EFFECT OF METAKAOLIN AND ALCCOFINE ON STRENGTH OF CONCRETE

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***Abstract*— Now-a-days enormous development occurred in the field of concrete technology. Many researchers have carried out several studies to investigate the possible utilization of broad range of supplementary cementitious materials as partial replacement of Portland cement. The use of supplementary cementitious materials in the production of concrete can result in major saving of cost and energy. It also helps to improve the strength and durability properties of concrete. The present investigation is carried out to study the effect of metakaolin and alccofine as partial replacement of cement on compressive strength and flexural strength of concrete. The replacement levels of metakaolin are selected as 5% and 7.5% and the replacement levels of alccofine are selected as 5%, 10% and 15% by weight of cement. From the results, it is observed that the compressive strength and flexural strength were increased with increase in replacement levels of metakaolin and alccofine.**

Keywords- Concrete; Alccofine; Metakaolin; Compressive Strength; Flexural Strength

1. INTRODUCTION

Concrete is the most widely used and versatile building material which is generally made to resist compressive stresses. By addition of some pozzolanic materials, the various properties of concrete viz.; workability, strength, permeability, and durability can be improved [1]. The production of Portland cement is not only costly and energy intensive, but also produces large amount of greenhouse gases which adversely impact on the environment. The utilization of calcined clay, in the form of metakaolin (MK), as a pozzolanic material for mortar and concrete has received considerable attention in recent years. This interest is part of the widely spread attention directed towards the utilization of wastes and industrial by-products in order to minimize ordinary Portland cement (OPC) consumption, the manufacture of which being environ-mentally damaging. Another reason is that mortar and concrete, which contain pozzolanic materials, exhibit considerable enhancement in durability properties [2]. Metakaolin is different from natural pozzolans or other types of artificial pozzolans in such a way that it requires a sequence of processes to obtain pozzolanic property. Metakaolin is a thermally activated alumino-silicate material obtained by calcining kaolin clay within the temperature range 650–800 °C [3]. Thermal activation process of the kaolin clay depends mainly on the mineralogical composition [4], [5] and [6]. Unlike industrial by-products, such as silica fume, fly ash, and blast-furnace slag, metakaolin is refined carefully to lighten its color, remove inert impurities, and control particle size. This well-controlled process results in a highly reactive white powder that is consistent in appearance and performance. The particle size of MK is generally less than 2μm, which is significantly smaller than that of cement particles, though not as fine as SF. It is typically incorporated into concrete to replace 5 to 20 wt% of cement. MK improves concrete performance by reacting with calcium hydroxide to form secondary C-S-H [7]. Alccofine 1203 (AF) is a specially processed product based on slag of high glass contentwith high reactivity obtained through the process of controlled granulation. The raw materials are composed primary of low calcium silicates. The processing with other select ingredients results in controlled particle size distribution. Due to its unique chemistry and ultra fine particle size, alccofine 1203 provides reduced water demand for a given workability, even upto 70% replacement level as per requirement of concrete performance. Alccofine 1203 can also be used as a high range water reducer to improve compressive strength or as a super workability aid to improve flow. Due to the lower water demand alccofine 1203 can be used as partial replacement for Portland cement which effectively enhances the properties of concrete, both in its fresh and hardened state. Thus in the present experimental investigation different levels of metakaolin and alccofine replacement for cement in concrete has made to analyze the effect of these mineral admixtures on strength of concrete.All standard paper components have been specified for three reasons: (1) ease of use when formatting individual papers, (2) automatic compliance to electronic requirements that facilitate the concurrent or later production of electronic products, and (3) conformity of style throughout a conference proceedings. Margins, column widths, line spacing, and type styles are built-in; examples of the type styles are provided throughout this document and are identified in italic type, within parentheses, following the example. Some components, such as multi-leveled equations, graphics, and tables are not prescribed, although the various table text styles are provided. The formatter will need to create these components, incorporating the applicable criteria that follow.

2. EXPERIMENTAL PROGRAM

The experimental program has been designed to evaluate the mechanical properties of concrete in ordinary Portland cement and ordinary Portland cement replaced by different percentages of metakaolin and alccofine. The details of the concrete mixtures used in this investigation are shown in Table 1.

