Development on the properties of concrete replacing Cement with metakaolin and silica fume

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Abstract - High strength concrete (HSC) may be defined as concrete with a specified characteristic cube strength between 60 and 100 N/mm^2, although higher strengths have been achieved and used. The use of higher strength concrete (HSC) in structures and bridge has become a common practice worldwide, Industrial by products such as Metakaolin and Silica fume are Used to increase the strength of concrete. Physical and chemical properties of materials has been studied. M60 grade of concrete is designed as per IS10262:2009. Super plasticizers is used to reduce water cement ratio. Cement has been partially replaced by Metakaolin and Silica fume in the order of 4%, 8% upto 28% Totally 63 cubes and cylinders are casted and Compression strength and Split tensile strength has been conducted for 7, 14 and 28 days. These replacements were then compared with conventional concrete and partially replaced concrete. The results were shown in the form of graph.

Keywords - Metakaolin, Silica fume, Concrete, High Strength Concrete, Super Plasticizers

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I. INTRODUCTION

Concrete is a composite material which is predominantly used all over the world. It is obtained by mixing cementing materials, aggregates and water in required quantities. The strength characteristics of concrete depend upon the properties of constituent of material and their combined action. In the production of cement Co_2 gas emission is more, due to these results in damage of natural climatic conditions. To reduce the consumption of cement partial replacement of cement with some supplementary cementitious materials like Metakaolin, fly-ash, bottom ash, rice husk, GGBS and silica fume etc., are used in concrete mix. Metakaolin is a dehydroxylated form of clay mineral Kaolin. Stone having high percentage of Kaolinite are known as china clay (or) kaolin was traditionally used in manufacture of porcelain i.e. ceramic material. Metakaolin reacts with Ca $(OH)_2$ one of the bi-product of hydration reaction of cement and results in C-S-H gel, which results in increasing strength of the concrete. Silica Fume (SF) is a byproduct of the smelting process in the silicon and ferrosilicon industry. It is also known as micro silica, condensed silica fume, volatlized silica or silica dust. Silica Fume colour is either premium white or grey. Its particles are approximately 100 times smaller than the average cement particle. It has been found that silica fume improves compressive strength, bond strength, and abrasion resistance reduces permeability; and therefore helps in protecting reinforcing steel from corrosion.

II. LITERATURE REVIEW

Hemant Chauhan et aL (2011) made an attempt to use industrial wastes like activated Fly ash, Iron Oxide and Metakaolin as supplementary Cementitious materials in various proportions. Using these mineral admixtures with OPC cement, five different types of concrete mixtures were prepared and same were used to find compressive strength of concrete cubes at 3,7,14,28 and 56 days. When OPC was replaced up to 42% with Metakaolin, it gives strength up to 40.67 N/mm^2 at a water cement ratio of 0.40 and at 0.55 ratio, it gave strength up to 25.47 N/mm^2 at 56 day. They reported that is was possible to make the concrete economical by 42% replacement of cement with different percentages of mineral admixtures like Fly ash (30%), Metakaolin (10%) and iron oxide (2%).

B.B. Patil and P.D. Kumar et aL (2012) performed an experiment on strength and durability properties of High performance concrete incorporating High reactive Metakaolin. High performance concrete is latest development in concrete. The present work deals with the properties normally workability, compressive strength and durability of M60 grade High Performance concrete with different percentages of Metakaolin. Finally they concluded that the Workability and Strength properties of High Performance Concrete mixes improved by incorporating reactive Metakaolin up to 7.5% of weight of cement.

Dojkov.l et aL (2013) experimentally studied the reaction between Metakaolin-Ca $(OH)_2$ -water and Fly ash – Ca $(OH)_2$ – water. It was clear that during the initial period of curing (up to 7 days), Metakaolin combined lime with a very high rate. This indicated that the overall rate of the reaction taking place in early age of Portland cement. Metakaolin concretes and cement mortars was limited by the hydration of the cement phases. The reaction between Fly ash – Ca $(OH)_2$ water was taking place at a moderate rate in the initial age as compared with Metakaolin –Ca $(OH)_2$ water. The experimental results justified the possible combined use of Metakaolin Fly ash – Portland cement in concrete industry.

Perraton et aL. (20) investigate the effect of silica fume on chloride permeability properties of concrete prepared with 0.4 and 0.5 w/c Ratios. It was observed that, by increasing the silica fume in concrete the chloride diffusion decreased. It happened due to the fine silica particle which reduce the large size pores and enhance the pozzolanic reaction by which densest corcrete has been obtained.

Khayat and Aitcin (16) examined that the addition of 10% silica fume in lean concrete of cement reduced the water demand. In normal concrete, addition of silica fume, the water demand is increased to maintain the slump. For producing very high strength and durable concrete, addition of silica fume up to 10% and use of super plasticizer to maintain the specified slump.

