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Research paper

Study of Concrete Strength Parameters Using Metakaolin as A Partial Replacement of Cement and M Sand as Fine Aggregate

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Abstract

Metakaolin is a pozzolanic material that is produced by high quality kaolin heated to a temperature between 600°C-800°C. It is the most efficient and widely used mineral admixtures in concrete these days. Because of its pozzolanic properties, it can also be used to replace cement to make High Performance Concrete (HPC) mixes. Metakaolin helps concrete to obtain both higher strength and economy. The aim of the research is to find out the compressive strength, split tensile strength ad flexural strength of concrete made with partial replacement of cement with metakaolin and Msand as fine aggregate. Cement is replaced with metakaolin in proportions of 5%, 10%, 15%, 20% ,25% & 30% and its strengths compared with the controlled specimens. From the experimental study, it is concluded that concrete containing metakaolin has higher compressive strengths, tensile strengths and flexural strength as compared to controlled specimen and it give better results when replaced upto 25%.

Keywords: *Mineral admixture, metakaolin, manufactured sand, pozzolanic properties*

1 Introduction

Concrete is the most widely uses material on earth for construction. Since the start of industrialisation and with the rise in development its constant usage has increased tremendously. As concrete consists of a mixture of cementing materials, water and aggregates, large amount of these raw materials which are present naturally are being utilised and the continuous use of these natural resources has led them to the verge of depletion. Therefore it is important to find out alternative ways to reduce the utilization of these resources.
Metakaolin is a pozzolanic material that is produced by high quality kaolin. It is a product that is manufactured for use rather than a by-product and is found when china clay, the mineral kaolin is heated to a temperature between 600°C-800°C. It is derived from a naturally occuring mineral and is manufactured specifically for cementing applications. MK is usually produced by thermal treatment i.e., calcinations of kaolin clays within a valuable range. It acts as a valuable admixture for cement and concrete applications.

2 Literature Review

Several literatures were reviewed to study the utilisation of pozzolanic materials in concrete .Sunny A Jagtap et al (2017) conducted a research work to find out the properties of concrete when Metakaolin(MK) is replaced in cement. The research includes conducting test for concrete specimens to evaluate the compressive strengths and flexural strengths at the age of 7 and 28 days. A concrete mix of M35 was determined according to IS 10262:2009 with a replacement of 5%, 10%, 15%, 20%, 25% MK. The test results showed that the strength increases as compared to conventional concrete. It was concluded that with the increase in percentage of MK, the workability of concrete decreases. Satyendra Dubey et al (2015) experimented on the effect of MK on the compressive strength of concrete. The study dealt with finding out the properties of M25 concrete with varying percentage replacement of MK. From the results obtained it was found that MK tends to increase the strength of the concrete mix when compared with conventional concrete. M Narmatha et al (2016) investigated on the effect of partial replacement of cement with MK in concrete to analyse its strength. The results concluded that the strength of all concrete containing MK increases abruptly compared to the strength of OPC. Concrete containing 15% of MK is most superior and it increases the compressive and split tensile strength. Manu Vijay et al (2017) carried an investigation to study the strength characteristics of M30 grade concrete mixes. Experimental investigations were conducted to assess the compressive strength and split tensile strength of concrete after 28 days curing. The test performance showed that there was an increase in compressive strength and also the split tensile strength with the increase in content of MK. However both the strength is maximum at 15% replacement gained at 28 days curing period. Partial replacement of cement by MK increases workability of fresh concrete, therefore use of superplasticizers is not important. Thus the study concluded that concrete containing MK give better performance compared to

concrete with MK.since Pozzalaonic materials has the tendency to gain strength after 28 days it was proposed in this research to extend the test at 56 days.

