Strength Characteristics and Durability Characteristics of Silicafume and Metakaolin based Concrete

A.Anbarasan
M.TechStudent,Department of Civil Engineering, Prist University, Kumbakonam Campus, Tamilnadu, India

M.Venkatesan
Asst. Professor, Department of Civil Engineering, Prist University, Kumbakonam Campus, Tamilnadu, India

Abstract - Silica fume (SF) and Metakaolin are cementitious materials used as admixtures to produce high strength concrete and to reduce the permeability. Also, Silica fume is used to make durable concrete structures in combination with ordinary Portland cement. In places where insufficient or poor curing concrete structures like sea shores, underground structures which undergo severe loss of compressive strength and permeability interconnected durability, use of Metakaolin and Silica fume in an optimum proportion proves to be very useful to modify the properties of concrete. This project deals with the properties of concrete, with varying percentage replacement of Silica fume and Metakaolin as a partial replacement for cement. The mix was obtained by replacing (35%, 15%); (40%, 10%) and (45%, 5%) mass of cement by Silica fume and Metakaolin respectively. Finally required specimens were casted to study the behaviors such as compressive strength, tensile strength and durability. Compressive strength and split tensile test were carried out for testing the strength properties and sorptivity test was conducted to check the durability properties of concrete. The test results indicated that the two admixtures Silica fume and Metakaolin when used at an optimum combination tend to increase the strength and durability of concrete when compared with conventional concrete.

Key Words:Silica fume, Metakaolin

I. INTRODUCTION

Ordinary Portland cement is one of the most important binding materials in terms of quantity produced. Since it is manufactured at a very high temperature, it consumes lot of energy. Besides huge amount of energy consumption, it emits harmful gases, which pollute the atmosphere. The production of every ton of Portland cement contributes about one ton of CO_2 in the atmosphere. Small amounts of NO_x and CH_4 gases are also emitted. Apart from energy consumption and emission of harmful gases, calcium hydroxide, one of the hydration products, obtained during the hydration of cement, is a nuisance for construction industry. This affects the durability properties of cement based materials.

Silica fume is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and natural waste Metakaolinwhich is a dehydroxylated form of the clay mineral kaolinite which when not disposed properly may cause environmental hazards to thesurrounding area. These two materials are usedin the concrete industry, are effective in increasing the compressive strength, tensile strength and improved durability.

II. EXPERIMENTAL INVESTGATION

A.Materials

Cement

The cement used for the investigation was Ordinary Portland Cement with 53 grade. The specific gravity of cement is 3.15

Coarse Aggregate

Aggregate available from local sources has been used. Aggregate passing through 20mm IS sieve and retained on 16mm IS sieve was used. The specific gravity of coarse aggregate is 2.70.

Fine Aggregate

Locally available river sand of size 2.36 mm was used. The specific gravity of fine aggregate is 2.65, fineness modulus was found to be 2.7 as per IS 383:1970.

*Silicafume And Metakaolin*arethe mineral admixture used in this work .The physical properties of silicafume are presented in table 1 and The physical and chemical properties of metakaolin are presented in table 2.

TABLE- 1 PHYSICAL PROPERTIES OF SILICAFUME

PROPERTY	VALUE
SPECIFIC GRAVITY	2.3
PHYSICAL FORM	Powder
COLOUR	Off-White

TABLE-2 PHYSICAL AND CHEMICAL PROPERTIES OF METAKAOLIN

PROPERTY	VALUE
SPECIFIC GRAVITY	2.6
PHYSICAL FORM	Powder
COLOUR	Off-White
INGREDIENTS	% BY WEIGHT
SiO_2	51.52
Al_2O_3	40.18
Fe_2O_3	1.23
CaO	2.0
MgO	0.12
K_2O	0.53
TiO_2	2.27
Na_2O	0.08

Water

Water used for curing and mixingwere as per IS 456:2000.

