EXPERIMENTAL INVESTIGATION OF STRENGTH PROPERTIES OF CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT BY USING METAKAOLIN

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ABSTRACT

In this experimental investigation, the study is based on the changes in strength properties of concrete specimens produced by Metakaolin as partial replacement material. The main objective of this work is to obtain a concrete with high compressive strength by using Metakaolin. The use of Metakaolin increases the mechani cal strength of concrete. Concrete is the most commonly used material for construction. The worldwide manufacture of cement has deeply increased since 1990. Manufacture of cement results in a lot of ecological pollution as it involves the emission of co_2 *gas. The supplementary cementations materials (SCM) are finely ground solid materials that are used to replace a portion of the cement in a concrete mixture. Leaving waste materials into environment directly results to natural climatic conditions, hence use of waste materials is made at most consequence in current day. In this experimental study, additions of metakaolin into the concrete were done as 10%, 20% and 30% respectively and compressive strength were tested at 7 and 14 days.*

Keyword: *Cement, Fine aggregate, Coarse aggregate, Water, Metakaolin etc……*

1. INTRODUCTION

Portland cement concrete is a mixture of Portland cement, aggregates, and water. Concrete is the most often-used construction material. The worldwide consumption of concrete was estimated to be about 8.8 billion tons per year. Due to increase in infrastructure developments, the demand for concrete would increase in the future.

The production of cement is increasing about 3% annually. The production of one ton of cement liberates about 0.7 tons of CO_2 to the atmosphere, as the result of de-carbonation of limestone in the kiln during manufacturing of cement and the combustion of fossil fuels.

The contribution of Portland cement production worldwide to the greenhouse gas emission is estimated to be about 1.35 billion tons annually or about 7% of the total greenhouse gas emissions to the earth's atmosphere. Cement is also among the most energy- intensive construction materials, after aluminum and steel. By the year 2016, the world cement consumption rate is expected to reach about 2 billion tones, meaning that about 1.4 tons CO_2 will be released. In order to address the environmental effect associated with Portland cement, there is a need to use other binders to make concrete.

1.1 CONCRETE

Basically made up of Portland cement, fine aggregates, coarse aggregates and water is one of the most versatile construction materials. The demand for Portland cement is increasing dramatically in developing countries. Portland cement production is one of the major reasons for CO_2 emissions into atmosphere. It is due to the use of fossil fuels, including the fuels required to generate electricity during cement manufacturing process.

Portland cement is the most used binder in the production of concrete; in 2008 the worldwide production of PC reached 2.83 billion tons. The production of 1 kg of PC generates 1 kg of CO_2, and considering that CO_2 is the main cause, after water Vapor, of the greenhouse effect, it is evident that alternative cementations materials are needed, in order satisfy mankind requirements of construction materials, with the least contribution to the current phenomenon of global warming and the consequent environmental impact.

1.2 METAKAOLIN

Metakaolin is refined kaolin clay that is fired under carefully controlled conditions to create an amorphous alumina silicate that is reactive in concrete. Kaolin is mined and crushed; it is separated from sand, refined to remove impurities and stored in store. Kaolin is fed into rotary kiln to produce Metakaolin is obtained from the calcinations of kaolinite clays at temperatures in the range of $650^{o}C – 700^{o}C$, high enough to allow for loss of hydroxyls but below temperatures that cause the formation of a vitreous phase and crystallization.

Metakaolin is very fine and highly reactive, gives fresh concrete a creamy, non-sticky texture that makes finishing easier. Metakaolin appears as a whitish haze on concrete, is caused when calcium hydroxide reacts with carbon dioxide in the atmosphere. Because Metakaolin is compatible with most concrete admixtures, such as super plasticizers, retarders, accelerators, etc. concrete made with Metakaolin can be cast finished and cured in almost the same fashion as ordinary concrete made without Metakaolin.

2. MATERIALS

2.1 Cement (OPC):

Portland cement of 43 grades available in local market was used. The cement used has been tested and Specific Gravity of Cement was found as g=3.12.

2.2 Fine Aggregate:

River sand from local sources was used as fine aggregate. River sand, (Grading zone-II conforming to IS: 383-1987) was used as fine aggregates in the experimental investigation. The specific gravity (G) of soil grains (or solids) usually called soil is the ratio of the weight in air of the given volume of dry soil solids at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature.

