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PERFORMANCE OF METAKAOLIN CONCRETE IN BOND AND TENSION

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ABSTRACT

Concrete is the most commonly used material for construction. Supplementary cementitious materials are finely ground solid materials that are used to replace a portion of the cement in a concrete mixture. These supplementary materials may be naturally occurring, manufactured or manmade waste. Metakaolin is a dehydroxylated aluminium silicate. From the recent research works using Metakaolin, it is evident that it is a very effective pozzolanic material and it effectively enhances the strength parameters of concrete. This paper presents the results of an investigation on the use of metakaolin (MK) as a supplementary cementing material to improve the performance of concrete. Three MK replacement levels are employed in the study: 10%, 15% and 20% by weight of the Portland cement used. The performance characteristics of the concretes are evaluated by measuring compressive and splitting tensile strengths, bond stress. The results revealed that the inclusion of MK remarkably increases the strength properties of concrete depending mainly on the replacement level of MK.

KEYWORDS: metakaolin, compressive strength, tensile strength, bond strength.

INTRODUCTION

Supplementary cementitious materials (SCMs) are finely ground solid materials that are used to replace part of the cement in a concrete mixture. These materials react chemically with hydrating cement to form a modified paste microstructure. In addition to their positive environmental impact, SCMs may improve concrete workability, mechanical properties, and durability. SCMs may possess pozzolanic or latent hydraulic reactivity or a combination of these. The term pozzolan refers to a silecious material, which, in finely divided form and in the presence of water, will react chemically with calcium hydroxide to form cementitious compounds. Pozzolans can be of natural or industrial origin. Natural pozzolans include volcanic ash and diatomaceous earth, although pozzolans from industrial by-products are more commonly used today. Metakaolin (MK) is an SCM that conforms to ASTM C 618, Class N pozzolan specifications. MK is unique in that it is not the by-product of an industrial process nor it is entirely natural; it is derived from a naturally occurring mineral and is manufactured specifically for cementing applications. Metakaolin is produced from carefully calcining kaolin clay between 600 and 800oC to make it reactive. Unlike by-product pozzolans, which can have variable composition, MK is produced under carefully controlled conditions to refine its colour, remove inert impurities, and tailor particle size. As such, a much higher degree of purity and pozzolanic reactivity can be obtained. MK has great promise as an SCM, as it can improve many properties of concrete while also reducing cement consumption. In addition to improving concrete performance, metakaolin also makes concrete greener because metakaolin production does not produce chemical CO2 as opposed to cement (de-carbonating limestone) and also requires lower temperatures to produce (800 as opposed to 1450 oC).

EXPERIMENTAL PROGRAMME

Materials

The details of various materials used during the study are presented here. The cement used is Ultratech Ordinary Portland Cement (OPC) of 53 Grade conforming to Bureau of Indian Standard Specifications (IS: 12269-1987) with a specific gravity of 3.15. The locally available natural sand conforming to grading Zone II (IS: 383-1970) is used in concrete. The natural coarse aggregates obtained from the locally available quarries with maximum size of 20 mm and satisfying the grading requirements of BIS (IS: 383-1970) is used during this work. A cementitious material, Metakaolin, is used for cement replacement. It is a calcined clay pozzolanic material obtained from Golden micro chemicals, Bhiwandi used in the present experimental investigation. Reinforcing bars (ribbed), TATA steel 500 of 16mm diameters are used.

Table 1: Properties of Natural Aggregate

Aggregate crushing value	12.41%
Aggregate impact value	10.58%
Specific gravity	2.7
Water absorption value	2.76%
Fineness modulus	3.36

Table 2. Chemical composition of metakaolin

SiO2	52.2%
Al2O3	36.3%
Fe2O3	4.21%
MgO	0.81%
CaO	<0.10%
K2O	1.41%
LOI	3.53%

Specimen Preparation

During present experimental investigation four proportions of concrete mixtures are prepared for M20 and M25 concrete each. One mix is prepared as normal concrete and remaining three mixes are prepared with 10%, 15% and 20% replacement of metakaolin by weight of cement. Mix is prepared without any admixture.

The mixing of concrete ingredients is done using pan mixer in the laboratory. The test specimens prepared are: cubes of size 150 x 150 x 150mm for compressive strength test and bond stress test and cylinders with 150 mm (diameter) and 300 mm (height) for tension test. All specimens are prepared and cured according to I.S.516. All tests confirming to I.S. 2770 (Part I) 1967 are carried out. Reinforcing bars having diameter 16 mm are used for pull out test (Bond Stress) and tested at the age of 28 days of curing. Embedded length of reinforcing bar in concrete is considered as 15 times diameter of bar. The average value of three specimens is taken.

