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Effects of Metakaolin Content on Fresh and Hardened Properties of Self Compacted Concrete

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ABSTRACT

Self-compacting concrete (SCC) is an innovative concrete that does not requires vibration for placing and compaction. SCC has higher powder content and a lower coarse aggregate volume ratio as compared to normally vibrated concrete. If only cement is used in SCC, it becomes high costly, susceptible to be attack and produces much thermal crack. Therefore it is necessary to replace some of the cement by additives like Metakaolin to achieve an economical and durable concrete. Metakaolin (MK) is a pozzolanic material. It is a dehydroxylated form of the clay mineral kaolinite. It is obtained by calcination of kaolinitic clay at a temperature between 500°C and 800°C. Kaolin is a fine, white, clay mineral that has been traditionally used in the manufacture of porcelain. A SSC mix prepaid with the replacement of cement by metakaolin in different ratios (5%, 10%, 15% and 20%). Slump flow and V- Funnel time increase with increase in the percentage of metakaolin and mechanical properties of SCC like Compressive strength, split tensile strength and elastic modulus of SCC decreases with increases in percentage of metakaolin at the age of 7 days and 28 days but increases with increases in percentage of metakaolin at the age of 90 days.

I. INTRODUCTION

The self compacting concrete is that which gets compacted due to its self weight and is deaerated (no entrapped air) almost completely while flowing in the formwork. In densely reinforced structural members, it fills completely all the voids and gaps and maintains nearly horizontal concrete level after it is placed. It consists of same components as conventionally vibrated normal concrete i.e. cement, aggregates, water, additives or admixtures. Self-compacting concrete (SCC) is an innovative concrete that does not requires vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. Self-compacting concrete (SCC) offers various advantages in the construction process due to its improved quality, and productivity. SCC has higher powder content and a lower coarse aggregate volume ratio as compared to normally vibrated concrete (NVC) in order to ensure SCC’s filling ability, passing ability and segregation resistance. If only cement is used in SCC, it becomes high costly, susceptible to be attack and produces much thermal crack. Okamura was proposed the necessity of this type of concrete in 1986. Study of this type of concrete with fundamental study on the workability of concrete, were carried out by Maekawa and Ozawa at the University of Tokyo.

It is therefore necessary to replace some of the cement by additives, to achieve an economical and durable concrete. This study aims to focus on the possibility of use of Metakaolin to improve the properties of SCC.

II. METHODOLOGY

2.1 Material

Cement: The ordinary Portland cement 43 grade used, conforming to IS: 8112 – 1989. The color of cement was uniform gray with light greenish shade.

2.1.1 Fine Aggregates

The locally available river sand used as fine aggregates of size less than 4.75 mm.

2.1.2 Coarse aggregates

The locally available course aggregates having size 20 mm used. The shape of the course aggregates was rounded.

2.1.3 Fly ash

The fly ash was obtained from 'RAJIV GANDI THERMAL POWER PLANT' Khedar, Haryana

Fig.1 Fly ash

2.1.4 Superplasticizer

Superplasticizer 'Conplast SP 430' was used as a chemical addmexture for concrete.

Fig.2 Superplasticizer

2.1.5 Metakaalin

The metakaolin was obtained from 'ASTRAA CHAMICALS' Chennai. The color of metakaolin was off- white.

Fig.3 Metakaalin

2.1.6 Water

The tab water having pH 6.4 is used in concrete. It was free from suspended solid and organic materials which is good for fresh and hardened properties of concrete.

2.2 Methodology for Concrete mix design

2.2.1 Mix-proportioning system

According to the Japanese SCC-designing method, suggested by Okamura et al. (2000), the mix proportions are determined as follows:

1. Air content is set at 2%, unless air entrainment is required when freeze-thaw resis- tant concrete is to be designed.
2. The coarse aggregate content in concrete, Vg, is limited to 50% of the dry rodded content (Vg,lim) excluding air volume.
3. The fine aggregate volume, Vs, corresponds to 40% of the mortar volume (Vm).
4. The water to powder volume ratio, Vw/Vp, is determined on the basis of paste and mortar tests.
5. The dosage of superplasticizer Sp/p (% of powder weight) is adjusted by a test on fresh concrete, to ensure self-compactability.
6. Finally, tests are performed on trial batches of concrete to finalize the mixture proportions.