B.Methodology and mix proportion: Fig1 shows the flow chart of methodology and Fig 2 shows the methodology of mix proportion. Concrete grade of M30 has been used in this work, mix design was done according to IS Method. A total of 3 combinations were prepared for the work and control concrete was also done for each mix. The mix ratio is 1:1.01:2.48 (Cement: Fine aggregate: Coarse aggregate). Details about mix proportion are shown in Table 4.

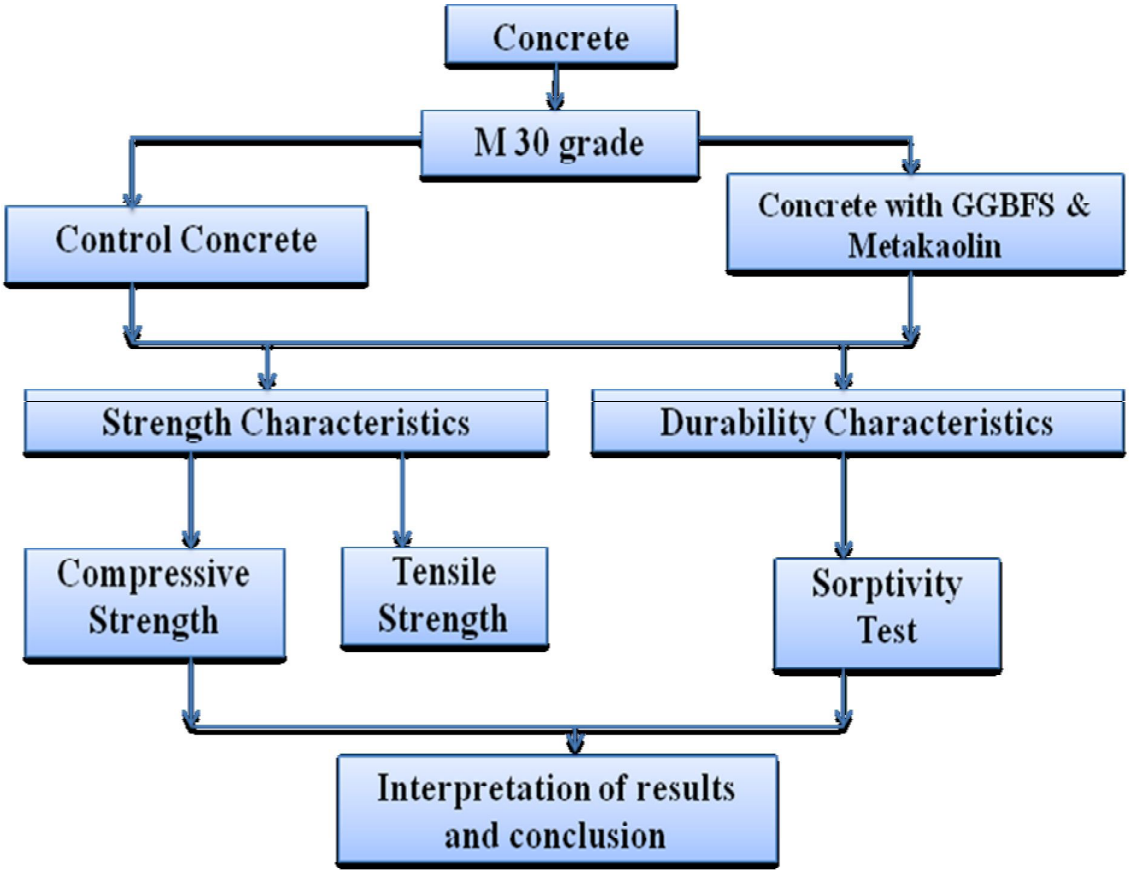

Fig1Flow chat showing methodology

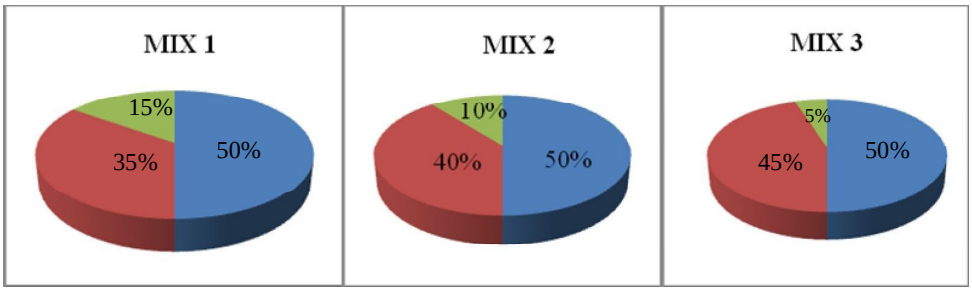

Fig2 Pie Chart showing Mixing Methodology

C.Specimen details

Cube and cylinder cast were done. Concrete cubes of size 150 mm x 150 mm x 150 mm and cylinders of size 150mm x 300 mm were cast to study the compressive and tensile strengths. Strength tests of cylinder and cube specimens were performed in Universal testing machineand compression testing machine. Three different mix of specimens were made, in mix 1 cement was replaced by silicafume and metakaolin by 35% and 15% respectively and in mix 2 cement was replaced by silicafume and metakaolin by 40% and 10% respectively and in mix 3 cement was replaced by silicafume and metakaolin by 45% and 5% respectively.