Table 1: Details of concrete mixtures

Mix ID	Blending material	Water content (kg/m^3)	Cement content (kg/m^3)
MK0AF0	only OPC	191.6	426
MK5AF0	OPC + 5% MK (replacement)	191.6	404.7
MK7.5AF0	OPC + 7.5% MK (replacement)	191.6	394.05
MK0AF5	OPC + 5% AF (replacement)	191.6	404.7
MK0AF10	OPC + 10% AF (replacement)	191.6	383.4
MK0AF15	OPC + 15% AF (replacement)	191.6	362.1

2.1 Materials Used

Ordinary Portland cement and blended cements metakaolin and alccofine were used. The chemical composition of different admixtures and cement used in the present investigation is shown in Table 1. Ordinary Portland cement (OPC) of 53 grade satisfying IS: 12269-1987 [8] was used in preparing control concrete specimens. Metakaolin (MK) was used as 5% and 7.5% replacement by weight of ordinary Portland cement to prepare MK blended cement concrete specimens. In the alccofine (AF) cement concrete specimens, AF was used as a 5%, 10% and 15% replacement by weight of ordinary Portland cement. A cementitious material content of 426 kg/m3 was used in all concrete mixes. Fine aggregate (sand) with specific gravity of 2.6 and conforming to grading zone II as per IS: 383-1970 [9], was used in the preparation of concrete specimens. Coarse aggregates of size 20 mm MSA (maximum size aggregate) and 10 mm MSA were used in proportion of 60% and 40% respectively of the total mass of coarse aggregate. The measured values of specific gravity of 20 mm MSA and 10 mm MSA were 2.65 and 2.63 respectively. Tap water from laboratory was used as mixing water in the preparation of concrete mixes. Water content of 191.6 Kg/m3 was used in the concrete mixes for a slump range of 20 mm – 50 mm. The concrete specimens were made with water to cementitious ratio (w/c ratio) of 0.45.

2.2 Specimen Preparation

Concrete cubes specimens of 150 mm x 150 mm x 150 mm size and concrete beam specimens of 150 mm x150 mm x 700 mm size were casted to evaluate the variation in compressive strength and flexural strength respectively. After casting, the concrete specimens were kept in the moulds for 24 hours. The specimens were then demoulded and moist cured in a curing tank till the age of 28 days.

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Table 2: The chemical compositions of cement and admixtures used

Constituent (wt. %)	Ordinary Portland cement	Metakaolin	Alccofine
Silicon dioxide	23.46	63.48	34.67
Aluminum oxide	5.05	32.4	16.4
Ferric oxide	3.4	0.9	1.8
Calcium oxide	59.76	0.39	62.12
Magnesium oxide	3.31	0.08	8.22
sulphur trioxide	1.42	-	0.43
potassium oxide	0.54	0.06	-
Sodium oxide	0.3	0.56	-

2.3 *Test Methods*

2.3.1Compressive strength test

The compressive strength test was conducted on cube specimens at the age of 28 days in a compression testing machine. For each concrete mix containing different percentages of metakaolin and alccofine, three cubes were tested and the average value of compressive strength was determined. The performance of different concrete mixes was evaluated by determining reduction in compressive strength. The increase in compressive strength was determined using the following relationship:

$$\text{Increase in compressive strength} = \frac{(A-B)}{A} \times 100$$

Where, *A* is the average strength of specimens made with ordinary Portland cement (MPa) and *B* is the average strength of specimens made with ordinary Portland cement and different replacement levels of metakaolin and alccofine (MPa).

2.3.2 Flexural strength test

The flexural strength test was conducted on beam specimens at the age of 28 days in accordance with IS: 9399-1979 [10]. Flexural strength is expressed in terms of modulus of rupture, which is the maximum stress at the extreme fibres in bending. The Three-Point bending test is conducted on a loading frame to determine the flexural strength of concrete beams. The beam specimen is simply supported on two rollers separated 600 mm apart at the base. The shear span separating the loading points from the supports was equal on both ends of the specimens creating a zero shear region between the two loading points. The load was applied gradually without shock increasing continuously. The load is divided equally between two roller points and is increased until the specimen fails. The schematic diagram of beam setup is shown in Fig. 1. For each concrete mix containing different percentages of metakaolin and alccofine, three prisms were tested and the average value of flexural strength was determined.

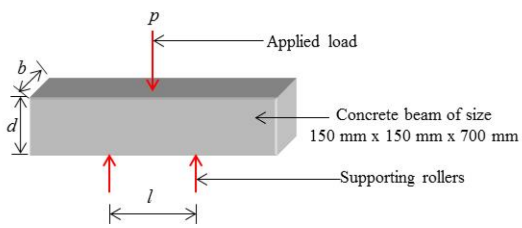

Fig. 1: schematic diagram of beam setup for flexural test

Modulus of rupture was calculated for the maximum load taken by the member as:

Modulus of rupture, $f_b = \frac{pl}{b\,d^2}$ for a > 133 mm

$f_b = \frac{3pa}{b\,d^2}$ for a < 133 mm

where P is the maximum load applied to the specimen (Kg), l is the span on which the specimen is supported (cm), b is the measured width of specimen (cm), d is the measured depth of specimen (cm), a is the distance between the line of fracture and the nearer support measured on the center line of the tension side of specimen (cm).

