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Experimental Study On The Strength Of Concrete By Partial Replacement Of Cement By Metakaolin And Using M-Sand As Fine Aggregate

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ABSTRACT
Concrete is a mixture of the cement, water, fine aggregate and the coarse aggregate which hardens gradually to become a super- strong material. In the present days, the use of pozzolanic substances as the replacement in the Ordinary Portland Cement is increasing because of its promising enhnace in properties. The most frequently used pozzolans are fly ash, sugarcane bagasshe, silica fumes, metakaolin etc. The reason why the pozzolanic materials are used as the replacement is to increase the long-term strength and the other material properties of the concrete probably the mechanical and durability properties. And, M-sand is crushed aggregates produced from hard granite stone which is cubically shaped with grounded edges, washed and graded with consistency to be used as the substitute of river sand. In this experimental study project the concrete grade, M-35 was used. In these concrete mixes the sand was replaced with the M-sand and the cement was partially replaced by the metakaolin in various percentages throughout the experiment such as- 0%, 10%, 20% and 30%. The concrete specimens as well as coventional concrete was studied for their compressive strength(Cube Test), according to the Bureau of Indian Standards, for 7, 14 and 24 days. The result thus obtained were compared between the conventional concrete and the concrete with the metakaolin. From the test results, it was found that mixing nearly 20% can improve the properties of the concrete but beyond that there had seen a decline in the properties of the concrete.

Index Terms: M-sand, Metakaolin, convential concrete and compressive strength

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I. INTRODUCTION

Concrete is a composite material composed of fine and coarse aggregate bonded together with a fluid cement(cement paste) that hardens (cures) over time. With the advancement of technology and increased field of application of concrete and mortars, the strength, workability, durability and other characteristics of the ordinary concrete can be made suitable for any situation. For this, definite proportions of cement, water, fine aggregate, coarse aggregate, mineral admixtures and chemical admixtures are required. The demand for Portland cement is increasing dramatically in developing countries. Portland cement production is one of the major reasons for CO2 emissions into atmosphere. Metakaolin when used as a partial replacement substance for cement in concrete, it reacts with Ca(OH)2 one of the by- products of hydration reaction of cement and results in additional C-S-H gel which results in increased strength.

Metakaolin is obtained from the thermal activation of the Kaolin, which is often called as China Clay, at nearly 600 to 750_0 C. This activation will cause a substantial loss of water in its constitution causing a rearrangement of its structure. To obtain an adequate thermal activation The principal reasons for the use of clay-based pozzolans in mortar and concrete have been due to availability of materials and durability enhancement. This metakaolin is used as the partial replacement of cement or as an admixture in the concrete to see improving properties.

II. EXPERIMENTAL INVESTIGATION

2.1 Sampl collection METAKAOLIN

The material is collected from an local dealer in Chennai and it was transported from the industry to the University where we conducted the experiments in labaratory. The specific gravity of the metakaolin of the specimen is 2.45

Fig.2.1 Metakaoiln sample

CEMENT

Cement is also purchased from the local dealer near to the BHARATH university. The grade of the cement we bought was OPC 53. We found different properties of the cement before actually conducting the experiment. The specific gravity of the cement was found to be 3.14.

FINE AGGREGATE

We have used M-sand as the fine aggregate in this experiment. The M-sand is uesd as the replacement for the river because it's availability and the properties. This was bought from the BHARATH university premises as they were using that for the construction. The specific gravity of the M-sand was found to be 2.6.

COARSE AGGREGATE

The fractions from 20 mm to 4.75 mm are used as coarse aggregate. The aggregate used in this project mainly of Granite rock which comes under normal weight category. The aggregates are locally available. Specific gravity of aggregate is 2.65. Aggregates are the most mined material in the world.

WATER

Water should be easily available and it should be clear and tap water also sufficient to mix the **i**ngredients and it should not be any alkali and should be free from more chlorides of calcium and magnesium. We have used water available inthe University.

Experimental work

Based on the samples received from the dealers, the labaratory tests were conducted on the material in Bharath institute of Higher Education and Research to obtain the different properties. Accordingly, the following different kinds of tests had been performed on the material that had collected.

CEMENT

FINENESS OF CEMENT :-

TRIAL	Weight of Cement(gm)	Weight of residue in sieve(gm)	Fineness
1	100	6	94
2	100	8	92

Table.1 Fineness of cement

The fineness of the taken cement sample was 93%

STANDARD CONSISTENCY TEST :-

This experiment was conducted to determine the minimum water requirment to start the chemical reaction between water and cement. The standard consistency of a taken sample was 32%.

