International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 09 | Sep 2020 www.irjet.net p-ISSN: 2395-0072

EXPERIMENTAL STUDY ON HIGH PERFORMANCE CONCRETE BY PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN

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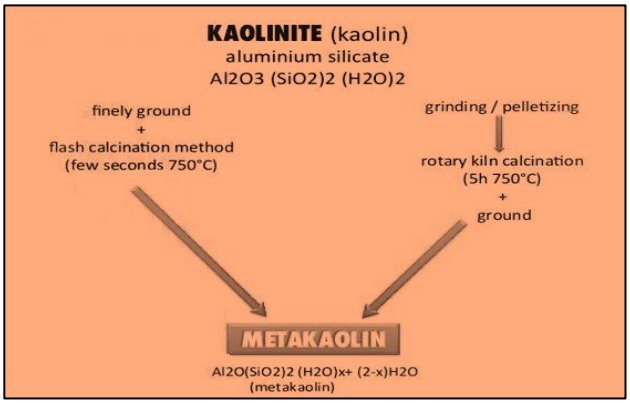
Abstract: Global attention being attracted by bad air quality in cities since last five years. Approx. $5.0 trillion economy being affected by polluted air as death and diseases rates increased exponentially.5% excess loss in GDP experienced in Indian economy. However substantial efforts being done by local governance for cleaning air quality in spite of that more serious measures needs to be done for speedy recovery. Some examples in this direction are closing coal power plants in Beijing and ban in construction of new power plants in China specifically in polluted zone; closing of Badarpur Power plant in mid- winter and 100% ban on burning coal in India to make the environment habitable; complete ban on diesel vehicle and introduction of electric vehicles in larger volume up to 2025 in some modern cities like Madrid, Paris, Athens and Mexico are some of the important planning and measures being undertaken by local governing bodies to control air pollution. Fly ash being replaced by Metakoilinto reduce the cost of cement concrete structure as well as to make it environment friendly.

Keywords:

Metakaolin, Cement-43 Grade, Coarse Aggregate (20mm & 10mm), Fine Aggregate (Coarse Sand-II Zone), Conplast SP430, Compressive strength Test, Split-tensile strength Test, Flexural strength Test.

1. Introduction

As Metakaolin is not a by-product being obtained by the process of calcinations having pure or refined Kaolinite clay heated at a temperature between 6500ºC and 8500ºC, then grinded to achieve a finesse of 700-900 m^2/kg where cement finesse is 225 m^2/kg. Metakaolin is a high quality Pozzolonic material, when is mixed with cement improved the durability of concrete. While mixed in concrete it will fill the empty/voids space between cement particles resulting to form impermeable membrane of concrete. Metakaolin, is a relatively new synthesized material in the industries which are making concrete, effectively increased the strength, reducing sulphateoccurrence rate and improving air-void network. Reactions in Pozzolanic process help in making the change in micro-structure of concrete and chemistry of hydration by products by consuming the released calcium hydroxide (CH) and making of additional calcium silicate hydrate (C-S-H), forming in an increased strength and abridgedporosity so there after better strength. The materialization and properties of Meta kaolin are shown in below. The sampling/specimen set aside submerge in water for 7 & 28 days.



2. Methodology/Analysis

2.1 Cement:

OPC of 53 Grade confirming to IS: 12269-1987 was used in the investigation. The specific gravity of cement was 3.10.

2.2 Metakaolin:

Met kaolin composed of de-hydroxylated form of the clay mineral kaolinite. The size of Metakaolin particles are smaller than cement particles, but not as fine as silica fume. Metakaolin is a pozzolanic material having specific gravity of 2.50.

Table-01 (Properties of Metakaolin& Cement)

SN	Description	Data		Remarks
		Metakaolin	Cement	
A	Physical			
1	Specific Gravity	2.50	3.15	
2	Colour	White	Fine Powder	
3	Physical form	Powder	Grey	
4	Average Particle Size	< 2.50 µm	50 µm	
5	% Age Retain on 45µ Sieve	< 1.00%	0.15	
B	Chemical			
6	LOI	0.68	1.30	
7	Silica- (SiO2)	54.30	34.00	
8	Alumina- (Al2O3)	38.30	5.50	
9	Calcium Oxide- (CaO)	0.39	63.00	
10	Ferric Oxide Calcium Oxide- (Fe2O3)	4.28	4.40	
11	Magnesium Oxide- (MgO)	0.08	1.26	
12	Potassium Oxide- (K2O)	0.50	0.48	
13	Sulphuric anhydride- (SO4)	0.22	1.92	

2.3 Coarse Aggregate:

Crushed stone metal with a below size of 25 mm from a local source having the specific gravity of 2.7 conforming IS383-1970 was used.