III. MATERIALS AND METHODOLOGY

1. Cement

The physical properties of the cement used in present investigation i.e. Ordinary Portland Cement of 53-Grade (JP cement) was shown in table 1.

TABLE. 1 PHYSICAL PROPERTIES OF CEMENT (OPC 53-GRADE)

PROPERTY	VALUE
Grade of cement	53
Specific gravity	3.15
Initial setting time	25 minutes

2. Metakaolin

TABLE. 2 PHYSICAL PROPERTIES OF METAKAOLIN

PHYSICAL PROPERTIES	RESULT
APPEARANCE	OFF — WHITE
PH(1O%SOLIDS)	4.5—5.5
BULK DENSITY (Kg/Lit)	0.4—0.5
SPECIFIC SURFACE AREA m^2/g (BET)	19—20
SPECIFIC GRAVITY	2.6

TABLE. 2.1 CHEMICAL COMPOSITION OF METAKAOLIN

CHEMICAL PROPERTIES	RESULT
$Si0_2$	52.0
Al_20_3	46.0
Fe_20_3	0.60(MAX)
$Ti0_2$	0.65(MAX.)
CaO	0.09(MAX.)
MgO	0.03(MAX.)
Na_20	0.10 (MAX.)
K_20	0.03(MAX)
LOSS ON IGNITION	1.00

3. Fine Aggregate (Coarse Sand)

Locally available river sand was used as a Fine aggregate. The Physical properties of Fine aggregate have been shown in table 3.1and Table 3.2 respectively.

TABLE. 3.1 PROPERTIES OF FINE AGGREGATE

S No.	PROPERTIES	COARSE AGGREGATE
1	SPECIFIC GRAVITY	2.61
2	CRUSHING VALUE	21
3	IMPACT VALUE	18
4	ABRASION VALUE	23
5	WATER ABSORPTION 12.5 mm	0.9%

NOTE: FINE AGGREGATE CONFORMS TO GRADING ZONE-II AS PER IS: 383-1970

SIEVE ANALYSIS OF SAND

IS SIEVE SIZE	Wt. of empty sieve	wt. of sieve retained	% wt. of retained	Cumulative % wt. retained
4.75mm	0	0.015	1.5	1.5
2.36mm	0	0020	2	3.3
1.18mm	0	0.130	13	16.5
600 microns	0	0.56	56	72.5
300 microns	0	0.205	20.3	93
150 microns	0	0.020	2	95
75 microns	0	0	0	0

4. Coarse Aggregate

Locally available crushed sand stone 20mm and 10mm sizes have been used as Coarse aggregates. The physical properties of the coarse aggregates of 20mm and 10mm sizes have been shown.

TABLE. 4.1 PHYSICAL PROPERTIES OF COARSE AGGREGATE (20 MM SIZE)

PROPERTIES OF COARSE AGGREGATE

Sr. No.	PROPERTIES	COARSE AGGREGATE
1	SPECIFIC GRAVITY	2.61
2	CRUSHING VALUE	21
3	IMPACT VALUE	18
4	ABRASION VALUE	23
5	WATER ABSORPTION (12.5 mm)	0.9%

TABLE. 4.2 PHYSICAL PROPERTIES OF COARSE AGGREGATE (10 MM SIZE)

Sr. No.	Property	Requirement as per IS : 383-1970	Observed Value
1	Water absorption (%)	1	0.8
2	Fineness Modulus	5.5-8	6.75
3	Specific gravity	2.6-2.8	2.69
4	Moisture content (%)	-	1

NOTE: THE COARSE AGGREGATE SAMPLE CONFIRMS TO IS CODE 383-1970.

5. Water

The water should be free from organic impurities. The potable water is generally considered satisfactory for the concrete as per clause 5.4 of IS: 456-2000. Tap water available in the laboratory was used for making concrete and curing of the concrete specimens.

6. Concrete Mi Design

Concrete Mix Design of M60 grade concrete has been done as per of the recommended guidelines of IS: 10262-2009 and IS:10262-1982. The ratio of mix proportion is 1:1.05:2.32 keeping water cement ratio 0.32 as shown in Appendix A .It was proposed to investigate the properties of Concrete, with partial replacement of cement with 4%, 8%, 12%, 16% ,20%,24% and 28% of Metakaolin and Silica fume through out the work in all mixes.

IV. CASTING AND TESTING DETAILS

The mixing of ingredients was done manually. Workability was measured by Slump Cone test. The test specimen's 150mm x 150mm x150mm cubes for compressive strengths l50mm x 300mm cylinders for split tensile strength were casted according to IS:516-1959. In this present study totally 162 samples are casted (63 cubes, 63 cylinders). The specimens were tested in the CTM at the age of 7, 14 and 28 days. The test procedure were followed as per relevant Indian standard specifications.