There are also some important conditions on applying this method (Takadaetal. 1998):

- The maximum aggregate size is 20mm.
- The border size between fine and coarse aggregates is 5mm.
- The particles finer than 0,09mm are not considered as aggregate but as powder.
- Japanese moderate heat Portland cement is used as a standard powder material.

Table 1.Powder compositions

Powder/mixture[a]	β_ρ	E_ρ	Powder/mixture[b]	β_ρ	E_ρ
Pc	1,08	0,061	100% pc	1,04	0,048
Pfa	0,59	0,024	85% pc+15% lsp	0,98	0,052
Ggbs	1,10	0,046	70% pc+30% lsp	0,93	0,053
Lsp	0,77	0,037	60% pc+40% lsp	0,91	0,061
pc+1% Sp	0,86	0,034	60% pc+40% pfa	0,92	0,041

Table 2.EFNARC Specification for Mix composition

Mix compositions	
Mix Design	Execute the mix design
	Course aggregate < 50%
	Water powder ratio = 0.8 1.0
	Total powder content = 400 – 600 Kg/m^3
	Sand content > 40% of the mortar (volume)
	Sand < 50% of the paste volume
	Sand > 50% by weight of total aggregate
	Free water < 200 l
	Paste > 40% of the volume of the mix

2.2.2 Trials for Mix Design

For designing the concrete mix proportions, quantities were for casting the specimens for different tests. As per the SCC method of design, by varying the mix proportions the results are obtained. The results are not obtained satisfactory in first trial but it obtained after some changes in proportions.

Table 3.Mix composition of Trial Mix

S.No	Mix	Proportion
1	Course Aggregates (Kg)	600
2	Fine Aggregates (Kg)	850
3	Cement (Kg)	415
4	Fly Ash (Kg)	110
5	Water (Kg)	200
6	Super plasticizer (Kg)	7

Table 4.Mix proportion of SCC mixes

Mixes	Cement (Kg)	MK (Kg)	Fly ash (Kg)	Powder (Kg)	Course agg (Kg)	Fine agg (Kg)	Water (Kg)	SP (Kg)	Total (Kg)
SCCMK0	415	0	110	525	600	850	200	7	2182
SCCMK5	394.5	20.5	110	525	600	850	200	7	2182
SCCMK10	373.5	41.5	110	525	600	850	200	7	2182
SCCMK15	352.75	62.25	110	525	600	850	200	7	2182
SCCMK20	332	83	110	525	600	850	200	7	2182

Where
MK = Metalaolin
SP = Superplasticizer
SCCMK0 = Self-compacted concrete with 0% replacement of cement with metakaolin.
SCCMK5 = Self-compacted concrete with 5% replacement of cement with metakaolin.
SCCMK10 = Self-compacted concrete with 10% replacement of cement with metakaolin.
SCCMK15 = Self-compacted concrete with 15% replacement of cement with metakaolin.
SCCMK20 = Self-compacted concrete with 20% replacement of cement with metakaolin.

Table 5. Specifications of specimen

Specimens	Size of Specimen (mm)	No. of Specimens for each mix	Property Study	Days
Cubes	150 x 150 x 150	9 X 5 = 45	Compressive Strength	7, 28 and 90 days
Cylinder	150 x 300	9 X 5 = 45	Tensile Strength	7, 28 and 90 days

III. RESULTS AND DISCUSSION

3.1 Fresh properties of SCC

The tests of fresh properties like Slump flow test, V-funnel test, L-box test, U-box test are performed and fresh properties of concrete mixes are studied with the partial replacement of cement with metakaolin (5%, 10%, 15% and 20%). When the percentage of metakaolin increases then slump flow diameter decreases and slump flow time increases. Due to the high chemical activity and surface area water demand also be increases. Therefore, it loses its fluidity.

