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Performance of Concrete by Partial Replacement of Cement by Metakaolin

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ABSTRACT: Among many mineral admixtures available, Metakaolin (MK) is a mineral admixture, whose potential is not yet fully tested and only limited studies have been carried out in India on the use of MK for the development of high strength concrete. MK is a supplementary cementitious material derived from heat treatment of natural deposits of kaolin. MK shows high pozzolana reactivity due to their amorphous structure and high surface area. The experimental work has been carried out as partial replacement of cement with MK in M30 grade of concrete at 0%, 5%, 10%, 15% and 20% of replacements. The mix design was made making the use of IS Standard method. Cubes and cylinders are tested for compressive and split tensile strength test. Conclusions are made from the various results and the discussions there on to identify the effect of partial replacement of cement by MK in the design concrete mix. The results conclude that, the concrete with 15% of metakaolin shows the maximum compressive strength and split tensile strength. Beyond % of metakaolin increases the strength should be decreases.

KEYWORDS: metakaolin, compressive strength, split tensile strength.

I. INTRODUCTION

Concrete is the most widely used and versatile building materials which is generally used to resist compressive force. By addition of some pozzolanic materials, the various properties of concrete viz, workability, durability, strength resistance to cracks and permeability can be improved. Many modern concrete mixes are modified with addition of admixture, which improve the microstructure as well as decrease the calcium hydroxide concentration by consuming it through a pozzolanic reaction.

Metakaolin is pozzolanic materials which are manufactured from selected kaolin's, after refinement and calcination under specific condition. It is a highly efficient pozzolana and reacts rapidly with the excess calcium hydroxide resulting from OPC hydration by a pozzolanic reaction, to produce calcium silicate hydrate and calcium aluminosilicate hydrates. This paper envisages the use of metakaolin as partial replacement of OPC in M-30 grade of concrete. The percentage replacement of OPC by metakaolin was 0%, 5%, 10%, 15% and 20%. The test specimens (cubes) casted and tested as per relevant IS code of practice for 3 days, 7 days, 28 days compressive strength.

USE OF METAKAOLIN IN CONCRETE

The use of Metakaolin becomes very important ingredients in the production of concrete of more than 30MPa or where service environments, exposure conditions or life cycle cost considerations dictate the use of High-Performance concrete. For High Strength Concrete Silica Fume/Micro Silica is used. When these are replaced by Metakaolin, concrete of equivalent strength and durability properties developed along with several additional features like reduced water permeability, workability and pumpability.

Metakaolin functions by converting an undesirable byproduct of the cement hydration process, calcium hydroxide (Free lime) to various forms of calcium aluminate. These materials can be described as cementitious, as they contribute to the strength of the concrete. In its pure form, Metakaolin reacts with upto 1.6 times its mass of CH.

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Metakaolin reduces the size of pores in cement paste and transforms many finer particles into discontinuous pores, therefore decreasing the permeability of concrete substantially. Metakaolin increases compressive and flexural strengths. It reduces water permeability and efflorescence. Also, it reduces heat of hydration.

II. MATERIALS AND METHODOLOGY

MATERIALS USED

Generally cement concrete is a combination of cement, fine aggregates, coarse aggregates and water. In order to increase the strength here we replaced cement partially with metakaolin.

Ordinary Portland Cement

The cement is a binding material. It conforming to IS456-2000-53 grade. It consists of grinding the raw materials, mixing them intimately in certain proportion depending upon their purity and composition and burning them in a kiln at a temperature of about 1300 – 1500 degree centigrade at which temperature, the material center and partially fuses to form modular chapped clinker. The clinker is cooled and ground to a fine powder with addition of 2 to 3% of gypsum the product formed by using this procedure Portland cement. Of all the materials that influence the behavior of concrete, cement is the most important constituent, because it is used to bind sand and aggregate and it resists atmospheric action.

Graded Fine Aggregates

The materials smaller than 4.75 mm size is called fine aggregates. Natural sand is generally used as fine aggregate. In this experimental work replacement of river sand by quarry waste (fineness modulus of crushed sand equal to 3.95) conforming to grading Zone III of IS – 383 – 1970 was used as fine aggregates.

Graded Coarse Aggregate

Locally available well graded granite aggregates of normal size greater than 4.75 mm and less than 20mm having fineness modulus of 3.95 was used as coarse aggregates.

Water

Potable water has been used for casting concrete specimens. The water is free from oils, acids, and alkalis and has a water-soluble Chloride content of 140 mg/lit. As per IS 456 – 2000, the permissible limit for chloride is 500 mg/lit for reinforced concrete; hence the amount of chloride present is very less than the permissible limit.

Metakaolin

Meta kaolin is not a by-product. It is obtained by the calcinations of pure or refined Kaolinite clay at a temperature between 6500 C and 8500 C, followed by grinding to achieve a finesse of 700-900 m²/kg. It is a high quality pozzolonic material, which is blended with cement in order to improve the durability of concrete. When used in concrete it will fill the void space between cement particles resulting in a more impermeable concrete. Metakaolin, is a relatively new material in the concrete industry, is effective in increasing strength, reducing sulphate attack and improving air-void network.

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Metakaolin

Super plasticizer:

To impart the additional desired properties, a super plasticizer (Conplast SP337) was used. Dosage of super plasticizer was added 1.5% by weight of cement.