The specific gravity of sand was found in the laboratory by using Pycnometer and other accessories the test was done on the sample thrice the average of which reported the result as =2.61

2.3 Coarse Aggregate:

Crushed granite metal with 60% passing 20 mm and retained on 12.5mm sieve and 40% Passing 12.5mm and retained on 4.75mm sieve were used. The weight of coarse aggregate was 60% of the total Aggregate and specific gravity of coarse aggregate is found 2.40. These are crushed aggregates of well graded igneous rocks.

fig -1: Metakaolin

2.4 SPECIFIC GRAVITY TEST ON COARSE AGGREGATES:

Weight of pycnometer W1 = 604 gm.

Weight of pycnometer + coarse aggregate W2 = 1017 gm.

Weight of pycnometer + coarse aggregate + water W3 = 1695 gm.

Weight of pycnometer + water W4 = 1454 gm.

Specific gravity of coarse aggregate= (W2-W1)/ (W2-W1)-(W3-W4) =(1017-604)/(1017-604)-(1695-1454)

Specific gravity of coarse aggregate = 2.40

2.5 SPECIFIC GRAVITY TEST ON FINE AGGREGATE:

Weight of pycnometer W1 = 624 gm.

Weight of pycnometer + fine aggregate W2 = 1042 gm.

Weight of pycnometer + fine aggregate + water W3 = 1780 gm.

Weight of pycnometer + water W4 = 1522 gm.

Specific gravity of fine aggregate = (W2-W1)/ (W2-W1)-(W3-W4) = (1042-624)/ (1042-624)-(1780-1522)

Specific gravity of fine aggregate = 2.61.

2.6 SPECIFIC GRAVITY TEST ON CEMENT:

Cement has been tested as per IS: 4031-1988 and properties like specific gravity=3.15, consistency = 32%, initial setting time 95 minutes and final setting 215 minutes.

Weight of empty flask W1 = 25 gm.

Weight of empty flask + cement W2 = 34.7 gm.

Weight of empty flask + cement + kerosene W3 = 67.2 gm.

Weight of water + water W4 = 60.6 gm

Specific gravity of cement = (W2-W1)/ (W2-W1)-(W3-W4) = (34.7-2)/ (34.7-25)-(67.2-60.6)

Specific gravity of cement = 3.15.

2.7 MIX DESIGN

The mix design of concrete mix was done by using the guidelines of IS code method (IS102626-2009). The design stipulations and the data considered for mix design has been presented below.

Table -1: Physical Properties of Metakaolin

Specific gravity	2.40 to 2.60
Specific surface	8-15 m^2/g

Physical form	Powder
Color	Off white, gray to buff
Brightness	80-82 Hunter L
BET	15 m^2/g

2.8 DESIGN STIPULATIONS

Grade designation : M20

Type of cement : OPC 43

Maximum size of aggregate : 20mm

Minimum cement content : 300 kg/m^3

Water cement ratio : 0.40 – 0.60

Workability : 25mm

Exposure condition : Mild

Degree of supervising : Good

Type of aggregate : Crushed, angular aggregate

Maximum cement content : 450 kg/m^3

Admixture : Metakaolin

2.9 TEST DATA

Specific gravity of cement = 3.15(OPC 43)

Admixture = Metakaolin

Specific gravity of Metakaolin = 2.40 - 2.60

Specific gravity of coarse aggregate = 2.40

Specific gravity of fine aggregate = 2.61

Water absorption of coarse aggregate = 0.97%

Water absorption of fine aggregate = 0.83%

Moisture content of coarse aggregate = 2.40

Moisture content of fine aggregate = 2.61

Target strength for mix proportioning = f_{ck}+1.65× S= 20+1.65×4.0

Target mean strength = 26.60 N/mm^2.

Water cement ratio = 0.50

Metakaolin @ 10% of total cementations materials = 350×10%= 35 kg.

Water content = 186 kg/m^3= 186+ 3/100×186= 191.58 kg/m$^{3.}$

Cement content =191.8/0.50=383.60 kg/m^3.

Proportion of volume of coarse aggregate and fine aggregate:

Volume of coarse aggregate = 0.62 m^3

Volume of fine aggregate = 1- 0.62 =0.38 m^3

3. MIX PROPORTIONS

The following ranges were selected for the constituents of the mixtures used. Mix proportion of M20 grade mix was obtained by making certain modifications in the mix proportion on using the guidelines of IS code method, a cement content of 390 kg/m3 and water cement ratio of 0.50 were finalized based on compressive strength gain of concrete mix. Thus for making mixes cement content and water cement ratio of 0.50 were used along with optimum content of metakaolin as admixture. After carrying out several preliminary mix trails, the optimum content of metakaolin at 10%, 20% and 30% by weight of cement, were found to give desired workab ility and strength properties. The final mix proportion was arrived at by altering the ratio of fine aggregate to coarse aggregate and is expressed as parts of water: fine aggregate: coarse aggregate as given by 0.45:1:1.50:3.Based on the limited past research on metakaolin available in the literature and the experience gained during the preliminary experimental work.

fig -2: casting of concrete cubes.

