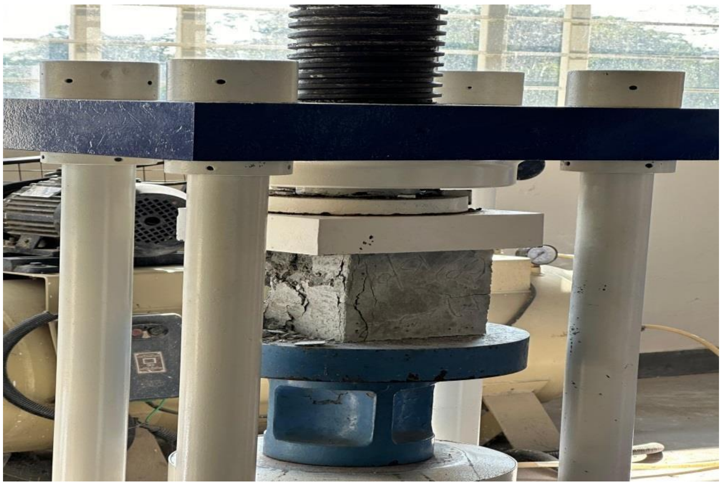
- Conventional curing:

Out of 72 cubes, total 36 cubes has to follow the conventional curing for 28 days which involves dipping the specimen in water at 25 degree Celsius at the end of 24 hours of casting after allowing for air drying.

After curing of 28 days the cubes are tested on compressive testing machine (CTM).

- Accelerated Curing:

After casting the specimen, out of 72 cubes, total 36 cubes are subjected to accelerated curing by as per IS 9013-1978. The specimen were stored in a place free from vibration, in moist air for at least 90 percent relative humidity and at a temperature of 27± 2 degree Celsius for 23 hours ± 15 minutes from the time of addition of water to the ingredients. The specimen were then gently lowered into the curing tank and totally immersed for a period of 3.5 hours ± 5 minutes. The temperature of the water in the curing tank was maintained to 100 degree Celsius. After curing for 3.5 hours ± 5 minutes in the curing tank, the specimen were removed from the boiling water tank, taken off the moulds and cooled by immersing in cooling water tank at 27 ± 2 degree Celsius for 2 hours.



IV. RESULT

TABLE IV: TEST RESULT OF M30 GRADE CONCRETE WITH METAKAOLIN

Grade Of Concrete (With Metakaolin)	Average Strength (Normal Curing) N/mm^2	Average Strength (Accelerated Curing) N/mm^2
M30 (10%)	34.64	32.88
M30 (15%)	35.48	34.50
M30 (20%)	30.72	29.75

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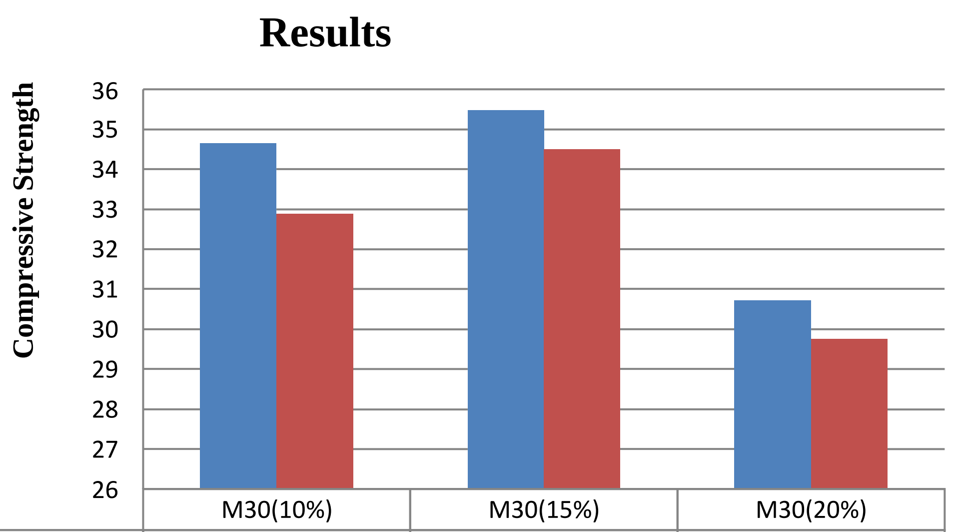

	M30(10%)	M30(15%)	M30(20%)
Avg.Comp.Strength(Normal Curing)	34.64	35.48	30.72
Avg.Comp.Strength(Accelerated Curing)	32.88	34.5	29.75

V. CONCLUSION

- In this project to utilize the metakaolin as a replacement of cement in construction industry. The percentage replacements of metakaolin varied from 10, 15% & 20 % in M30 grade concrete.

- In compressive test results shows that when compare to conventional concrete the % replacement of metakaolin in cement (10, 15%) strength is increases and above 15% there is decrease in strength of concrete.

- Hence the optimum replacement of metakaolin is 15% in concrete.

- By using normal curing 100 % strength of concrete with metakaolin is achieved after 28 days of curing.

- By using accelerated curing 95% strength of concrete with metakaolin is achieved within 24 hours.

- The replacement of 15% of the cement by Metakaolin is superior to all other mixtures, so it can be considered as the optimal percentage of Metakaolin.

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