PERFORMANCE OF HIGH STRENGTH SELF COMPACTING CONCRETE AT ELEVATED TEMPERATURES

Manjula. D[1], Seshagiri Rao. M.V.[2]
[1]P.G. Scholar, Department of Civil Engineering, Jawaharlal Nehru Technological University, Hyderabad- 500 072, Telangana, India
[2]Professor, Department of Civil Engineering, Jawaharlal Nehru Technological University, Hyderabad- 500 072,Telangana, India,

Abstract: Concrete is the second largest commodity consumed in the present society after water. Due to the scarcity in the available land space, vertical growth is becoming inevitable, resulting in high rise structures and sky scrapers. The vertical increase in the structures result in congested reinforcement necessitating concretes which can easily pass through the space between the reinforcement. Hence special concrete suiting specific requirements on the site are becoming popular. Recently, in construction industry self compacting concrete has gained a huge importance to build high rise structures and sky scrapers due to its various advantages like it can compact due to its own weight, better durability properties, and its pumping capability to higher elevations.
In this study, high strength self compacting concrete (HSSCC) has been developed by using Metakaolin(MK) and Micro silica (MS) as an admixtures. In order to prepare suitable mix proportions for different grades of MK based HSSCC, investigation were undertaken replacing cement with 0%, 10%, 20%, 30%, 40% of Met kaolin. Further investigation focused on the impact of strength properties at elevated temperatures 100°C, 200°C, 400°C, 600°C for 1hr, 2hr, 4hr and 6hr duration.

Keywords: High strength self compacting concrete (HSSCC), Metakaolin(MK) and Microsilica (MS), Elevated temperatures

I. INTRODUCTION

Self-Compacting Concrete (SCC) was first introduced to overcome the problems of durability and decline of skilled labour for reinforced structures in seismic regions which are highly congested. Self compacting concrete was first developed in 1988, although the necessity of this type of concrete was proposed by Okamura in 1986. Since then, various investigations have been carried out. This type of concrete has been used in practical structures in Japan. Self Compacting Concrete is defined as a concrete which fill the narrow gaps of the congested reinforcement and flow through, fill the corners of the moulds by its own weight without any external vibrators. The problems associated with pumpable concrete and in-situ concrete due to its resistance to segregation and high fluidity can hence be tackled by using SCC (Ozawa et al., 1989). Self-compacting concrete (SCC) is an innovative concrete that does not require 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. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete. In my investigation, high strength self compacting concrete (HSSCC) has been developed by using Metakaolin(MK) and Microsilica (MS) as an admixture. In order to prepare suitable mix proportions for different grades of MK based HSSCC, investigation were undertaken replacing cement with 0%, 10%, 20%, 30%, 40% of Metakaolin. Further investigation focused on the strength properties at elevated temperatures 100°C, 200°C, 400°C, 600°C for 1hr, 2hr, 4hr and 6hr duration. There is a continuous increase in concrete strength from 50-200 N/mm^2. By using the Metakaolin (MK) and Microsilica (MS). Metakaolin reacts with the calcium hydroxide (lime) byproducts produced during cement hydration. Calcium hydroxide accounts for up to 25% of the hydrated Portland cement and calcium hydroxide does not contribute to the concrete's straight or durability. Metakaolin combines with the calcium hydroxide to produce additional cementing compounds, the material responsible for holding concrete together.

II. MATERIAL AND MIX PROPORTIONS

The materials used in the experimental investigation of SCC were Ordinary Portland cement-53 grade, Coarse Aggregate of size 10mm,River sand, Water and Admixtures like (a). Mineral Admixtures (Metakaolin and Micro silica) and (b). Chemical Admixtures (B233 and Viscosity Modified Agent).

Metakaolin is supplementary cementitious material that conforms to ASTM specification. Metakaolin is unique in that it is not the by-product of industrial process nor is it entirely natural. It is derived from a naturally occurring mineral and is manufactured specifically for cementing applications. Metakaolin is refined kaolin clay that is fired (calcined) under carefully controlled conditions to create an amorphous aluminosilicate that is reactive in concrete. Like other pozzolans, Metakaolin reacts with the calcium hydroxide (lime) byproducts produced during cement hydration.

Micro Silica, During the last three decades, some new Pozzolana materials have emerged in the building industry as an off shoot of research aimed at energy conservation and strict enforcement of pollution control measures to stop dispersing the materials into the atmosphere. Silica fume (other names have been used are silica dust, condensed silica fumes and micro silica) is one such Pozzolana, which has been used as a partial replacement of Portland cement due to its versatile properties.