SPECIFIC GRAVITY :-
The specific gravity of cement is determined according to density bottle method "Standard Test Method for Specific Gravity of Soils".
Specific Gravity (G) = 3.14

COARSE AGGREGATE

IMPACT TEST :-
The Impact test was done to determine the aggregate impact value of Coarse Aggregate as per IS: 2386 (Part-IV)-1963.
The Impact value of the coarse aggregate was 8.15%.

LOS ANGLES ABRASION TEST :-
The Los Angles Abrasion Test is to determine the abrasion value of the taken Coarse Aggregate as per IS: 2386 (Part- IV)-1963.

The average value of Los Angeles Abrasion Test of taken Coarse Aggregate was 4.216%.

SI. NO	DESCRIPTION	SAMPLE 1	SAMPLE 2
1	Weight of Coarse Aggregate (w1)	5kg	5kg
2	Weight of given sample retained in IS sieve 1.7mm (w2)	4.206kg	4.226kg

Table.1.2 los angeles abrasion

WATER ABSORPTION TEST :-
The water absorption test is done to check the water that is absorbed by the Coarse Aggregate when it is in contact with water.
The water absorption of the Coarse Aggregate is 0.2%.

FINE AGGREGATE

2.2.3 SPECIFIC GRAVITY :-
The specific gravity of M-sand is determined according to the pycnometer method using "Standard Test Method for Specific Gravity of Soils".
Specific Gravity (G) = 2.6

SIEVE ANALYSIS :-
A sieve analysis (or gradation test) is a practice or procedure used in civil engineering and chemical enginnering to assess the particle size distribution (also called *gradation*) of a granular material by allowing the material to pass through a series of sieves of progressively smaller mesh size and weighing the amount of material that is stopped by each sieve as a fraction of the whole mass.
This was the graph obtained from the sieve analysis with the values which was determined during the sieve analysis experiment.

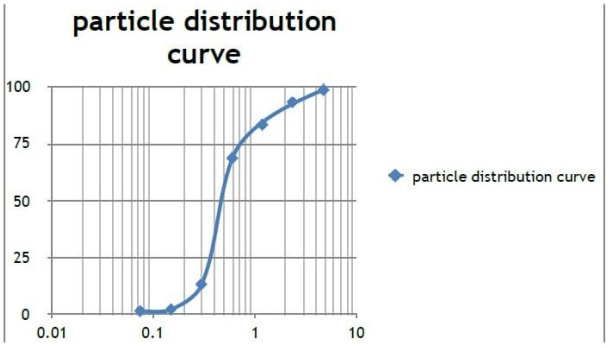

Fig 1 Sieve Analysis of M-sand

The fine aggregate that we had tested is in **ZONE III** which is obtained through the Sieve Analysis.

WATER ABSORPTION TEST :-

The water absorption test is done to check the water that is absorbed by the Fine Aggregate when it is in contact with water.

The water absorption of the Fine Aggregate is 2.3%.

METAKAOLIN

Metakaolin is obtained from the thermal activation of the Kaolin, which is often called as China Clay, at nearly 600 to 750_0 C. This activation will cause a substantial loss of water in its constitution causing a rearrangement of its structure.

So, it is important to determine the properties of the metakaolin.

SPECIFIC GRAVITY :-

The specific gravity of Metakaolin is determined according to density bottle method "Standard Test Method for Specific Gravity of Soils".

Specific Gravity (G) = 2.45

PROPERTIES OF CEMENT

Sl.No	Parameter	Value
1	Specific Gravity, G	3.14
2	Fineness	93%
3	Standard Consistency test	32%

Table.1.3 Properties of cement

PROPERTIES OF COARSE AGGREGATE

Sl.No	Parameter	Value
1	Specific Gravity, G	2.75
2	Impact test	8.15%
3	Los Angeles Abrasion Test	4.216%
4	Water Absorption	0.2%

Table.1.4 Properties of Coarse Aggregate

PROPERTIES OF FINE AGGREGATE(M-SAND)

Sl.No	Parameter	Value
1	Specific Gravity, G	2.6
2	Water Absorption	2.3%
3	Sieve Analysis	Zone III

Table.1.5 Properties of Fine Aggregate

2.3.4 PROPERTIES OF METAKAOLIN

Sl.No	Parameter	Value
1	Specific Gravity, G	2.45

Table.1.6 Properties of Metakaoiln

III. MIX DESIGN

Concrete is a composite mixture which consists of Cement, Sand and Aggregate. Concrete mix design is the procedure for finding the right quantities of these materials to achieve the desired strength. Accurate concrete mix design makes concrete construction economical. Large constructions such as Bridges, dams requires huge amount of concrete, using the right quantity of constituents make the structure economical. In order to calculate or find the right amount of cement, sand and aggregate required in 1m3 of concrete; you need to know about different grades of concrete.