Compressive Strength

COMPRESSIVE STRENGTH FOR CONVENTIONAL CONCRETE:

Sr. No.	NO. OF CURING DAYS	SPECIMENS	LOAD(KN)	COMPRESSIVE STRENGTH(N/mm^2)
1	7	3	600	26.67
2	14	3	1085	48.22
3	28	3	1605	71.33

MODIFIED CONCRETE

The effect of Metakaolin and Silica fume used in the present study on compressive strength of concrete for M60 grade of concrete with varying dosages 4%, 8%, 12%,16% ,20%,20% ,24% and 28% of Metakaolin and Silica fume replacing cement by weight at 7 days, 14 days and 28 days has been shown.

7TH DAY TEST:

Sr. No.	PARTIAL REPLACEMENT IN% (M+S.F)	NUMBER OF SPECIMENS	LOAD (KN)	COMPRESSIVE STRENGTH (N/mm^2)
1	4	3	625	27.77
2	8	3	685	30.44
3	12	3	705	31.33
4	16	3	710	34.55
5	20	3	825	39.67
6	24	3	890	40.55
7	28	3	845	37.53

14^{TH} DAY TESTING:

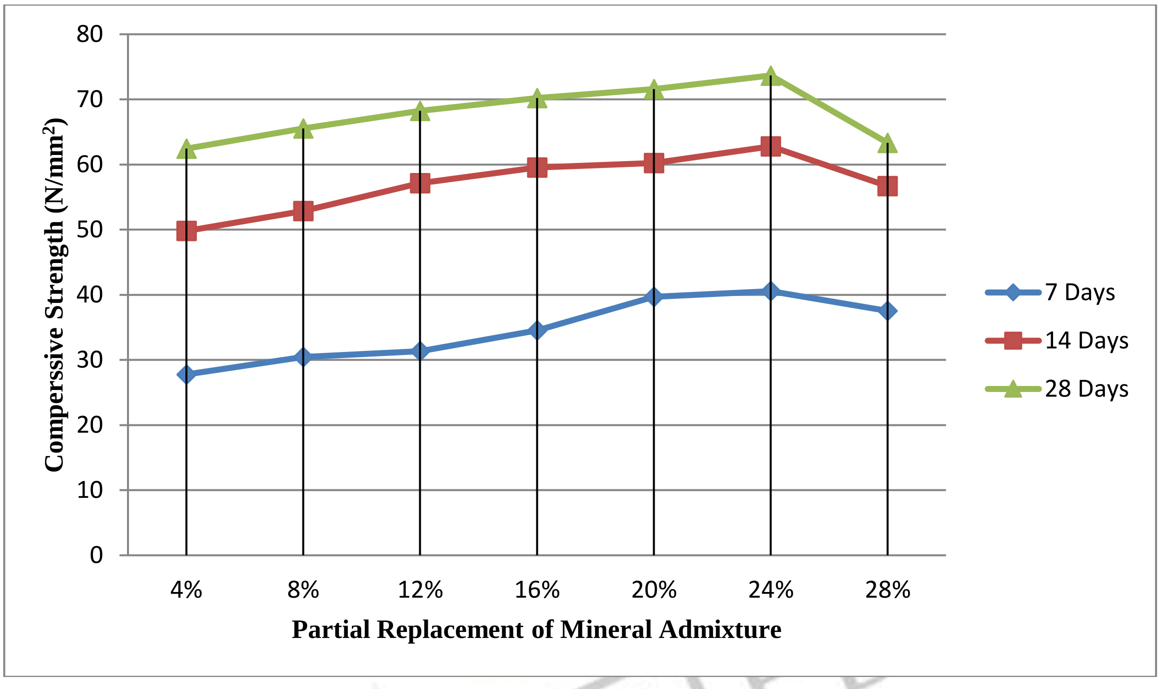
Sr. No.	PARTIAL REPLACEMENT IN% (M+S.F)	NUMBER OF SPECIMENS	LOAD (KN)	COMPRESSIVE STRENGTH (N/mm^2)
1	4	3	1120	49.80
2	8	3	1190	52.88
3	12	3	1285	57.11

4	16	3	1295	59.55
5	20	3	1310	60.22
6	24	3	1345	62.78
7	28	3	1275	56.67

28Th DAY TESTING:

Sr. No.	PARTIAL REPLACEMENT IN% (M+S.F)	NUMBER OF SPECIMENS	LOAD (KN)	COMPRESSIVE STRENGTH (N/mm^2)
1	4	3	1405	62.44
2	8	3	1475	65.55
3	12	3	1535	68.22
4	16	3	1580	70.22
5	20	3	1600	71.56
6	24	3	1560	73.67
7	28	3	1425	63.33