Table -4Mix proportioning

S.NO	Parameters	Mix Properties
1	Grade of concrete	M30
2	Mix Proportion	1:1.01:2.48
3	Cement (kg/m^3)	478 kg/m^3
4	Fine Aggregate (kg/m^3)	519 Kg/m^3
5	Coarse Aggregate	1179 Kg/m^3
6	Water	191 Kg/m^3

III. RESULTS AND DISCUSSION

i)Mean compressive strength

Figure 3 shows the mean compressive strengths of control concrete, (35%, 15%), (40%, 10%) and (45%, 5%) of silicafume and Metakaolin imparted specimens respectively for 7, 14 and 28 days curing. The compressive strength of the control concrete for 7, 14 and 28 days are 24.2 N/mm2, 28.4 N/mm2 and 37.6 N/mm2. For the first mix, that is for the concrete made by replacing cement with 35% silicafume and 15% Metakaolin, the 7 days strength seems to be 29.6 N/mm2, the 14 days strength is 35.4 N/mm2 and the 28 days strength is 43.6 N/mm2. Similarly for the second mix, that is for the concrete made by replacing cement with 40% silicafume and 10% Metakaolin, the strengths are 28.22 N/mm2, 32.8 N/mm2 and 40.24 N/mm2. As for the third mix the strengths are as follows, 25.08 N/mm2, 31.14 N/mm2 and 38.8 N/mm2respectively.