According to the IS456:2000, the mix calculations of the cement, fine aggregate, coarse aggregate and water is carried out for **M35** mix and found **1:1.538:2.498**

MATERIAL REQUIREMENT PER CUBIC METER ACCORDING TO MIX DESIGN :-

WATER (L)	CEMENT (Kg)	METAKAOLIN (Kg)	FA (Kg)	CA (Kg)
197	437.7	0(0%)	637.29	1093.6
197	394	43.77(10%)	637.29	1093.6
197	350.16	87.54(20%)	637.29	1093.6
197	306.39	131.39(30%)	637.29	1093.6

Table.1.7 Mix calculations per meter cube FA- Fine Aggregate. CA- Coarse Aggregate

IV. COMPRESSIVE STRENGTH TEST ON SPECIMEN

SLUMP CONE TEST :-

A Slump cone test or concrete Slump test is to determine the workability or consistency of the concrete mixture prepared in the laboratory or at the construction site during the course of work. A concrete Slump test is performed from batch to batch to check the uniform quality of the concrete during construction.

According to IS 1199 – 1959, the experiment was conducted and results were obtained as shown below

S.NO	%(Added Metakaolin to Concrete)	Slump in mm
1	0%	100
2	10%	92
3	20%	86
4	30%	78

Table.1.8 Slump Cone Test

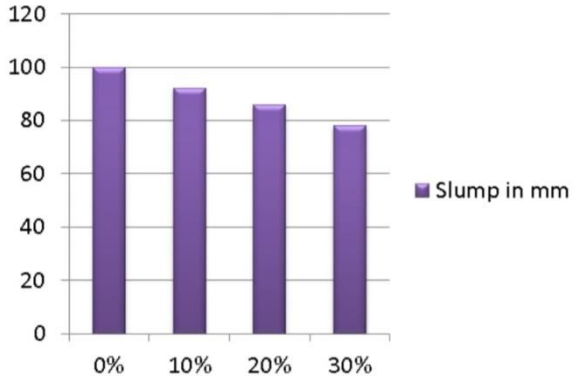

Fig 2 Slump cone test of Conceret

CUBE CASTING

The amount of materials added or mixed to get the desired cube of M35 for 0, 10, 20 and 30% of Metakaolin.

MATERIAL REQUIREMENT FOR THREE CUBES ACCORDING TO MIX DESIGN :-

% of Metakaolin	Cement (Kg)	FA (Kg)	CA (Kg)	Metakaolin (Kg)
0	5.76	8.862	14.39	0
10	5.184	8.862	14.39	0.576
20	4.608	8.862	14.39	1.152
30	4.032	8.862	14.39	1.728

Table.1.9 Mix calculations for three cubes FA- Fine Aggregate. CA- Coarse Aggregate

CUBE TEST

Compressive strength is the capacity of material or structure to resist or withstand under compression. The Compressive strength of a material is determined by the ability of the material to resist failure in the form cracks and fissure. In this test, the push force applied on the both faces of concrete specimen and the maximum compression that concrete bears without failure is noted.

The cubes were prepared according to the mix desgin and the cubes were started casting by mixing the concrete with the specimens and then the cubes were being cured for 7, 14 and 28 days to find the 28^{th} day compressive test of the cube.

According to the IS 516:1959, the experiment was carried out in the laboratory by the universal testing machine.

Fig 3 Testing of cube

Age of Specimens (days)	Compressive Strength M35 (N/mm^2)			
	Conventional concrete	With Metakaolin		
	0%	10%	20%	30%
7	22.6	23.5	26	24.6
14	33.3	33.6	36.2	33.8
28	37.6	38.4	40	37.2

