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STUDY ON STANDARAD CONCRETE BY USING METAKAOLIN

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Abstract — *Metakaolin is a dehydroxylated form of the clay mineral kaolinite. Metakaolin is refined kaolin clay that is fired (calcined) under carefully controlled conditions to create an amorphous aluminosilicate that is reactive in concrete. Metakaolin reacts with the calcium hydroxide (lime) byproducts produced during cement hydration. Calcined between 600° and 850°C the kaolin is transformed to an amorphous phase called Metakaolin. This mineral is activated and metastable. Metakaolin can then react with cement and lime. Heating above 900°C produces mullite, a non pozzolanic material. The study is to investigate the mechanical properties of Normal concrete with different replacement levels of ordinary Portland cement by Metakaolin. The standard cubes (150mmX150mmX150mm) were caste. In all specimens with M25 grade mix proportional (1:1:2) cases were caste and tested. The material testing lick cement, fine aggregate (Sand) and coarse aggregate (Kapchi). The strength effect of Normal concrete of various amounts of replacement of cement viz., 0%, 3%, 5% with Metakaolin of M25 grades were compared with that of the Normal concrete without Metakaolin. The compressive strength at 7 and 28 Days have been obtained.*

Keywords- *Ordinary Portland cement (OPC), Partial replacement, Metakaolin, Structural Properties, Concrete.*

I. INTRODUCTION

Metakaolin is a dehydroxylated form of the clay mineral kaolinite. Metakaolin is refined kaolin clay that is fired (calcined) under carefully controlled conditions to create an amorphous aluminosilicate that is reactive in concrete. Like other pozzolans (fly ash and silica fume are two common pozzolans), Metakaolin reacts with the calcium hydroxide (lime) byproducts produced during cement hydration. Calcined between 600° and 850°C the kaolin is transformed to an amorphous phase called Metakaolin. This mineral is activated and metastable. Metakaolin can then react with cement and lime. Heating above 900°C produces mullite, a non pozzolanic material.

The quality and reactivity of Metakaolin is strongly dependent of the characteristics of the raw material used. Metakaolin can be produced from a variety of primary and secondary sources containing kaolinite:

- High purity kaolin deposits
- Kaolinite deposits or tropical soils of lower purity
- Paper sludge waste (if containing kaolinite)
- Oil sand tailings (if containing kaolinite)

High-reactivity Metakaolin:

High-reactivity Metakaolin (HRM) is a highly processed reactive aluminosilicate pozzolan, a finely-divided material that reacts with slaked lime at ordinary temperature and in the presence of moisture to form strong slow-hardening cement. It is formed by calcining purified kaolinite, generally between 650–700 °C in an externally fired rotary kiln. It is also reported that HRM is responsible for acceleration in the hydration of ordinary Portland cement (OPC), and its major impact is seen within 24 hours. It also reduces the deterioration of concrete by Alkali Silica Reaction (ASR), particularly useful when using recycled crushed glass or glass fines as aggregate. The amount of slaked lime that can be bound by Metakaolin is measured by the modified Chapelle test.

II. EXPERIMENTAL PROGRAM

2.1 Cement:

Ordinary Portland cement available in local market (Ultratech Cement) was used in the investigation. Care has been taken to see that the procurement made from a single batch and is stored in airtight containers to prevent it is being affected by atmospheric, monsoon moisture and humidity. The specific gravity was 3.10 and fineness was 3200 m2/Kg. The details are given in Table 1. The cement confirms to 53 Grade.

Properties	OPC (53 grade)	Metakaolin (MK)
Physical		
Specific gravity	3.1	2.5
Mean grain size (µm)	22.5	2.54
Specific area cm^2/gm	3250	150000-180000
Colour	Ivory to Cream	Dark Grey
Chemical compositions (%)		
Silicon dioxide (SiO2)	20.25	60-65
Aluminium oxide (Al2O3)	5.04	30-34
Iron oxide (Fe2O3)	3.16	1
Calcium oxide(CaO)	63.61	0.2-0.8
Magnesium oxide (MgO)	4.56	0.2-0.8
Sodium oxide (Na2O)	0.08	
Potassium oxide (K2O)	0.51	0.5-1.2
Loss on ignition	3.12	<1.4

Table 1: Physical Properties of 53 grade OPC and Metakaolin

2.2 Aggregate:

Aggregate properties greatly influence the behavior of concrete, since they occupy about 80% of the total volume of concrete. The aggregate are classified as:
(I) Fine aggregate
(II) Course aggregate

Fine aggregate are material passing through an IS sieve that is less than 4.75mm gauge beyond which they are known as coarse aggregate. Coarse aggregate form the main matrix of the concrete, where as fine aggregate form the filler matrix between the coarse aggregate. The most important function of the fine aggregate is to provide workability and uniformity in the mixture. The fine aggregate also helps the cement paste to hold the coarse aggregate particle in suspension.

