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An Experimental Assessment on Properties of Plain Cement Concrete by Partial Replacement of Cement with Metakaolin & Fine Aggregate with Silica Sand

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Abstract

Concrete is widely used material in the construction industry for building structures that are ordinary to those that involve highly specialized jobs. The use of alternative aggregate like silica sand is a natural step in solving part of depletion of natural aggregates. Supplementary Cementious material like Metakaolin and additive material as Silica Sand has been tried by a number of researchers in the past. In this dissertation work, Metakaolin have been used by varying its percentage by weight of cement as 7.5%, 10%, 12.5% and 15% and Silica Sand as 40%, 50%, 60% replacement to fine aggregates by its weight for various grades of concrete M25 and M35 to cover the largest contribution to the construction industry using ordinary concrete as also substantially large component of the same using standard concrete. Effect of Metakaolin and Silica Sand percentages on various properties of concrete like workability, compressive strength, split tensile strength etc. has been studied. Optimum percentages of both materials for various grades of concrete from view point of maximizing compressive strength and split tensile strength have been calculated.

Keywords- *Metakaolin, Silica Sand, compressive strength, split tensile strength, standard concrete.*

I. INTRODUCTION

Production of one ton of cement releases approximately one ton of CO2 which makes up 7% of all CO2 emissions produced globally. It is a pressing need today for the concrete industry to produce concrete with lower environmental impact, these-called green concrete. This can be achieved in three ways. The first one is by reducing the quantity of cements one tonne of cement saved will save equal amount of CO2 to be discharged into atmosphere. Secondly by reducing the use of natural aggregates whose resources are limited and are exhausting very fast. It is also achieved by utilizing maximum possible waste materials like metakaolin, fly ash, Ground Granulated Blast Furnace Slag, Rice husk ash, silica sand and silica fume are some of the pozzolanic materials in concrete. This will reduce the requirement of landfill area and make system more sustainable.

Hence this study explores the possibility of replacing part of fine aggregate with silica sand and reducing the consumption of natural resources.

Silica is the composition of silicon and oxygen. Silicon and oxygen are the earth's two most abundant elements. Silica is one of the earth's three most common rock forming material. It is a key raw material in the industrial revolution especially in glass, foundry and ceramic industries. Now a day's silicon is used in information technology products like plastics of computer mouse and providing the raw materials for silicon chips. For industrial pure deposits of silica sand capable of yielding products of at least 95% silica are required. Silica sand is obtained from the raw material (locally available in mamuara village in Kutch district). After washing the raw material the silica sand is separated by sieve size 1.18 of raw material. From the raw material different size of silica sand are separated by different size of sieve. Sand size of 30 meshes to 80 meshes (500 micron) is used in the glass industries. Sand size 1.18mm to 600 micron can be used in making concrete mix as the partial replacement of fine aggregate.

Supplementary cementitious materials (SCMs) are finely ground solid materials that are used to replace part of the cement in a concrete mixture. These materials react chemically with hydrating cement to form a modified paste microstructure. In addition to their positive environmental impact, SCMs may improve concrete workability, mechanical properties, and durability.

Unlike by-product pozzolanas, which can have variable composition, MK is produced under carefully controlled conditions to refine its color, remove inert impurities, and tailor particle size. As such, a much higher degree of purity and pozzolanic reactivity can be obtained. MK has great promise as an SCM, as it can improve many properties of concrete.

II. EXPERIMENTAL PROGRAMME

Metakaolin and silica sand were used for the purpose of this dissertation work. Replacement percentage of the metakaolin as 7.5%, 10%, 12.5% and 15% by the weight of the cement were suggested in this study. Replacement percentage of the silica sand as 40%, 50% and 60% by the weight of fine aggregate were suggested in this study .The binder consists of ordinary Portland cement. The coarse aggregate used was 20mm maximum size. Naturally available fine aggregate were used for the study wok.
For fresh concrete, the standard slump cone test was conducted according to the IS: 1199-1959 for all mixes immediately after the mix was completed. Cubic samples 150 x150 x 150 mm were used for compressive strength. The concrete cube specimen were

taken out from the tank, their surfaces were dried of excess water, cleaned and kept in the laboratory for a few minutes to obtain saturated dry surfaces specimens. Then their weight and dimensions were measured and noted.

The specimens were tested at ages of 7 days and 28 days (3 cubes at each age) for compressive strength. The split tensile specimens were tested at the age of 7 days. Control mix details are listed in the table 1 below

Table-1 Mix details

Grade	Contents			
	Cement kg/m^3	Water kg/m^3	FA kg/m^3	CA kg/m^3
M25	372	197	811	1094
M35	448	197	783	1056

III. RESULTS AND DISCUSSIONS

3.1. Slump of the fresh concrete

M25 GRADE		M35 GRADE
VARIATIONS	SLUMP VALUE (IN mm)	SLUMP VALUE (IN mm)
NC	80	65
MK1	55	50
MK2	55	40
MK3	45	40
MK4	40	42
SS1	75	55
SS2	85	60
SS3	80	50

Table-2 Slump in mm

Increasing the percentage of metakaolin (by weight of cement) leads to a decrease in slump. This is mainly due to the fact that C-S-H gel restrained the flow ability of fresh concrete and results in a decrease in workability. On the other hand as percentage of silica sand up to 50% workability increases than after decreases.