RESULT AND DISCUSSION

Table.3 compressive strength of M20 concrete

Sr. No.	Percentage of MK	7days strength (N/mm2	28 days strength (N/mm2)
1	0	16.82	23.76
2	10	20.66	26.51
3	15	24.73	31.44
4	20	20.37	28.66

Table.4 compressive strength of M25 concrete

Sr. No.	Percentage of MK	7 days strength (N/mm2)	28 days strength (N/mm2)
1	0	20.24	27.89
2	10	22.77	29.07
3	15	25.89	33.29
4	20	21.44	30.22

Graph1: % of MK v/s comp. strength for M20

Graph2: % of MK v/s comp. strength for M25

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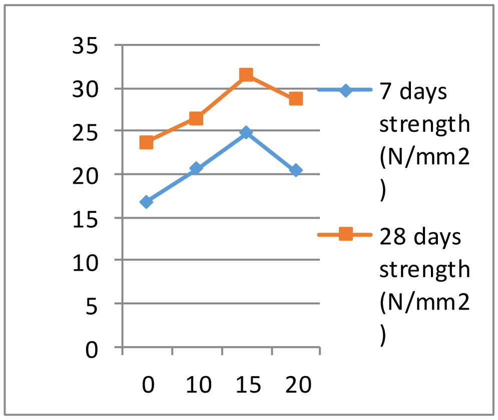
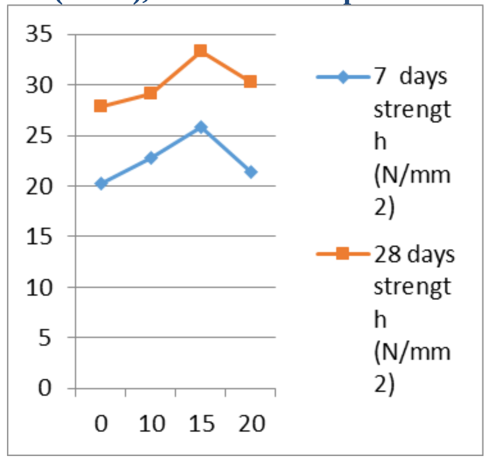




From the above table 3 & 4 it is seen that for both grade of concrete compressive strength increases with increase in percentage of metakaolin up to 15% and then it decreases. As the content of metakaolin increases workability of concrete decreases and concrete becomes harsh resulting into honeycomb structure.

Table. 5 Tensile strength for M20 & M25

Sr. No.	Percentage of MK	Tensile strength of M20 (N/mm2)	Tensile strength of M25 (N/mm2)
1	0	2.36	2.63
2	10	2.67	2.75
3	15	3.21	3.22
4	20	2.81	2.85

Graph 3. % of MK V/S tensile strength

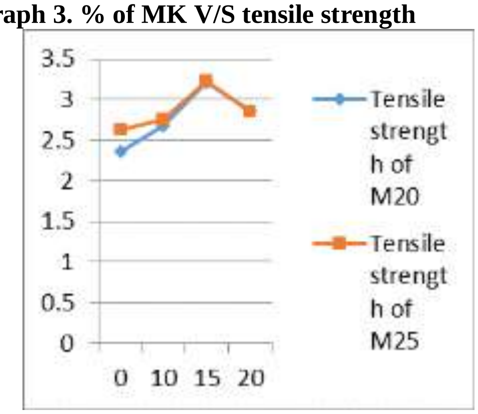
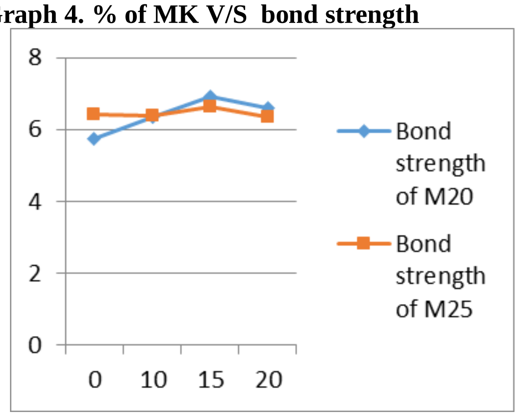


Table 5 shows the values of splitting tensile strength of concrete at different percentage of metakaolin. Tensile strength increases with increase in compressive strength.

Table. 6 Bond strength for M20 & M25

Sr. No.	Percentage of MK	Bond Strength of M20 (N/mm2)	Bond Strength of M20 (N/mm2)
1	0	5.75	6.41
2	10	6.36	6.38
3	15	6.91	6.65
4	20	6.59	6.34

Graph 4. % of MK V/S bond strength



In single pull out test (bond test) it is observed that specimen failure occure due to splitting. Table 6 shows the results of bond strength for 16mm dia. bar. As the compressive strength increases bond strength also increases but percentage increase in bond strength decreases.

CONCLUSION

The following conclusions are drawn on the use of metakaolin in concrete making:

1. Metakaolin reduces workability of concrete forming honeycomb structure.
2. The gain in compressive strength is improved depending upon the replacement level of OPC by metakaolin. At the replacement level of 10%, 15% and 20% of metakaolin by weight cement, maximum compressive strength occurs at 15%.
3. The metakaolin inclusion improves tensile strength and bond strength. It increases with increase in compressive strength.

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