Table 6.Fresh properties of Self compacting concrete

Mix	Slump Flow		L-Box		V-Funnel	U-Box
	Dia. (mm)	T_{50m} (sec)	T_L (sec)	(H_2/H_1) (mm)	T_{10} (sec)	$(H_1\text{-}H_2)$ (mm)
SCCMK0	636.35	5.78	16.80	0.875	11.19	7
SCCMK5	632.34	6.38	17.23	0.969	11.32	6
SCCMK10	631.31	6.59	16.85	0.940	12.23	5
SCCMK15	628.89	6.61	17.85	0.971	12.29	5
SCCMK20	626.14	6.77	20.16	0.990	12.35	4

3.2 Mechanical properties:

3.2.1 Compressive strength

The effects of partial replacement of cement with metakaolin (5%, 10%, 15%, and 20%) were carried out in compressive strength. The cubes specimens of size 150mm x 150mm x 150mm was tested on compressive testing machine at the ages of 7 days, 28 days and 90 days of curing. The water- powder ratio was kept constant at 0.36. The test result of 5% to 20% replacement of cement with metakaolin gives more strength at both short and long age.

Table 7.Compressive strength of SCC

Mix	Compressive strength N/mm^2		
	7 days	28 days	90 days
SCCMK0	27.50	34.33	40.80
SCCMK5	27.11	34.70	47.25
SCCMK10	22.62	31.50	43.61
SCCMK15	22.55	29.90	46.01
SCCMK20	22.51	28.60	47.42