Viscosity modifying agents, these admixtures enhance the viscosity of water and eliminate the bleeding and segregation phenomena in the fresh concrete as much as possible. VMA is a neutral, biodegradable, liquid chemical additive designed to reduce the bleeding, segregation, shrinkage and cracking that occur in high water/cement ratio concrete mixes. VMA also contribute to stabilization for SCC mixes that are susceptible to segregation at high slump ranges. The VMA used in this investigation was Glenium stream-2 which is a product of BASF construction chemicals.

Metakaolin is supplementary cementitious material that conforms to ASTM specification. Metakaolin is unique in that it is not the byproduct of industrial process nor is it entirely natural. It is derived from a naturally occurring mineral and is manufactured specifically for cementing applications. Metakaolin is refined kaolin clay that is fired (calcined) under carefully controlled conditions to create an amorphous aluminosilicate that is reactive in concrete. Like other pozzolans, Metakaolin reacts with the calcium hydroxide (lime) byproducts produced during cement hydration.

S.No	Description of physical properties	Units	Results
1	Color		1Close To Std
2	Appearance		1 OFF white Powder
3	Bulk Density	Gm/liter	356
4	Oil Absorption	Gm/100gm	
5	Moisture (EX-Work)	%	0.22
6	PH (10% A2 Slurry)		6.22
7	RESIDUE on 325 Mesh	%	0.13
8	PSD –D(50)- 50% particles	μ	1.68
9	Specific gravity		2.63

Table 2.1. Physical properties of Metakaolin

Micro Silica During the last three decades, some new Pozzolana materials have emerged in the building industry as an off shoot of research aimed at energy conservation and strict enforcement of pollution control measures to stop dispersing the materials into the atmosphere. Silica fume (other names have been used are silica dust, condensed silica fumes and micro silica) is one such Pozzolana, which has been used as a partial replacement of Portland cement due to its versatile properties.
The Specific gravity of silica fume is 2.2 and the physical properties and chemical composition are shown in table 5

S.No.	**Description**	**Results**
1	State	Amorphous Sub micron Powder
2	Colour	Grey
3	Specific Gravity	2.1 to 2.4
4	Solubility	Insoluble
5	Specific Surface	$18m^2/g$
6	Bulk density (a) Densified (b) Un Densified	 608 to 720 kg/m^3 192 to 320 kg/m^3

Table 2.2. Physical properties of Microsilica

Viscosity modifying agent These admixtures enhance the viscosity of water and eliminate the bleeding and segregation phenomena in the fresh concrete as much as possible. VMA is a neutral, biodegradable, liquid chemical additive designed to reduce the bleeding, segregation, shrinkage and cracking that occur in high water/cement ratio concrete mixes. VMA also contribute to stabilization for SCC mixes that are susceptible to segregation at high slump ranges. The VMA used in this investigation was Glenium stream-2 which is a product of BASF construction chemicals. The properties of VMA are given in

S. No.	**Property**	**Result**
1.	Aspect	Colourless free flowing liquid
2.	Relative density	1.01
3.	pH	≥6
4.	Chloride ion content	< 0.2%
5.	Compatibility	Can be used with all types of cements
6.	Incompatible	use with naphthalene sulphonate based superplasticizer admixtures.
7.	Mechanism of action	It consists of a mixture of water soluble copolymers which is adsorbed onto the surface of the cement granules, thereby changing the viscosity of the water and influencing the rheological properties of the mix.
8.	Dosage	50 to 500 ml/100 kg of cementitious material.

Table 2.3. Details of Viscosity Modifying Agent

Mix proportions The experimental program consisted of casting and testing specimens for testing the effect of elevated temperature on M70 grade of concrete with Metakaolin and micro silica as filler material. Nan Su method of mix design [2001] was adopted to arrive at the suitable mix proportions. A total of 30 cubes of standard size 150x150mmx150 mm size, 30 prisms of standard size 100 mm x 100 mm x 500 mm and 30 cylinders of 150 mm diameter and 300 mm height were cast for determining the compressive strength, flexural strength and split tensile strength respectively. A total of 75 cubes of size 100mmx100mmx100mm for each w/c ratio were cast for studying the effect of elevated temperatures on cubes. The fresh concrete mixes were poured into the moulds of 150mm side cubes for compressive strength, cylinder for split tensile strength and prisms for flexural strength tests.

III. EXPERIEMENT RESULTS & DISCUSSION

The results of fresh and hardened properties of the concrete specimens tested are as tabulated in Tables 3.1 to 3.4 AND Figures 3.1 to 3.4 respectively. The mix design based on NanSu method and results are tabulated below.