2.4 Fine Aggregate:

The particle sizes are less than 4.75mm, Fine aggregates also known as coarse sand which is conforming to grading zone-II as per IS383-1970 was used. The specific gravity of fine aggregate was 2.54.

2.5 Super Plasticizer:

Sulphonated NaphthalenePolymers based chemical was used as super plasticizer as a name "**Conplast SP-430**". The specific gravity of plasticizer was 1.20 that is confirming IS code 9103-1999.

2.6 Water:

Fresh portable water needs to be free from concentration of acid and organic substance as used for mixing the concrete and curing.

2.7 Mix Proportions:

Trial mixtures being prepared obtaining targeted strength more than 68 N/mm^2 for the control mixture at 28 days and the water/cement ratio for all the mixtures were kept at 0.32. The slump of fresh concrete found as 105 to 110mm. The mix proportions for conventional and weight based partial replacement OPC by Metakaolin presented as following Table-02.

Table-02 (Proportion of Concrete)								
SN	Description	Unit	Mix Proportion					Remarks
			Only OPC Cement	OPC + 5% Metakaolin	OPC + 10% Metakaolin	OPC + 15% Metakaolin	OPC + 20% Metakaolin	
1	Cement	Kg	510	484	459	433	408	
2	Metakaolin	Kg	0	26	51	77	102	
3	Aggregate							
a	Course Sand	Kg	806	806	806	806	806	
b	10mm	Kg	398	398	398	398	398	
c	20mm	Kg	573	573	573	573	573	
4	Water	Ltr.	168	168	168	168	168	
5	Superplasticizer	Ltr.	4	4	4	4	4	
6	Slump (mm)	mm	120	110	120	110	100	

3.0 Sampling & Testing

3.1 Casting of Specimens:

M60 grade concrete using OPC, natural river sand and crushed stone with Metakaolin were used in casting the specimen. The average value being obtained by making three numbers of specimens each. Cube size was 150mm for Compressive strength testing and for flexural strength testing sample size was 100mm x 100mm x 500mm. All the Specimens de-molded after 24hrs.The specimens were allowed to the standard curing periods confirming to IS 516–1999.

3.2 Testing of Specimen:

Below table presents Compressive Strength, and Flexure Strength of test values. For getting compressive strength, For each mix, total Thirty number of cubes of size 150mm were casted (for 7days and 28days) periods and being tested using Compression Testing Machine (CTM). The specimen placed on the platform of the CTM and load being applied gradually until the failure stage comes. The ultimate load noted and calculated the compressive strength of corresponding specimen. It conforms to IS 516–1999.\

3.3 Compressive Strength:

The Compressive Strength being compared with control specimen having various percentages of Metakaolin. Compressive Strength grades of specimens mentioned in below Table. The seven day Compressive Strength wide-rangingfrom 45 and 55 N/mm^2. The 28 day strength speckledfrom 62 and 73 N/mm^2. The 20% replacement Metakaolin mixture displayed lower strengths relatively than the other Metakaolinproportions. All the concrete together with the control achieved their target strength of 60 N/mm^2 at 28 days and all the concretes achieved strength of more than 70 N/mm^2. Table-03 presents the relation between Compressive Strength and Metakaolin percentages at 7 and 28 days. The highest for the Metakaolin 15% mixtures achieving strength of 72.70 N/mm^2 at 28days. This clearly shows the replacement level of 15% was the optimum Compressive Strength is concerned. When compared to all other mixes. Metakaolin 15% is the best proportion for add in cement.