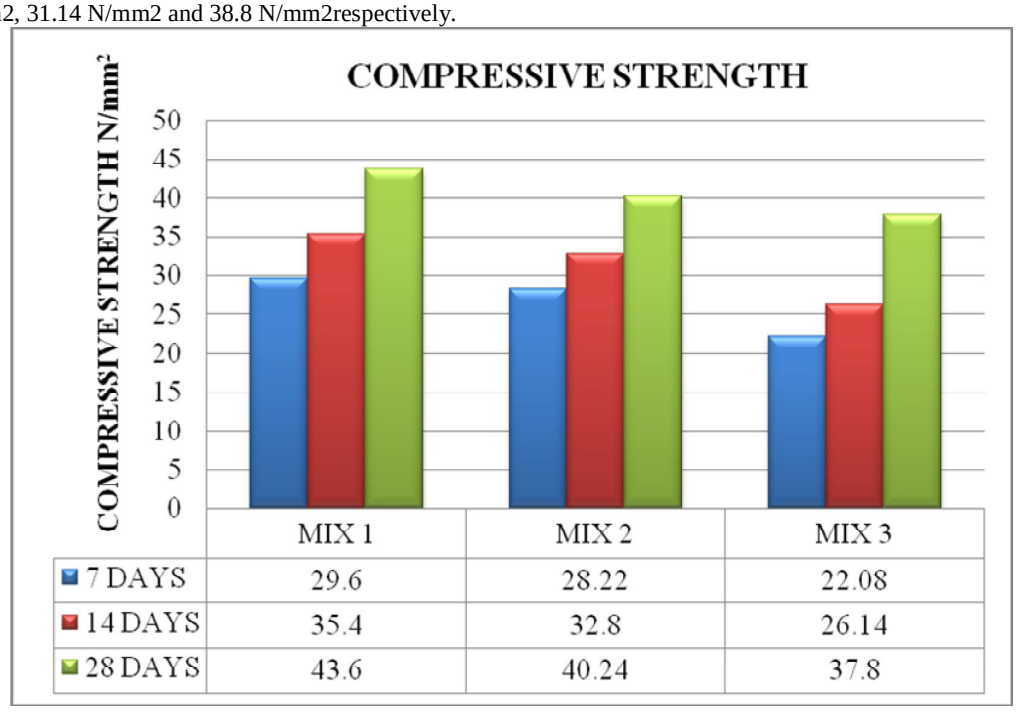

FIG3 BARCHART SHOWING COMPRESSIVE STRENGTH FOR THE THREE MIXES IN N/mm^2

ii)Mean tensile strength

Figure 4 shows the mean tensile strengths of control concrete, (35%, 15%), (40%, 10%) and (45%, 5%) of silicafume and Metakaolin imparted specimens respectively for 7 and 28 days curing. The tensile strength of the control concrete for 7 and 28 days are 1.2 N/mm2 and 1.8 N/mm2. For the first mix, that is for the concrete made by replacing cement with 35% silicafume and 15% Metakaolin, the 7 days strength seems to be 1.6 N/mm2 and the 28 days strength is 2.3 N/mm2. Similarly for the second mix, that is for the concretemade by replacing cement with

40% silicafume and 10% Metakaolin, the strengths are 1.4 N/mm2 and 2.2 N/mm2. As for the third mix the strengths are as follows, 1.2 N/mm2 and 2.0 N/mm2.