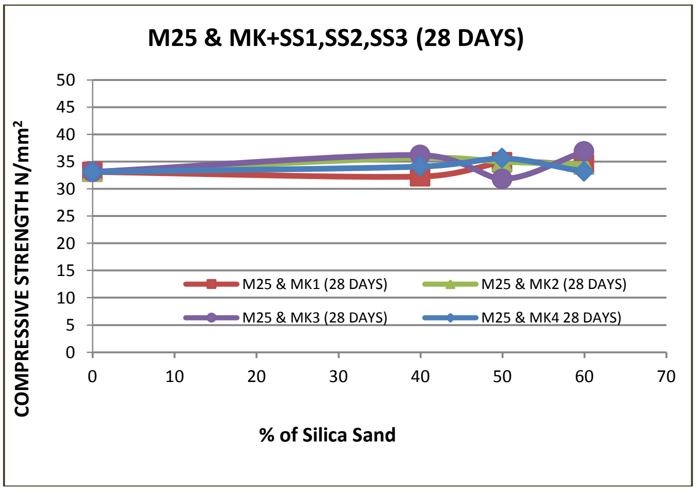
3.2. Strength of the concrete

3.2.1. Compressive strength

SR. No	MIX VARIATIONS OF M25	COMPRESSIVE STRENGTH	
		(7 Days) N/mm^2	(28Days) N/mm^2
1	PLAIN	21.73	33.11
2	MK1	26.86	32.23
3	MK2	25.41	33.45
4	MK3	26.66	32.04
5	MK4	23.65	31.20
6	SS1	20.89	30.24
7	SS2	20.76	31.23
8	SS3	24.33	23.54

9	MK1SS1	29.05	32.25
10	MK1SS2	27.03	34.86
11	MK1SS3	28.44	34.42
12	MK2SS1	26.69	35.71
13	MK2SS2	30.23	34.96
14	MK2SS3	28.9	34.52
15	MK3SS1	22.89	36.19
16	MK3SS2	27.15	31.8
17	MK3SS3	28.06	36.84
18	MK4SS1	32.9	34.08
19	MK4SS2	26.39	35.61
20	MK4SS3	21.97	33.14

Table 3- Compressive strength of M25 at the age of 7 and 28 days

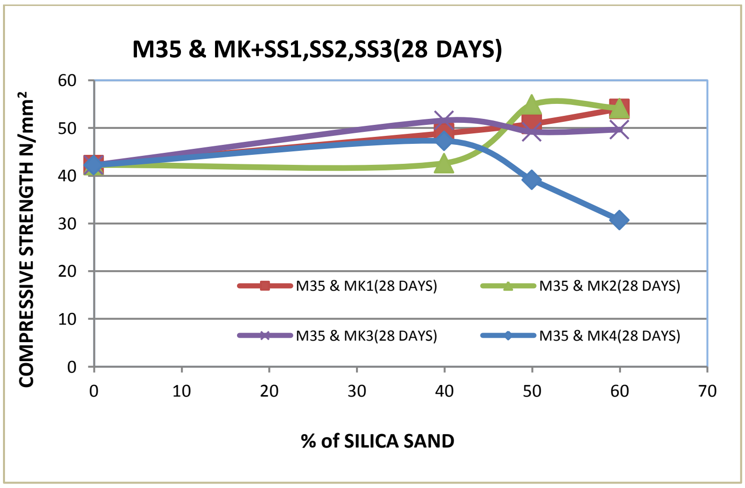


Graph-1 Compressive strength Vs MK & SS% at the age of 28 days for M25 grade

SR NO.	MIX VARIATIONS OF M35	COMPRESSIVE STRENGTH	
		(7 Days) N/mm^2	(28Days) N/mm^2
1	PLAIN	29.75	42.24
2	MK1	28.91	43.45
3	MK2	31.27	43.7
4	MK3	32.01	44.45
5	MK4	32.81	40.5
6	SS1	28.07	41.06
7	SS2	27.22	39.01
8	SS3	25.18	41.11
9	MK1SS1	36.41	48.89
10	MK1SS2	28.17	50.88

11	MK1SS3	33.44	54.04
12	MK2SS1	31.61	42.63
13	MK2SS2	31.8	54.93
14	MK2SS3	28.78	54.16
15	MK3SS1	26.31	51.6
16	MK3SS2	31.09	49.19
17	MK3SS3	33.02	49.67
18	MK4SS1	31.13	43.71
19	MK4SS2	15.79	39.13
20	MK4SS3	18.37	37.70