According to IS 383:1970 the fine aggregate is being classified in to four different zone, that is Zone-I, Zone-II, Zone-III, Zone-IV. Also in case of coarse aggregate maximum 20 mm coarse aggregate is suitable for concrete work. But where there is no restriction 40 mm or large size may be permitted. In case of close reinforcement 10mm size also used.

2.2.1 Fine Aggregate (Sand):

The locally available river sand was used as fine aggregate in the present investigation. The sand is free from clayey matter, salt and organic impurities. The sand is tested for its properties like Specific Gravity, Bulk Density etc in accordance with IS 2386-1963.Sand was provided by locally area at Sankheda, Dist: Vadodara, Gujarat.

Fig 1: Fine Aggregate (Sand)

2.2.2 Course Aggregate (Kapchi):

Machine Crushed angular granite metal of maximum size of 20mm retained on 4.75mm I. S. sieve confirming to I.S. 383-1970 was used in the present investigation. It is free from impurities such as dust, clay particles and organic matter etc. Kapchi was provided by locally area at Sevaliya, Dist: kheda, Gujarat.

Fig 2: Course Aggregate (Kapchi)

2.3 Water:

Water is the least expensive but most important ingredient of the concrete. The water, which was used for making concrete was clean and free from harmful impurities like oil, alkalis, acids etc. in general, the water which is fit for drinking should be used for making concrete.

Fig 3: Water

2.4 Metakaolin:

Metakaolin is a dehydroxylated form of the clay mineral kaolinite. Metakaolin is refined kaolin clay that is fired (calcined) under carefully controlled conditions to create an amorphous aluminosilicate that is reactive in concrete. Like other pozzolans (fly ash and silica fume are two common pozzolans), Metakaolin reacts with the calcium hydroxide (lime) byproducts produced during cement hydration. Calcined between 600° and 850°C the kaolin is transformed to an amorphous phase called Metakaolin. This mineral is activated and metastable. Metakaolin can then react with cement and lime. Heating above 900°C produces mullite, a non pozzolanic material.

Fig 4: Metakaolin

2.4.1 Uses of Metakaolin:
Our experience has shown that optimal performance is achieved by replacing 10% to 15% of the cement with Metakaolin. While it is possible to use less, the benefits are not fully realized until at least 10% Metakaolin is used. The advantage of replacing some of the cement with Metakaolin, rather than simply adding Metakaolin to the mix, is that any existing color formulas or mix designs won't change, or will only very slightly change. This is because the dosage of pigments and super plasticizers are based on the cement content in the concrete.

2.4.2 Application of Metakaolin:
Facilitate finishing concrete surfaces by rubbing and smoothing due to the lack of stickiness of concrete to the tool and good thixotropy, It reduces the amount of cement in the formation of concrete, especially in concrete with high requirements for water resistance, Can significantly increase the residual strength of refractory concrete after firing; typically lose 50% of its strength after heating to 800oC, The strength and durability of concrete increases, Use of Metakaolin accelerates the initial set time of concrete, Compressive strength of concrete increases @ 20 % with Metakaolin.

III. DESCRIPTIONS OF MATERIALS:

3.1 Result of Cement:

Material: Cement (Ultratech)
Grade: 53 OPC
Ref. Code: I.S. 12269: 1987

Sr. No.	Particular	Result	IS Recommendation
1.	Consistency in %	29.50	----
2.	Setting Time (minutes)		
	Initial (Minimum)	69	30 (mini)
	Final (Maximum)	195	600(max)
3.	Soundness, expansion	2.00	10.00 (max)
	Le-Chatleier in mm		
4.	Specific Gravity	3.15	----

Table 2: Result of Cement

3.2 Result of Aggregate:

3.2.1 Fine Aggregate (Sand):

Ref. Code: IS: 383 & 2386

Sr. No.	Description	Results	Recommendation
1	Gradation Test :		
	Size of Sieves	% of Passing	% of Passing
	10.00 mm	96.00	100
	4.75 mm	84.50	90-100
	2.36 mm	72.70	60-95
	1.18 mm	48.80	36-70
	600 microns	41.00	15-34
	300 microns	5.00	5-20
	150 microns	1.00	0 - 1 0
	Fineness Modules	3.50	--
	Zone	I	--
2	Water Absorption	2.10	<1 %
3	Specific Gravity	2.59	--
4	Silt Content	1.00	<3%