Table-03 (Compressive Strength In N/mm^2)							
SN	Description	Sample	7 Days		28 Days		Remarks
			Strength	Avg. Strength	Strength	Avg. Strength	
1	Only OPC Cement	S-1	43.90	45.10	63.10	61.93	
		S-2	47.40		61.10		
		S-3	44.00		61.60		
2	OPC + 5% Metakaolin	S-1	50.20	50.87	63.50	64.53	
		S-2	51.50		67.50		
		S-3	50.90		62.60		
3	OPC + 10% Metakaolin	S-1	52.90	51.87	67.50	70.43	

		S-2	52.30		72.40		
		S-3	50.40		71.40		
4	OPC + 15% Metakaolin	S-1	52.80	54.83	72.80	72.70	
		S-2	56.80		71.10		
		S-3	54.90		74.20		
5	OPC + 20% Metakaolin	S-1	52.10	51.40	67.20	69.67	
		S-2	51.90		70.20		
		S-3	50.20		71.60		

3.4 Flexural Strength:

Different % age of the Metakaolin, the flexural strength May changes in variously, when compared with control specimen at 5% dose of Metakaolin flexural strength increased 4.76%. At 10%, 15% and 20% dose of Metakaolin flexural strength increases 11.62%, 12.26% and 6.98% respectively. 15% of Metakaolin gave high flexural strength. 5.28% of strength decreases at 20% dose of Metakaolin as compared to 15% of MK Dose. So we can say MK 15% of metakaolinis the best percentage to add in cement to reduce the cement quantity. The Flexural strength and various mix concrete test values are presents in below Table-04 and variation of Flexural strength shown in.

Table-04 (Flexural Strength In N/mm^2)

SN	Description	Sample	28 Days			Remarks
			Strength	Avg. Strength	% age increase from 0% MK	
1	Only OPC Cement	S-1	6.40	6.30	-	
		S-2	5.90			
		S-3	6.60			
2	OPC + 5% Metakaolin	S-1	6.50	6.60	4.76%	
		S-2	6.60			
		S-3	6.70			
3	OPC + 10% Metakaolin	S-1	6.80	7.07	11.62%	
		S-2	7.20			
		S-3	7.20			
4	OPC + 15% Metakaolin	S-1	7.00	7.17	12.26%	
		S-2	7.20			
		S-3	7.30			
5	OPC + 20% Metakaolin	S-1	6.70	6.80	6.98%	
		S-2	6.90			
		S-3	6.80			

3.5 SPLIT TENSILE STRENGTH:

Todetermining the tensile strength of concrete, we had casted 3 no of cylindrical specimens in size of 150 mm in diameter and 300 mm long for each batch. All specimen deeply cured in water on room temperature 27°±2°C for testing after 28 days.

For the testing cylindrical specimen placed in a manner that the longitudinal axis is perpendicular to the load, two strips of normal thick plywood, free of deficiencies, approx. (25mm) wide and equal in length, Bearing strips are placed between the specimen and both upper and lower bearing blocks of the testing machine.

Load shall be applied shock free & continuously increased at standard rate within the range 1.2 N/(mm2/min) to 2.4 N/ (mm2/min), than record the ultimate applied load indicated by the testing machine at failure point. Ultimate load calculated through following equation to know actual splitting tensile strength of the specimen.

Split Tensile Strength T = 2P (Load in KN) x π x L(Length) x d(Dia)

Split Tensile Strength In N/mm^2						
SN	Description	Sample	28 Days			Remarks
			Strength	Avg. Strength	% age increase from 0% MK	
1	Only OPC Cement	S-1	4.21	4.26	-	
		S-2	4.28			
		S-3	4.30			
2	OPC + 5% Metakaolin	S-1	4.32	4.37	2.50%	
		S-2	4.36			
		S-3	4.43			
3	OPC + 10% Metakaolin	S-1	4.48	4.49	5.19%	
		S-2	4.45			
		S-3	4.54			
4	OPC + 15% Metakaolin	S-1	4.85	4.89	13.88%	
		S-2	4.89			
		S-3	4.92			
5	OPC + 20% Metakaolin	S-1	4.73	4.71	9.07%	
		S-2	4.47			
		S-3	4.92			

4.0 CONCLUSIONS

From the present investigation, the following conclusions were drawn; based on studies and examinations done on the effect of partial replacement of cement with Metakaolin in concrete.

1. The strength of OPC over shoot by the strength of all Metakaolin concrete mixes.
2. Metakaolin is superior to all other mixes as about 15% cement is replaced by this.
3. Tested compressive strength, Splite tensile strength & Flexural strength improves with the increase in Metakaolin content up to 15% cement replacement.
4. As a pozzolanic material for partial replacement in producing high performance concrete which results encourage for the use of Metakaolin.

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