LABORATORY TEST RESULTS

Cement

SL NO	CHARACTERISTICS	RESULTS	SPECIFICATIONS
1	Specific gravity	3.19	IS:2720[part 3]
2	Standard consistency	30%	IS:4031[26-33%]
3	Fineness	4.33%	Not more than 10%
4	Initial setting time	45min	IS:4031[>30min]

Metakaolin

The specific gravity of metakaolin is 2.45

Fine Aggregate

SL NO	PROPERTIES	TEST RESULT
1	Specific gravity	2.65
2	Optimum moisture content	1.21%
3	Fineness modulus	3.95
4	Bulk density	1810 kg/m ³
5	Grading zone	II

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Coarse Aggregate

20mm downsize crushed stone aggregates were procured from a local quarry.

SL NO	PROPERTIES	TEST RESULT
1	Specific gravity	2.67
2	Fineness modulus	6.61
3	Bulk density	1630 kg/m ³
4	Crushing value	49.73%
5	Impact value	18.60%
6	Water absorption	0.6%

III. MIX DESIGN

Mix proportion

Cement (Kg/m ³)	FA(Kg/ m ³)	CA(Kg/ m ³)	Water(lts)	SP
340.0	748.68	1175.86	153.246	3.94
1	2.19	3.45	0.45	0.015

IV. TESTS ON CONCRETE

The various tests are conducted to know the performance of concrete by partial replacement of cement by metakaolin

1. Compressive strength test
2. split tensile strength test

COMPRESSION STRENGTH TEST RESULTS:

Compression Test Results

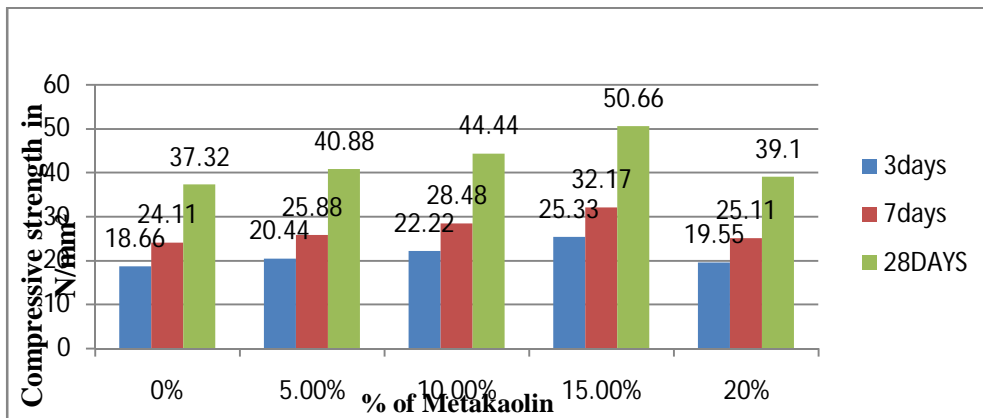
Compressive strength in N/mm ²	Age(days)		
	3	7	28
0%	18.66	24.11	37.32
5%	20.44	25.88	40.88
10%	22.22	28.48	44.44
15%	25.33	32.17	50.66
20%	19.55	25.11	39.10

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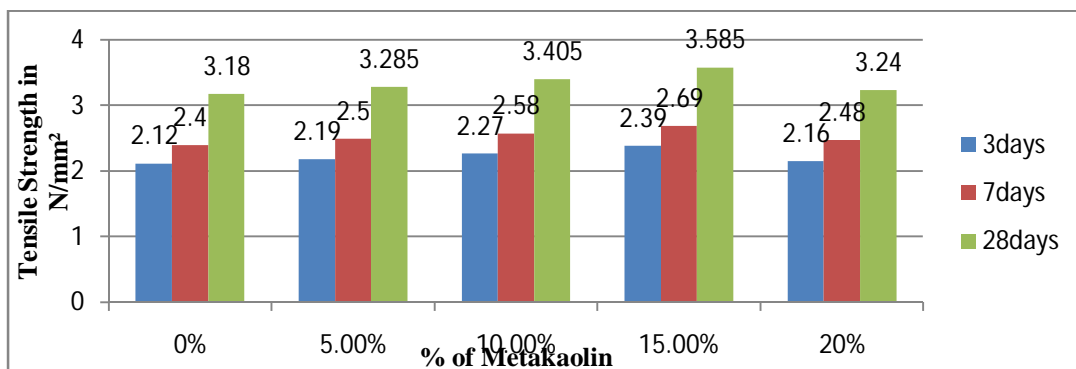


Comparison of Compressive Strength

SPLIT TENSILE TEST RESULTS

Split Tensile Test Results

Tensile strength in N/mm ²	Ages(days)		
	3	7	28
0%	2.12	2.4	3.18
5%	2.19	2.50	3.285
10%	2.27	2.58	3.405
15%	2.39	2.69	3.585
20%	2.16	2.48	3.24



Comparison of Split Tensile Strength

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V. CONCLUSION

The following broad conclusion can be drawn from the experimental study on performance of concrete by partial replacement of cement with metakaolin,

1. Maximum compressive strength & Split tensile strength is achieved at 15% metakaolin, then after it decreases.
2. It can be concluded that the addition of metakaolin increases the compressive strength and split tensile strength of concrete by 35%, at 15% replacement of cement by metakaolin in concrete.
3. As the percentage of metakaolin increases workability of concrete decreases.

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