3. Results and Discussions

3.1 Compressive Strength

The compressive strength values of the different concrete mixes made from ordinary Portland cement and ordinary Portland cement replaced by different percentages of metakaolin and alccofine are shown in Fig. 2. The percentage increase in compressive strength at different replacement levels of metakaolin and alccofine is shown in Fig. 3.

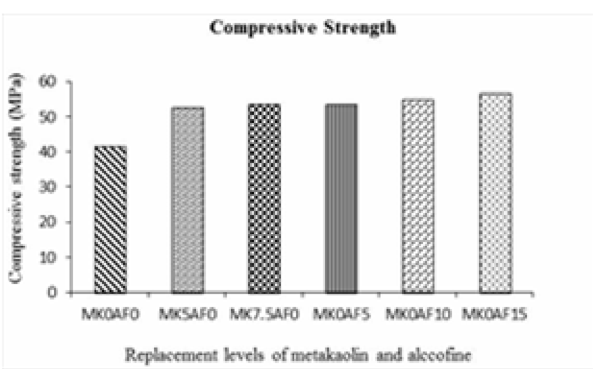

Fig.2: Compressive strength in different concrete mixes

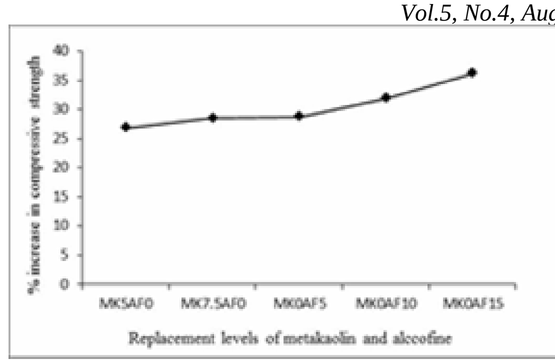

Fig.3: Percentage increase in compressive strength of different concrete mixes at different replacement levels of metakaolin and alccofine

From Fig. 2 it is observed that, the concrete specimens made with ordinary Portland cement showed lower compressive strength than the concrete specimens made with the ordinary Portland cement replaced by metakaolin and alccofine. Further it is also observed that, the compressive strength increased with increase in replacement levels of metakaolin and alccofine.

From Fig. 3, it is observed that the maximum increase in strength is achieved with 15% replacement of alccofine. The increase in compressive strength due to increase in replacement of cement by metakaolin and alccofine is attribute to its void filling ability. The pozzolanic materials form additional calcium silicate hydrate (C–S–H) upon the reaction of reactive silica of pozzolan and calcium hydroxide (CH) produced by the cement hydration. Thus the production of additional C-S-H gel due to pozzolanic reaction and extremely higher pozzolanic activity index and specific surface of metakaolin and alccofine increased the compressive strength of concrete as compared to control mix.

3.2 Flexural Strength

The flexural strength values of the different concrete mixes made from ordinary Portland cement and ordinary Portland cement replaced by different percentages of metakaolin and alccofine are shown in Fig. 4.

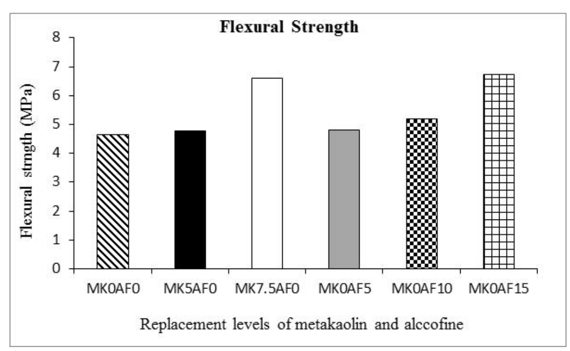

Fig. 4: Flexural strength in different concrete mixes

From Fig. 4, it is observed that the flexural strength of concrete specimens made with the ordinary Portland cement replaced by metakaolin and alccofine is higher as compared to specimens made with control mix. Further it is also observed that the flexural strength increased with increase in replacement levels of metakaolin and alccofine. The maximum flexural strength is achieved for ordinary Portland cement replaced by 15% alccofine. The dense pore structure and inbuilt calcium oxide of alccofine has increased the 28 days flexural strength as compared to control mix.

4. CONCLUSIONS

From the experimental investigations the following conclusions are drawn.

1. All the concrete mixes made with different replacement levels of metakaolin and alccofine by weight of ordinary Portland cement showed higher compressive strength and flexural strength as compared to concrete mix made with ordinary Portland cement.

2. The compressive strength of concrete was increased with increase in replacement levels of metakaolin and alccofine. The maximum increase in compressive strength was achieved with 10% replacement of alccofine.

3. The flexural strength of concrete was increased with increase in replacement levels of metakaolin and alccofine. The maximum increase in flexural strength was achieved with 10% replacement of alccofine.

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