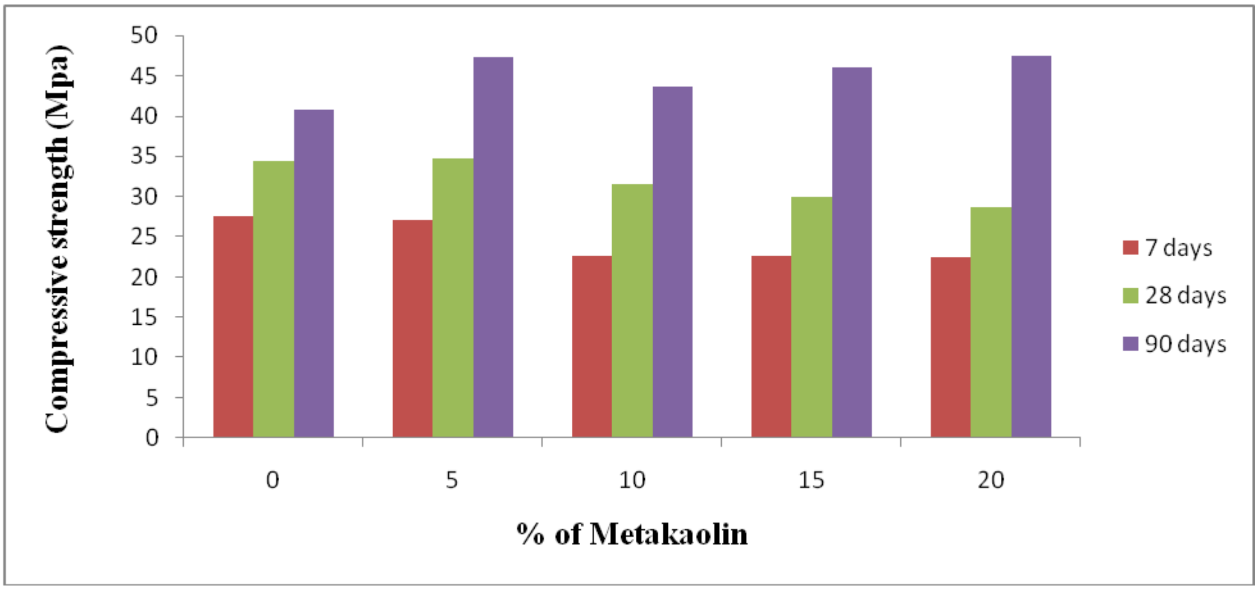

Fig.4 Compressive strength of SCC with metakaolin

3.2.2 Tensile strength test

The effects of partial replacement of cement with metakaolin (5%, 10%, 15%, and 20%) were also carried out in tensile strength. The cylinder specimens of size 150mm x 300mm was tested at the ages of 7 days, 28 days and 90 days of curing.

Table 8.Split Tensile Strength of SCC Mixes

Mix	Tensile strength (N/mm^2)		
	7 days	28 days	90 days
SCCMK0	1.61	1.73	1.83
SCCMK5	1.29	1.6	1.78
SCCMK10	1.25	1.41	1.69
SCCMK15	1.22	1.32	1.7
SCCMK20	0.99	1.31	1.67

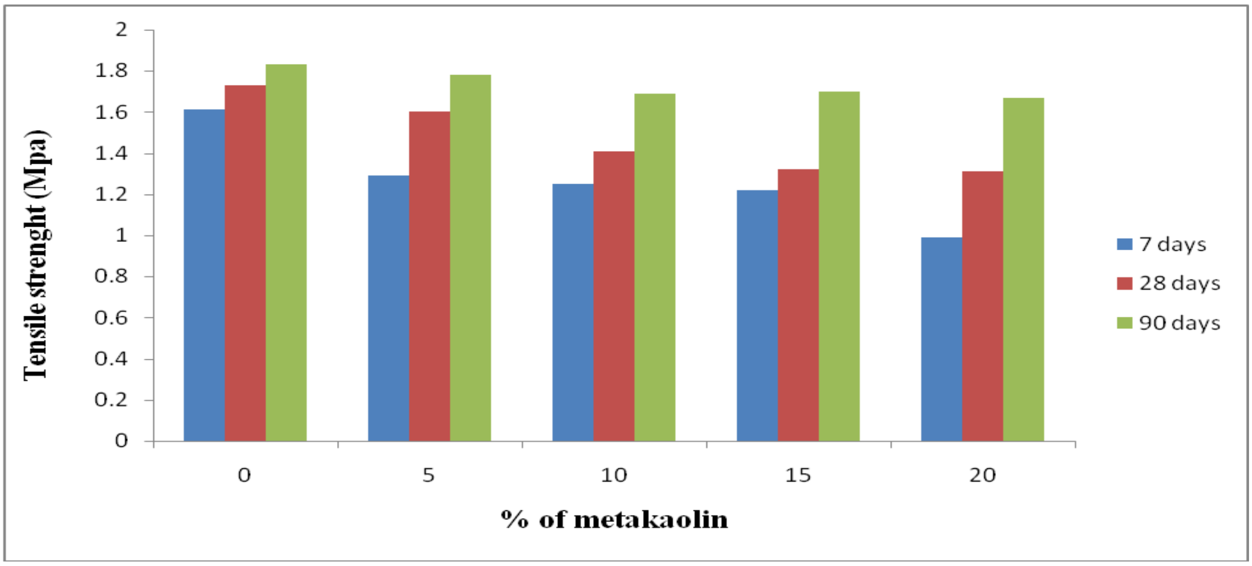

Fig.5 Tensile strength of SCC with % of metakaolin

3.2.3 Ultrasonic Pulse Velocity Test

As per the guidelines of IS: 13311 – 1992, if the velocity is about 4.5 Km/sec, then the quality of concrete is excellent. Velocity criteria for concrete quality grading