Table.2 Compressive Strength of Cubes by age

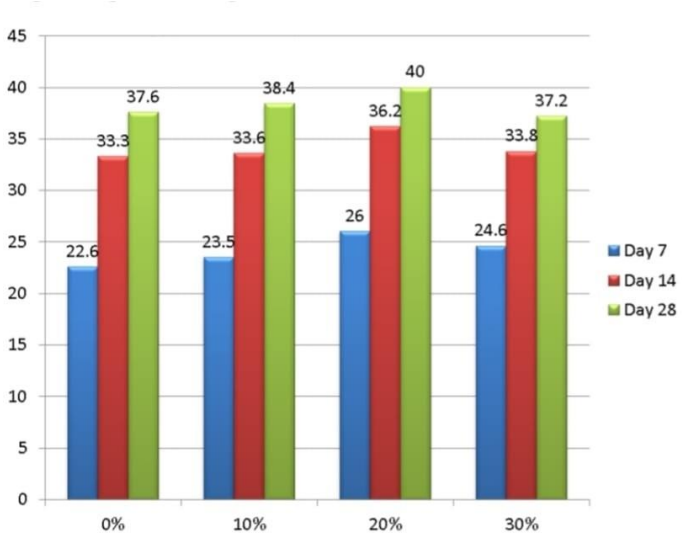

Fig 4 Bar chart of compressive strength

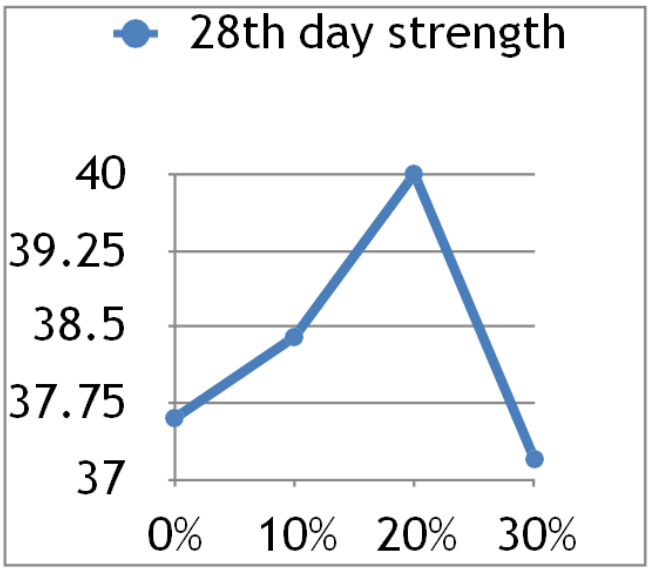

Fig 6 28th day compressive strength comparison

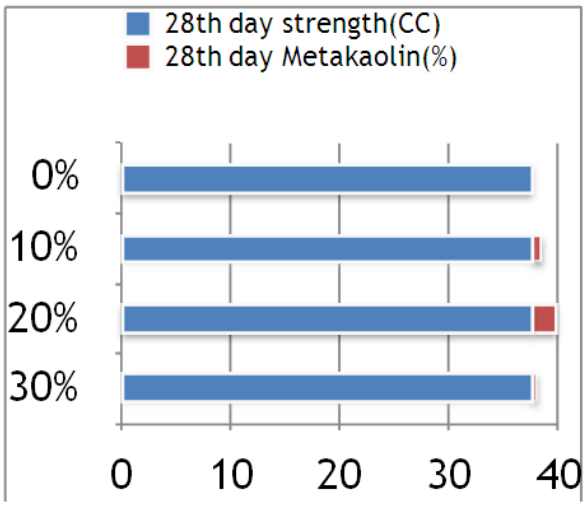

Fig 5 28th day compressive strength
CC - Conventional concrete

V. RESULTS AND DISCUSSION :-

Analysis Based on the experimental results and comparison with the conventional concrete,

- The Compressive strength of concrete increased when cement is replaced by Metakaolin for M35 grade of concrete.
- At 20% replacement of cement by Metakaolin the concreter attained maximum compressive strength for M35 grade of concrete.
- After addition of 30% Metakaolin, Compresive strength of concrete decreases with grade of concrete For M35grade concrete
- Adding Metakaolin to M35 grade Concrete. In general, we can conclude that addition of Metakaolin as replacement of OPC gives higher strength at 28 days and also improves the workability of concrete with lower w/c ratio.
- But adding excess amount of metakaolin can decrease its workability of concrete

VI. CONCLUSION :-

From the results of this study the concept of the properties of the materials and the compressive strength test . From the statistical analysis and the discussion part one can observe that there is a increase in the mechanical and the durability properties of the concrete The following conclusions may be made based on the above test results, discussions and correlations.

- It shows an increase in the strength of concrete upto 20%.
- It shows a decrease in the strength of concrete beyond 20%.
- It reduces the permeability of water into the concrete.
- It increases in the workability of the concrete.
- By observing the results of all the tests and prediction values, the concrete gains strength with the addition of metakaolin,which upto 20% shows a promising results.

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