3 Materials Used

Ordinary Portland Cement (53 grade) conforming to IS 8112 was used throughout the experimental study. The metakaolin that is being used throughout the experiment is collected and contains the following properties:

- Colour: Off-white
- pH (10% SOLIDS): 4.5–5. 5
- Bulk density (Kg/Lit): 0. 4 – 0. 5
- Specific surface area in m^2/g (BET): 19 – 20
- Specific gravity: 2. 6

The chemical composition of metakaolin is given in the table 1 below:

Table 1: Composition of Metakaolin

CHEMICALS	PERCENTAGE(%)
SiO2	52.0
Al2O3	46.0
Fe2O3	0.60 (MAX)
TiO2	0.65 (MAX)
CaO	0.09 (MAX)
MgO	0.03 (MAX)
Na2O	0.10 (MAX)
K2O	0.03 (MAX)
LOSS ON IGNITION	1.00

The fine aggregate that is being used in this experimental study is M sand. M sand is sand produced from crushing of hard granite stone which is used as a substitute of river sand for concrete construction. It is of cubical shape with grounded edges, washed and graded to fit as a construction material. The size of manufactured sand is less than 4.75mm.The physical properties of M sand as per preliminary investigations are given in the table in table 2.

Table 2: Physical Properties of M sand

PARAMETERS	VALUES
Particle Shape	Irregular
Appearance	Grey
Surface Texture	Smooth
Specific gravity	2.6
Water absorption (%)	2.8%
Fineness modulus	2.6%

The Coarse aggregates of size 20mm and with a finenesss modulus of 6.8 was used. Potable water was used for mixing. A concrete mix of grade M30 was prepared with a constant w/c ratio of 0.45.

4 Experimental Analyses

The concrete was casted into cube moulds having edges of 150mm, cylindrical moulds having a diameter of 150mm and height of 300mm and prisms of dimension 150x150x700mm. The concrete inside the mould was compacted properly and left at room temperature for 24 hours. After 24 hours, the concrete specimens were removed from the moulds thereby they are being immersed in water for curing. The specimens were then taken out from the curing tank for testing at 7,28 and 56 days of curing. Flexural Strength Test Conducted results are tabulated in tables 3,4 and 5.Specimens were designated based upon percentage of replacement viz,first two letters represent Metakaolin(MK) and next numerical is for Percentage replacement.

Table 3 Strength results of specimens at 7,28 and 56 days

Metakaolin Content (%)	Compressive Strength at			Tensile strength at			Flexural strength at		
	7 days N/mm^2	28 days N/mm^2	56 days N/mm^2	7 days N/mm^2	28 days N/mm^2	56 days N/mm^2	7 days N/mm^2	28 days N/mm^2	56 days N/mm^2
MK0	20.09	32.3	33.22	1.50	2.69	3.23	2.36	4.23	5.17
MK5	18.088	34.52	38.07	1.54	2.75	3.65	2.57	4.60	5.61
MK10	19.33	37.57	41.3	1.58	2.82	3.86	2.67	4.78	5.88
MK15	21.03	44.47	46.7	1.74	3.11	4.35	2.76	4.93	6.07
MK20	24.90	38.83	42.1	1.61	2.88	3.76	2.71	4.84	5.85
MK25	21.74	35.13	36.96	1.54	2.74	3.57	2.56	4.58	5.69
MK30	19.67	31.6	32.06	1.32	2.35	2.71	2.17	4.09	4.75

From the compressive strength values it was found that upto 25% replacement of cement with Metakaolin there was increase in compressive strength when compared with controlled concrete. At a percentage replacement of 15% it has experienced the maximum strength . For 28 days, the tensile strength of MK5, MK10. MK15, MK20, MK25 increases gradually when compared to the controlled concrete MK0 at 28 days and 56 days. Beyond this replacement there is a declination of strength as the content of metakaolin is increased. The flexural strength results are tabulated in table 3. Figure 2 illustrates the variation of flexural strength with metakaolin content. The illustration clearly shows that the increase in strength is only upto 15% replacement beyond which the strength decreases. But when compared to controlled concrete the strength increases upto 25% .So metakaolin of 25% is the optimum replacement for better strength of concrete.