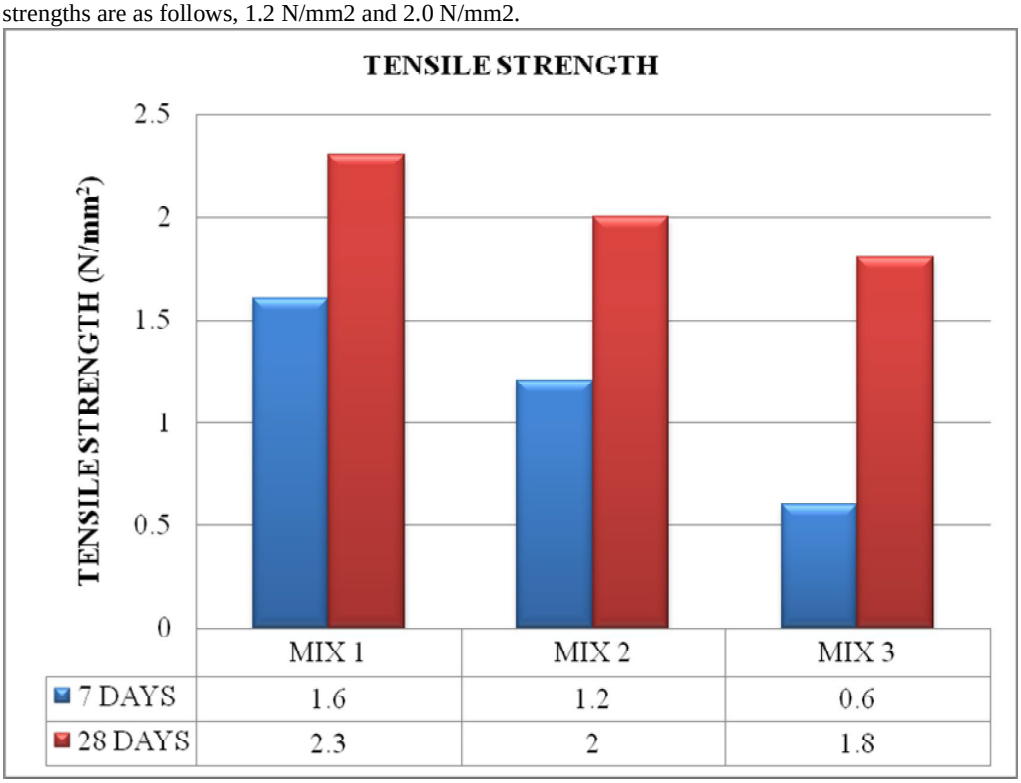

FIG 4 GRAPH SHOWING TENSILE STRENGTH FOR THE THREE MIXES

iii)Sorption coeffecient

From the obtained values, sorption coefficient is computed values are shown in table 5 and table 6. Low sorption coefficient samples are more impermeable and they show good durability performance Form this short term durability characteristics are found out.

Table-5Sorptivity Test Readings

T(s)	√T	Q (mm^3)				A
	(s)	0	10	20	25	(mm^2)
0	0	0	0	0	0	7854
60	7.74596	0	0	1000	0	7854
120	10.9544	1000	0	2000	1000	7854
240	15.4919	2000	1000	4000	3000	7854
480	21.9089	4000	2000	5000	6000	7854
960	30.9838	10000	6000	8000	10000	7854
1920	43.8178	15000	10000	12000	14000	7854
3840	61.9677	21000	11000	16000	17000	7854
7680	87.6356	34000	13000	21000	20000	7854
15360	123.935	44000	16000	25000	25000	7854

Table-6 Q/A values for the three mixes

TIME (S)	√TIME (√S)	AREA (mm^2)	Q/A FOR CONTROL CONCRETE (mm)	Q/A FOR GGBFS 35% and Metakaolin 15% (mm)	Q/A FOR GGBFS 40% and Metakaolin 10% (mm)	Q/A FOR GGBFS 45% and Metakaolin 5% (mm)
60	7.75	7854	0	0	0	0.1273
120	10.95	7854	0.1273	0	0.1273	0.2546
240	15.49	7854	0.1273	0.1273	0.3819	0.5092
480	21.90	7854	0.2546	0.2546	0.7639	0.6366
960	30.98	7854	1.2732	0.7639	1.2732	1.0185
1920	43.81	7854	1.5278	1.2732	1.7825	1.5278
3840	61.96	7854	1.9098	1.4005	2.1645	2.8011
7680	87.63	7854	2.6737	1.6552	2.5464	2.6737
15360	123.93	7854	4.3290	2.0371	3.1830	3.1830

The sorption coefficient for control concrete is 3.68x10-2 mm/sec1/2. As for the three mixes the values of sorption coefficients are 1.87x10-2 mm/sec1/2, 2.76x10-2 mm/sec1/2 and 2.84x10-2 mm/sec1/2. It is seen from the results that the sorption coefficient for the three mixes is comparatively less than that of the control concrete. This implies that the durability of the mix-1 that is, for 35% silicafume and 15% Metakaolin is more. The durability of the other two mixes is also high than the control concrete. Of the three mixes the better durability is obtained for the mix I.

IV. CONCLUSION

It was observed from the test results that the compressive strength and tensile strength of concrete cubes replaced with silicafume and Metakaolin showed better results compared with control concrete. The two admixtures silicafume and Metakaolin when used at an optimum combination of (35%, 15%) respectively, tend to increase the compressive strength of concrete. Thereafter there is slight decline in strength for (40%, 10%) and (45%, 5%) combinations, but not less than that of the target mean strength. It was observed from the test results that the tensile strength of concrete cylinders replaced with silicafume and Metakaolin at an optimum combination of (35%, 15%) showed better results compared with control concrete. Also the two admixtures silicafume and Metakaolin when used at an optimum combination of (35%, 15%) respectively, tend to increase the durability of concrete. The test results indicated that the two mineral admixtures silicafume and Metakaolin when used at an optimum combination of (35%, 15%) respectively tend to increase the strength and durability of concrete when compared with conventional concrete. Therefore the best combination of Metakaolin and silicafume is 35% and 15%.

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