Particulars	Cement	Metakaolin	FA	CA	SP	Water	Micro Silica	VMA
Quantity (kg/m^3)	574.02	54.75	829.40	790.94	11.32	158.62	40.18	1.72
Proportion	1	0.10	1.44	1.38	0.02	0.28	0.07	0.003

Table3.1. Mix Design for M70 Grade of SCC with W/C Ratio=0.25

Mix Components	Concrete Mixes				
	MIX 1 0%	MIX 2 10%	MIX 3 20%	MIX 4 30%	MIX 5 40%
	Qty.	Qty.	Qty.	Qty.	Qty.
CEMENT	574.02	516.62	459.22	401.82	344.41
C.A	790.94	790.94	790.94	790.94	790.94
F.A	829.40	829.4	829.4	829.4	829.4
WATER	158.62	158.62	158.62	158.62	158.62
METAKAOIN	54.75	112.15	169.55	226.96	284.36
S.P	11.32	11.32	11.32	11.32	11.32
MICRO SILICA	40.18	40.18	40.18	40.18	40.18
V.M.A	1.722	1.722	1.722	1.722	1.722

Table 3.2. Quantities of mix for different percentage of Metakaolin as mineral admixture

Type of mix	Compressive Strength (N/mm2)		Split Tensile Strength (N/mm2)		Flexural Strength (N/mm2)	
	7days	28days	7days	28days	7days	28days
MIX 1 (0%)	54.96	78.5	3.65	4.04	5.18	6.201
MIX 2 (10%)	57.715	82.45	3.85	4.243	5.32	6.352
MIX 3 (20%)	58.177	83.11	3.965	4.285	5.33	6.382
MIX 4 (30%)	54.93	78.48	3.765	4.069	5.19	6.21
MIX 5 (40%)	54.544	77.93	3.38	3.743	5.16	6.179

Table 3.3. Mechanical properties of M70 HSSCC (7days and 28days)