Table 9.Ultrasonic Pulse Velocity Test of SCC Mixes

Mix	Velocity (Km/sec)	Quality of concrete	Velocity (Km/sec)	Quality of concrete	Velocity (Km/sec)	Quality of concrete
SCCMK0	5339	Excellent	5631	Excellent	5739	Excellent
SCCMK5	5422	Excellent	5499.52	Excellent	5733	Excellent
SCCMK10	5455	Excellent	5509	Excellent	5734	Excellent
SCCMK15	5332	Excellent	5619.80	Excellent	5710	Excellent
SCCMK20	4919	Excellent	5444.70	Excellent	5677	Excellent

This test is also used for finding the elastic modulus of SCC. As per IS: 13311 (part 1), elastic modulus can be calculated using the equation given below:

$E = \rho\,(1 + \mu)(1 - 2\mu)\,V^2/(1-\mu)$

Table 10.Elastic Modulus for SCC mixes

Mix	Elastic Modulus x 10^{10} MPa		
	7 days	28 days	90 days
SCCMK0	6.06	6.74	7.00
SCCMK5	6.25	6.43	6.99
SCCMK10	6.32	6.45	6.98
SCCMK15	6.04	6.71	6.93
SCCMK20	5.14	6.38	6.85

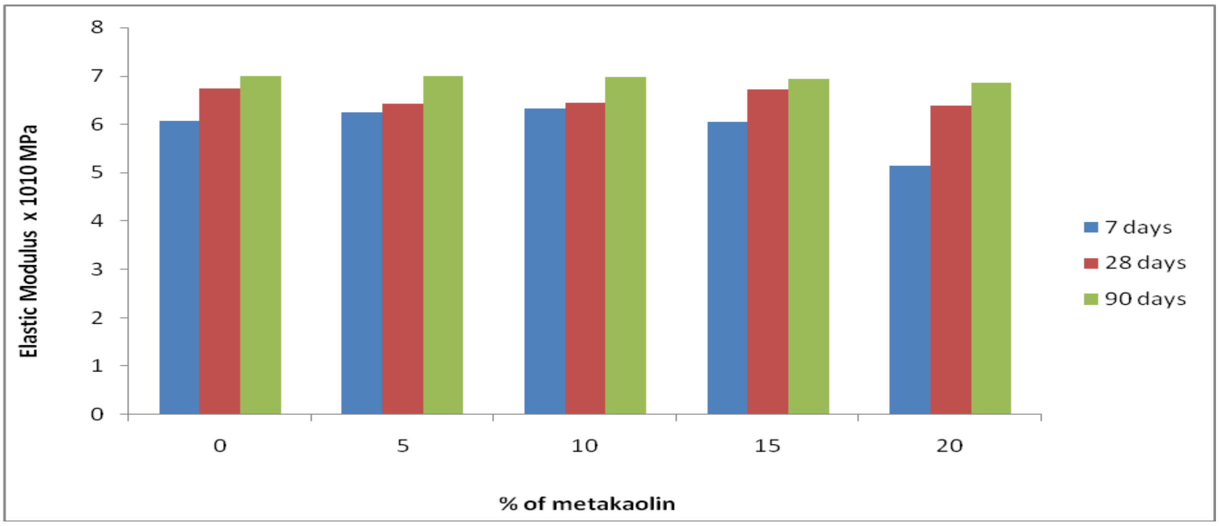

Fig.6 Elastic modulus of SCC with % of metakaolin

IV. CONCLUSIONS

Slump flow time increase with increase in the percentage of metakaolin. Compressive strength of SCC decreases with increases in percentage of Metakaolin at the age of 7 days and 28 days but compressive strength increases with increases in percentage of metakaolin at the age of 90 days. Tensile strength decreases with increases in the percentage of metakaolin at 7 days and 28 days but it observed nearby equal with increases in the percentage of metakaolin at the age of 90 days. The ultrasonic pulse velocity it indicates that quality of concrete is excellent. Elastic modulus of SCC decreases with increases in percentage of Metakaolin at the age of 7 days and 28 days but nearly equal with percentage of metakaolin at the age of 90 days.

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