Table 4- Compressive strength of M35 at the age of 7 and 28 days



Graph-2 Compressive strength Vs MK & SS % at the age of 28 days for M35 garde

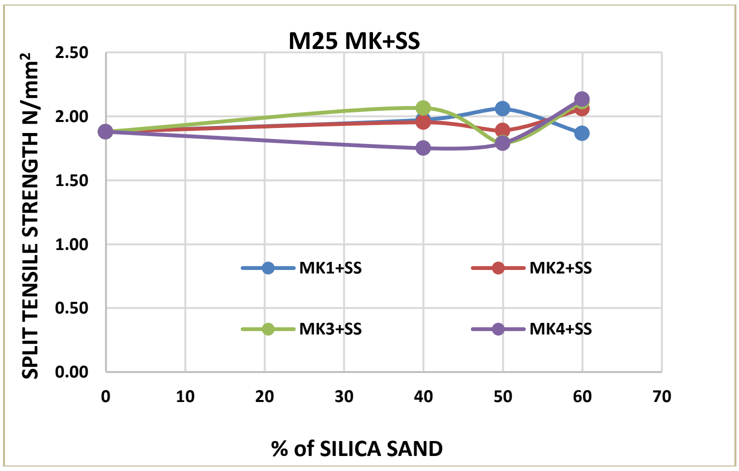
Results of 7 and 28 days indicate the increase in the compressive strength at various percentages added for both grades of concrete.

3.2.2. Split tensile strength

SR. NO	MIX VARIATIONS OF M25	SPLIT TENSILE STRENGTH (7 Days) N/mm^2
1	PLAIN	1.88
2	MK1	1.39
3	MK2	2.26
4	MK3	2.19
5	MK4	1.87
6	SS1	1.85
7	SS2	1.87
8	SS3	1.88
9	MK1SS1	1.97
10	MK1SS2	2.06
11	MK1SS3	1.87

12	MK2SS1	1.95
13	MK2SS2	1.89
14	MK2SS3	2.06
15	MK3SS1	2.06
16	MK3SS2	1.79
17	MK3SS3	2.11
18	MK4SS1	1.75
19	MK4SS2	1.79
20	MK4SS3	2.14

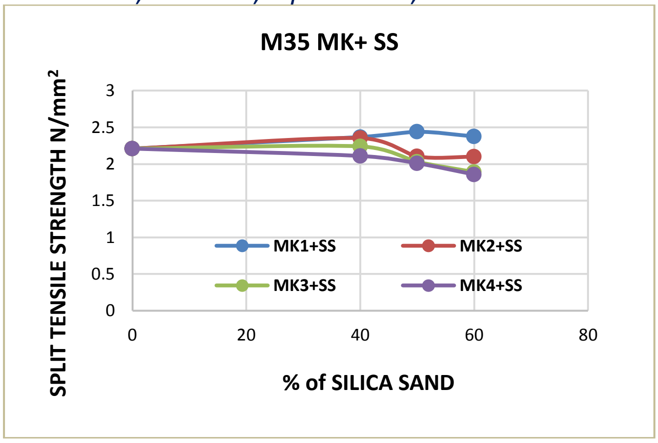
Table-5.Split tensile strength of M25 at the age of 7 days



Graph-3 Split tensile strength Vs MK &SS % at the age of 7 days for M25 garde

SR. NO	MIX VARIATIONS OF M35	SPLIT TENSILE STRENGTH (7 Days) N/mm^2
1	PLAIN	2.21
2	MK1	2.19
3	MK2	2.23
4	MK3	1.76
5	MK4	1.71
6	SS1	2.20
7	SS2	2.21
8	SS3	2.23
9	MK1SS1	2.37
10	MK1SS2	2.44
11	MK1SS3	2.38
12	MK2SS1	2.35
13	MK2SS2	2.10
14	MK2SS3	2.09
15	MK3SS1	2.24
16	MK3SS2	2.03
17	MK3SS3	1.89
18	MK4SS1	2.11
19	MK4SS2	2.01
20	MK4SS3	1.86

Table-6.Split tensile strength of M35 at the age of 7 days



Graph-4 Split tensile strength Vs MK &SS % at the age of 7 days for M35 garde

IV. CONCLUSION

- Fresh properties results showed that with increase in amount of Metakaolin decreased for both grade of concrete and Silica Sand workability increases up to 50%.
- For M25 grade, compressive strength of concrete with 12.5% of MK replacement and 60% of SS addition with cement increase about 12% in comparison with normal concrete at 28days.
- The split tensile strength of concrete with 12.5% of MK replacement and 60% of SS addition with cement increase about 13% in comparison with normal concrete at 7days.
- For M35 grade, compressive strength of concrete with 10% of MK replacement and 50% of SS addition with cement increase about 30% in comparison with normal concrete.
- Split tensile strength of concrete with 5% of MK replacement and 50% of SS addition with cement increase about 10% in comparison with normal concrete at 7 days

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