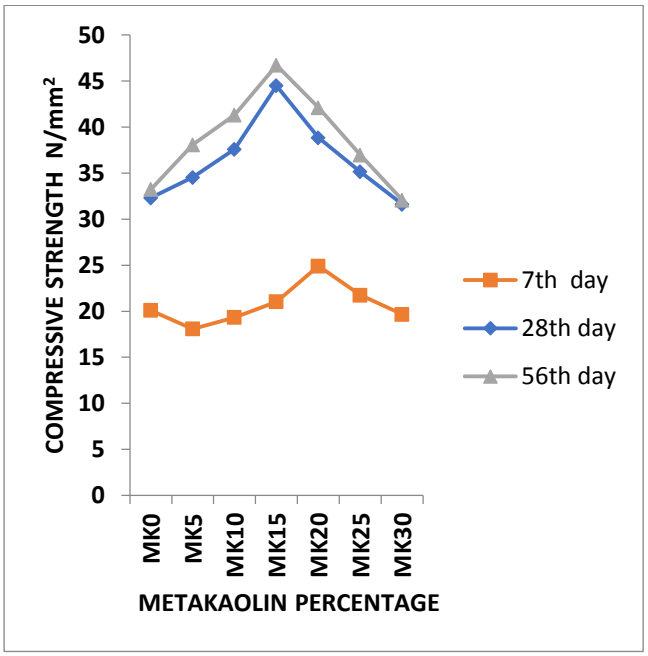

Figure 1 Variation of compressive strength with metakaolin content

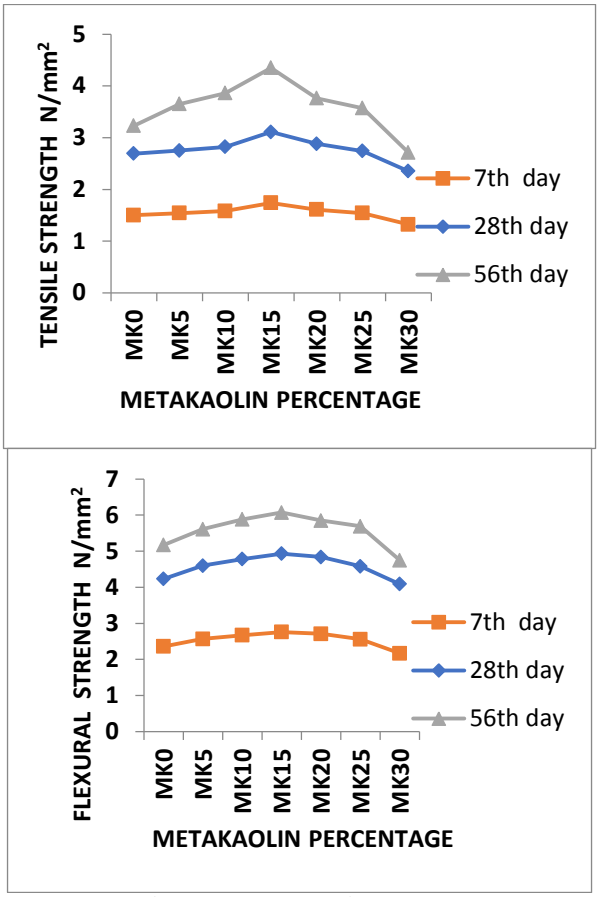

Figure 2 Variation of Tensile strength and flexural strength with metakaolin content

5 Conclusions

The study on the effect of incorporating metakaolin as a partial replacement of cement and fully replacing fine aggregate with Msand draws the following conclusions:

- Metakaolin when replaced with cement and natural sand with Msand improves the strength of concrete . Both the physical and chemical properties of metakaolin and cement are in meets the codal specifications.
- The compressive strength, tensile strength and flexural strength of metakaolin concrete at 28 and 56 days were found to increase with increase in metakaolin content with the maximum strength at 15% replacement. Upto a percentage replacement of 25% it is more than controlled concrete. A noticeable strength reduction at 7^{th},28^{th} and 56 th days of curing was observed at 30% Metakaolin.
- The optimum replacement of cement with metakaolin is found to be 25%.It was also observed that there is sufficient increase in strength with respect to increase in curing.
- Metakaolin can be used as a replacement in cement in the production of concrete for controlling the cost of production and also for sustainable development.

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