COMPARISONS OF RESULTS FOR COMPRESSIVE STRENGTH



TESTING RESULT FOR SPLIT TENSILE STRENGTH:
SPLIT TENSILE STRENGTH FOR CONVENTIONAL CONCRETE

Sr. No.	NO. OF CURING DAYS	SPECIMENS	LOAD(kN)	COMPRESSIVE STRENGTH(N/mm^2)
1	7	3	60	1.73
2	14	3	85	2.46
3	28	3	150	4.34

MODIFIED CONCRETE
7TH DAY TESTING:

Sr. No.	PARTIAL REPLACEMENT IN% (M+S.F)	NUMBER OF SPECIMENS	LOAD (KN)	COMPRESSIVE STRENGTH (N/mm^2)
1	4	3	75	2.17
2	8	3	110	3.18
3	12	3	150	4.34
4	16	3	165	4.77
5	20	3	175	5.06
6	24	3	170	5.91
7	28	3	115	3.32

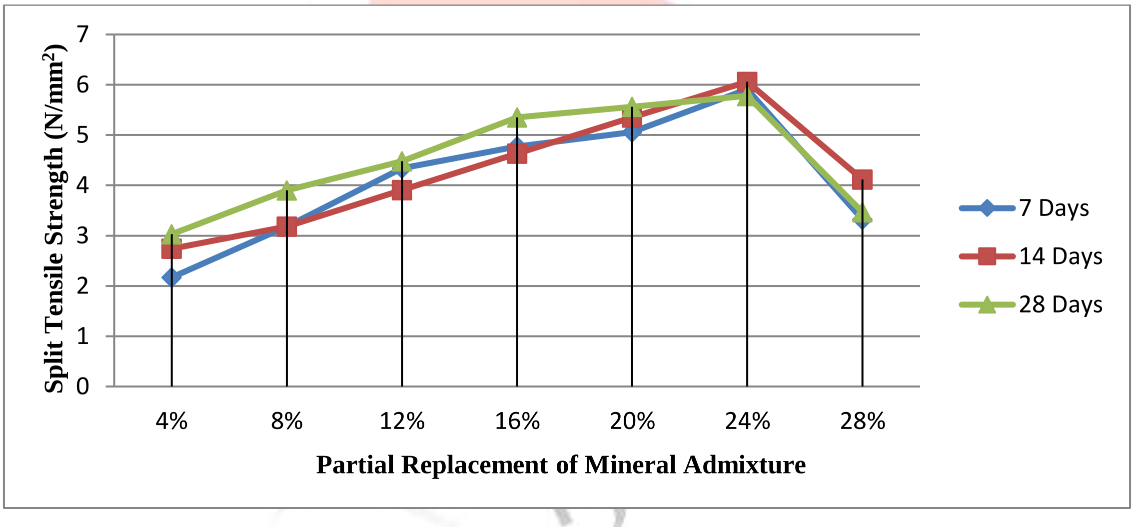
14TH DAY TESTING:

Sr. No.	PARTIAL REPLACEMENT IN% (M+S.F)	NUMBER OF SPECIMENS	LOAD (KN)	COMPRESSIVE STRENGTH (N/mm^2)
1	4	3	95	2.74
2	8	3	110	3.18
3	12	3	135	3.91
4	16	3	170	4.63
5	20	3	185	5.35
6	24	3	175	6.06
7	28	3	125	4.12

28TH DAY TESTING:

Sr. No.	PARTIAL REPLACEMENT IN% (M+S.F)	NUMBER OF SPECIMENS	LOAD (KN)	COMPRESSIVE STRENGTH (N/mm^2)
1	4	3	95	3.03
2	8	3	110	3.9
3	12	3	135	4.48
4	16	3	170	5.35
5	20	3	185	5.56
6	24	3	175	5.78
7	28	3	125	3.47

COMPARISONS OF RESULTS FOR SPLIT TESTING



V. CONCLUSION

On the basis of experimental investigation of the present research study, the following conclusions have been drawn.

- This project presents the results of an experimental investigations carried out to find the suitability of silica fume and metakaolin combination in production of concrete.
- The optimum dose of Silica fume and Metakaolin in combination is found to be 12% and 12% (by weight) respectively at both 7 and 28 day compressive strength.
- By comparing these percentages we prefer that 24% gives more strength than compared with conventional concrete. Therefore use of silica fume in concrete has engineering potential arid economic advantage. Economically by reducing the consumption of cement, the ecology of earth can be improved enormously and the air pollution due to the production of cement can be reduced.

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