3.1 TESTING OF SPECIMEN

After 7 days and 14 days curing period, the specimens were taken outside the curing tank and were tested under a compression testing machine of 2000KN capacity of compressive strength. The cracking loads and ultimate loads were noted and the average compressive strength of three specimens is determined. The compressive strength values of specimens subjected to different durability conditions.

3.2 Determination of split tensile strength:

Three cylinders of concrete specimens of size 150 mm×300 mm the specimens were tested at the age of 7 days and 14 days in the compressive testing machine. Apply the load horizontally, till the failure occurs and note the maximum load at failure. The load at failure shall be the maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine.

Split tensile strength in N/mm^2 = $\frac{2P}{\Pi l d}$

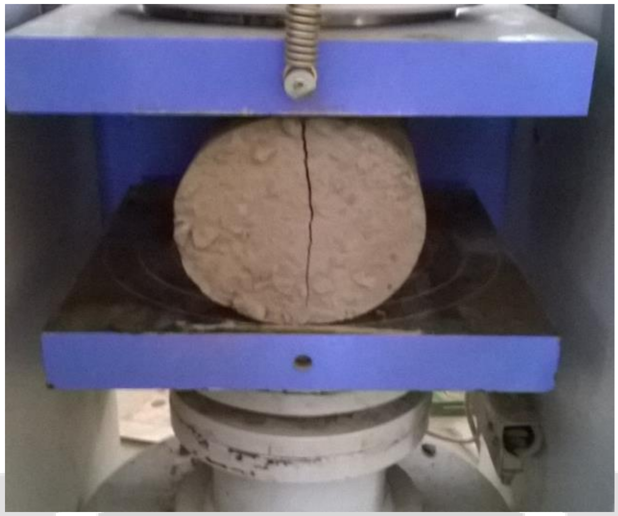

Fig -3: Split Tensile Test on Specimen

4. TEST RESULTS AND DISCUSSIONS

4.1 COMPRESSIVE STRENGTH

The compressive strength of metakaolin concrete was determined by using 150×150×150mm cubes. The development of compressive strength with age of all mixes is investigated. The compressive strength development depends upon the metakaolin dosage and the age of concrete. From the below obtained values metakaolin admixture mixes attains higher compressive strength than the conventional mix. The test results of failure load and compressive strength of conventional and metakaolin concrete for 7 and 14 days are shown in the table

MIX	Cracking load (KN)		Ultimate load (KN)	
	7 days	14 days	7 days	14 days
Conventional concrete	90	160	170	310
10% of metakaolin	130	210	230	390
20% of metakaolin	190	250	280	430
30% of metakaolin	270	280	370	440

Table -2: Failure load of compression

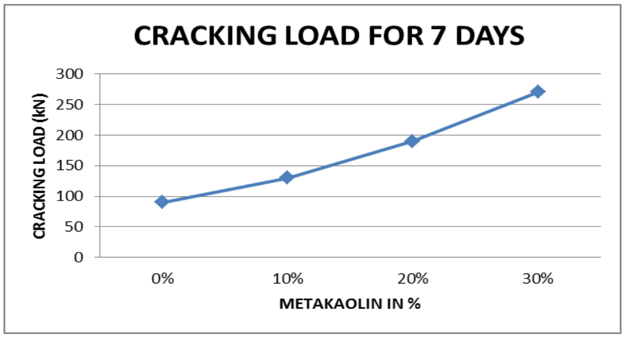

Chart -1: Failure load of compression

4.2 SPLIT TENSILE STRENGTH

The split tensile strength of a cured conventional and metakaolin concrete was determined by using 150mm diameter and 300mm height cylinders. Apply the load horizontally, till the failure occurs and note the maximum load at failure. The load at failure shall be the maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine. The test results of 7 and 14 days split tensile strength of concrete are shown in table.

4.3 Split tensile strength of concrete

MIX	Split tensile strength of concrete (mpa)	
	7 days	14 days
Conventional concrete	1.48	1.84
10% of metakaolin	1.84	2.05

. **Table -3:** Split tensile strength of concrete

5. DISCUSSION

On this experimental investigation, we are studied from the strength gain on concrete by the replacement of metakaolin at 10%, 20% and 30% in cement. It gives better strength compared to the performance of conventional concrete. Additional of metakaolin resulting in concrete with greater strength properties than the normal mixes.

6. REFERENCES

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