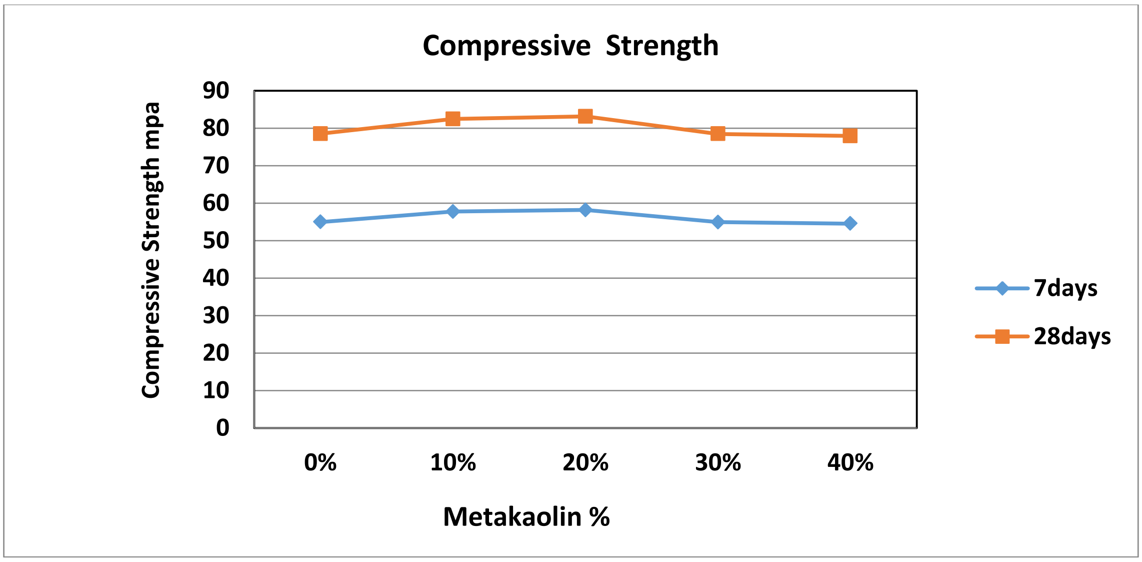

Fig.3.1: Mechanical properties of M70 HSSCC

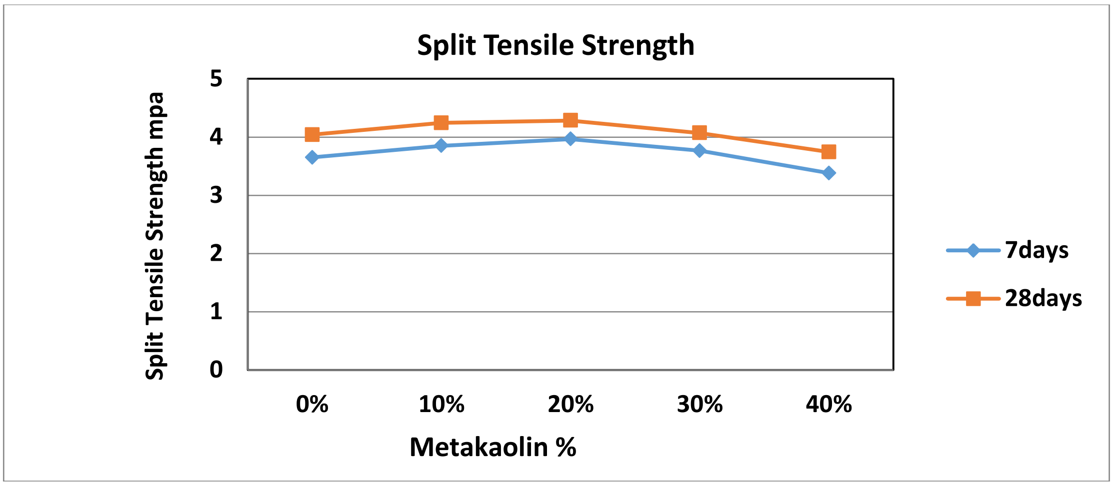

Fig.3.2: Mechanical properties of M70 HSSCC

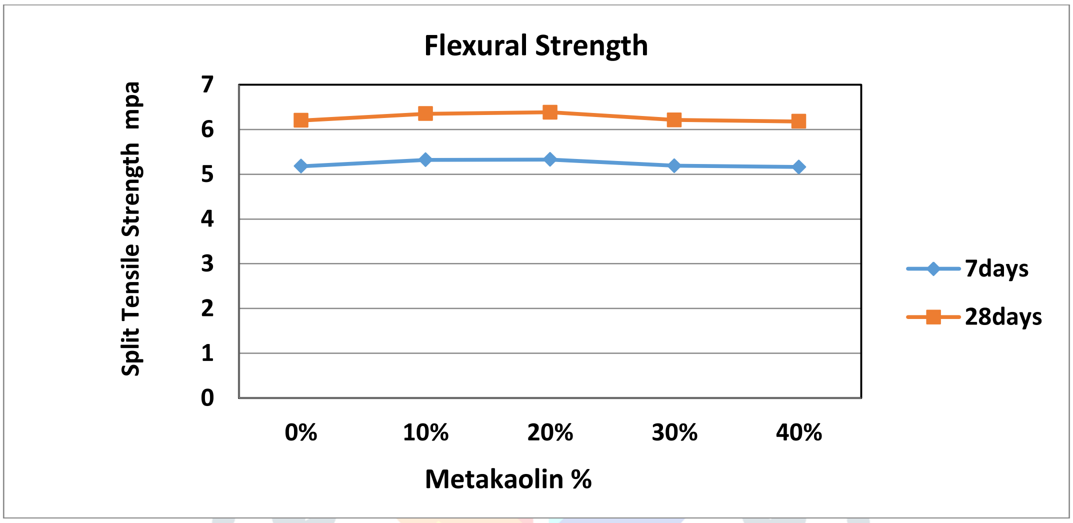

Fig.3.3: Mechanical properties of M70 HSSCC

Loss in Compressive Strength after heating at	Comp. Strength at Room Temp.	CS After heating 1h	%Loss in C.S after Heating 1h	CS After heating 2h	%Loss in C.S after Heating 2h	CS After heating 4h	%Loss in C.S after Heating 4h	CS After heating 6h	%Loss in C.S after Heating 6h
100^0 C	81.65	81.65	0.00	78.18	0.11	81.62	0.20	81.42	0.28
200^0 C	81.65	81.56	4.25	75.96	6.97	71.14	9.36	54.54	11.61
400^0 C	81.62	81.49	11.46	74.01	12.84	66.77	18.19	52.02	26.28
600^0 C	81.62	81.42	31.94	72.17	33.18	60.17	36.27	49.18	39.75

Table 3.4. Loss in Compressive strength after heating 100°C, 200 °C, 400 °C & 600°C at 1hr,2hr,4hr & 6hr duration intervals