Table 3: Result of Fine Aggregate

3.2.2 Coarse Aggregate (Kapchi):

Size of Material: 10 - 20 mm

Ref. Code: IS: 383 & 2386

Sr. No.	Test	Result	IS Recommendation
1.	Water Absorption	1.80	<2 %
2.	Specific Gravity	2.77	--
3.	Impact Value	10.70	< 30 %
4.	Crushing Value	13.90	a) 45 % Max for Structural work b) 30 % Max for Road, Runway, Pavement

Table 4: Result of Coarse Aggregate (Kapchi)

3.2.3 Course Aggregate (Grit):

Size of Material: 6 - 10 mm

Ref. Code: IS: 383 & 2386

Sr. No.	Test	Cumulative % Passing	IS Recommendation
1.	Water Absorption	2.10	< 1 %
2.	Specific Gravity	2.78	--

Table 5: Result of Coarse Aggregate (Grit)

IV. TESTING METHODS:

Experimental investigation of fresh mix properties of fiber reinforced Metakaolin concrete was conducted compressive strength was determined using IS: 516 – 1959. Compressive strength was measured 7, 28 days. Specimens were cube with a 150 mm X 150 mm X 150 mm side for compressive strength.

V. TESTING PROGRAMME:

5.1 Compressive Strength Test:

Ref.Code: IS-456, IS-516
Compressive test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. The cube specimen is of the size 15 x 15 x 15 cm. If the largest nominal size of the aggregate does not exceed 20 mm, 10 cm size cubes may also be used as an alternative. Smaller test specimens may be used but a ratio of the diameter of the specimen to maximum size of aggregate, not less than 3 to 1 is maintained.

Fig 5: Compressive Strength Test

5.2 Results of Compressive Strength Test:

Ref.Code: IS-456, IS-516

Metakaolin	Compressive Strength N/mm^2	
	7 Days	28 Days
0 % MK	28.8	35.59
3 % MK	34.66	48.29
5 % MK	36.77	49.60

Table 6: Results of Compressive Strength Test (Rice Husk Ash)

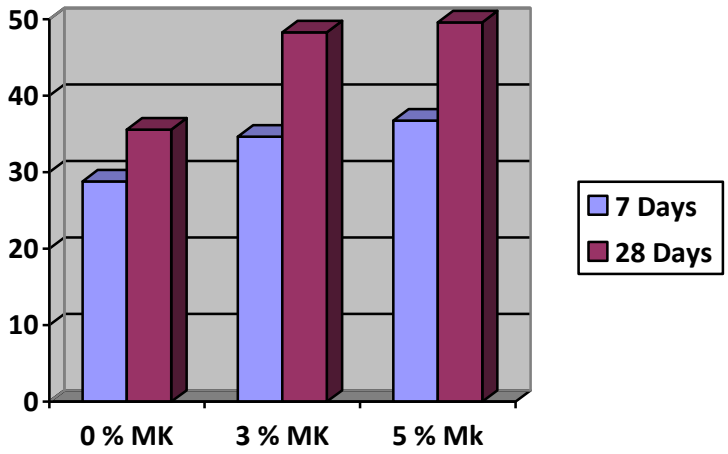

Fig. 6: % of MK vs. Compressive strength. After 7 days & 28days.

VI. CONCLUSION:

1. While it is possible to use less, the benefits are not fully realized until at least 10% Metakaolin is used.
2. Values of compressive strength of concrete with Metakaolin after 28 days can be higher by 20%. Dosage of 15% of Metakaolin causes decrease of workability of suspension in time.
3. Increasing amount of perceptual proportion of Metakaolin in concrete mix seems to require higher dosage of super plasticizer to ensure longer period of workability.
4. Metakaolin is a new active mineral admixture used in cement concrete product. It has a good effect on the mechanical properties of cement. By incorporating 5%, 10%, 15%, 20% Metakaolin. It was found that the compressive strength increased up to 15% replacement. Beyond which it decreased.
5. When OPC is replaced up to 3% & 5% in concrete, it gives strength up to 48.29 N/mm2 & 49.60 N/mm2 in 0.45 w/c, ratio we can get concrete of M25 grade level.
6. Compressive strength increases with the increase in the percentage of Metakaolin up to replacement (3% & 5%) in 28 days of Cement in Concrete for different mix proportions.
7. In general, we can conclude that addition of pozzolanic materials like (activated flyash, Metakaolin, iron oxide) as replacement of OPC gives higher strength at 56 days and also improves the workability of concrete with lower w/c ratio.

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