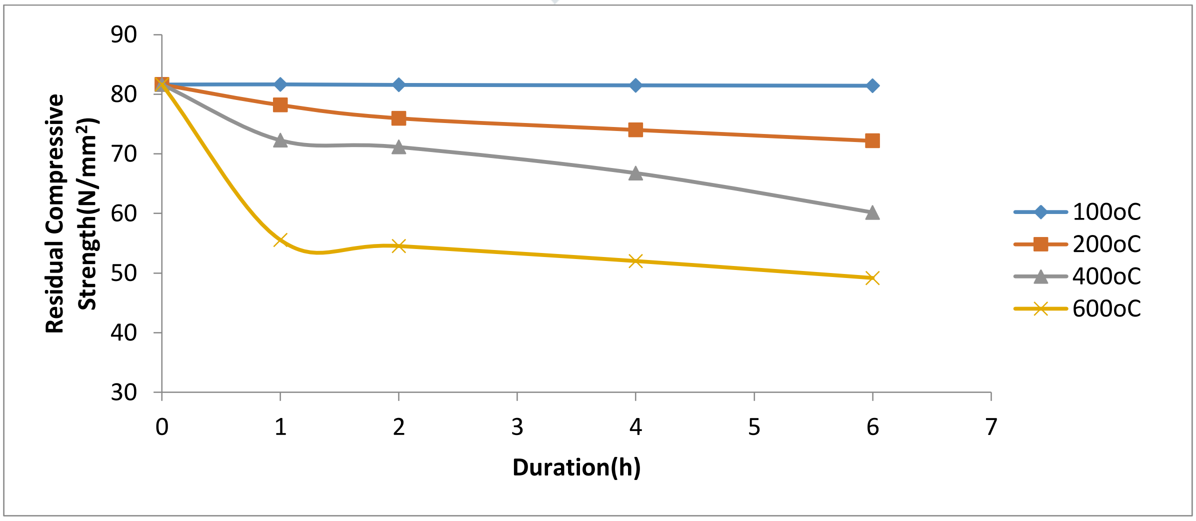

Figure 3.4. Duration Vs Residual Compressive Strength

IV. CONCLUSION

The compressive strength, split tensile strength and flexural strength increased with the increase in the percentage of metakaolin from 0% to 20% & decreases from 30% to 40%. Hence, in this study of experiment we considered as optimum percentage value of Metakaolin is 20%.

Based on studies in Loss of compressive strength at elevated temperatures i.e after heating 100°C, 200°C, 400°C & 600°C, with duration of 1 hr, 2hr, 3hr and 4hr and considering the optimum percentage of Metakaolin i.e 20%. It is observed that at 100°C &1hour duration, percentage loss in compressive strength for HSSCC is zero and it increases gradually as duration increases.

At 100°C 1hour duration percentage loss in compressive strength for HSSCC is 0 (zero)
At 100°C 6 hour duration percentage loss in compressive strength for HSSCC is 0.28
At 200°C 1 hour duration percentage loss in compressive strength for HSSCC is 4.25.
At 200°C 6 hour duration percentage loss in compressive strength for HSSCC is 11.61.
At 400°C 1 hour duration percentage loss in compressive strength for HSSCC is 11.46.
At 400°C 6 hour duration percentage loss in compressive strength for HSSCC is 26.28.
At 600°C 1hour duration percentage loss in compressive strength for HSSCC is 31.94.
At 600°C 6hour duration percentage loss in compressive strength for HSSCC is 39.75.

REFERENCES

[1] Okamura, H. and Ouchi, M., "Self-compacting concrete-development, present and future", Proceedings of the First International RILEM symposium on Self-Compacting Concrete, pp. 3-14.

[2] Okamura, H. and Ouchi, M., (2003). "Self-compacting concrete", Journal of Advanced Concrete Technology, Vol. 1, No. 1, April, pp. 5-15.

[3] P J Tikalsky, P M Carrasquillo and R L Carrasquillo. "Strength and Durability Considerations affecting Mix proportioning of Concrete Containing Fly Ash". ACi Materials journal, Vol 85,1998.

[4] Potgieter-Vermaak, S. and Potgieter, J. (2006). "Metakaolin as an Extender in South African Cement." J. Mater. Civ. Eng., 10.1061/(ASCE)0899-1561(2006)18:4(619), 619-623.

[5] SeshgiriRao. M.V., Janardhan.M. Ravindra Kumar. B. "High Fly Ash Concrete with RHA as an admixture".1999. Vol.80. Journal of Institution of Engineers, (India).pp.57-63.

[6] M.S. Shetty, (2015). Textbook on Concrete Technology – Theory and Practice, Seventh Revised Edition, S. Chand Publishing, New Delhi.

[7] Indian Standards,(1970) Coarse and Fine Aggregates from Natural Sources for Concrete (Second Revision) (IS:383-1970). Ninth Reprint September 1993.

[8] EFNARC, (n.d.). Specifications and Guidelines for Self Compacting Concrete, Retrieved from www.efnarc.org.