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Study on Properties of Fresh and Hardened Self Compacting Concrete with Varied Percentages of Metakaolin as Mineral Admixture (M40 Grade)

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Abstract: *The objective of this paper is to study the properties of fresh and hardened self compacting concrete with varied percentages of metakaolin as mineral admixture (M40 grade). In this study cement is replaced by metakoalin with varied percentages, 20%, 22%, 24%, 26%, 28%, 30%, 32%, 34%, 36% & 38% with a constant packing factor of 1.14. In the present study, B233 GLENIUM super plasticizer is used. As per the European guidelines for Self-compacting concrete, the workability tests such as slump flow test, V-funnel test and L- box, U-box test were carried out in laboratory. The concrete specimens were cured in the tank for 7 and 28 days and tested for determining the compressive strength and split tensile strength and flexural strength respectively. From the study it is observed that workability and mechanical properties such as Compressive strength, Split tensile strength and Flexural strength test increased with increase in metakoalin up to 30% and decreased from 32% to 38%. Non Destructive Test is also performed to assess the quality of concrete in the hardened state.*

Keywords: *Self Compacting concrete, Metakaolin, super plasticizer, NDT, Fresh and Hardened properties.*

I. Introduction

Self compacting concrete (scc) is highly engineered concrete with much higher fluidity without segregation and is capable of filling every corner of formwork under its self weight. Thus SCC eliminates the vibration for the compaction of concrete without affecting its engineering properties. In general Self Compacting Concrete results in reduced construction times and reduced noise pollution. 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. 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. Literature Review

Hagime Okamura & Masahiro Ouchi. [1] Investigation for Establishing a rational mix design method and self compact ability testing methods have been carried out from the view point of making SCC a standard concrete.

J.M. Justice et al, [2],Investigated the Comparison of two Metakaolins and a Silica Fume Used as Supplementary cementitious Materials. The performance of two metakaolin as supplementary cementitious materials (SCMs) was evaluated at 8% by weight cement replacement.

Vilas V. Karjinni and Shrishail B. Anadinni. [3] They emphasized on the mixture proportion which is one of the important parameter in the self compacting concrete. They have used modified Nan-su method and obtained mix design in normal grades with different mineral admixtures & the compressive strength and flow properties of SCC were also studied.

B.B Sabir, S. Wild, J Bai. [**4**] This paper reviews work carried out on the use of Metakoalin as a partial pozzolanic replacement for cement in mortar and concrete and in the containment of hazardous wastes. The literature demonstrates that Metakoalin is an effective pozzolan which causes great improvement in the pore structure and hence the resistance of the concrete to the action of harmful solutions. On the basis of above studies, an attempt has been made in the present investigation was to study on behavior of self compacting concrete with various percentages of replacement of cement with metakoalin. The modified Nan-su method was used for mix design of SCC along with chemical admixture such as B233 glenium.

III. Experimental Programme

An extensive experimental Programme involving the various processes of material testing, mix proportioning, mixing, casting and curing of specimens and testing of specimens were done. The forthcoming sections elaborate the various physical and chemical properties of each material separately.

3.1 Materials Used

The materials used in the preparation of concrete mixes includes cement, fine aggregate, coarse aggregates, metakaolin and Poly carboxylic ether based admixture namely Glenium B233 (brought from BASF) was used to enhance the flow ability of the mixtures. Each material was tested & its physical properties are described below.

3.1.1 Cement

OPC of 53 grade has been used in the study conforming to recommendations stated in IS: 12269-1987. It was procured from a single source and stored.OPC - Ultratech cement was used throughout the experimental work. The physical properties of OPC are tabulated in Table 1. [8]

Table 1: Physical properties of Ordinary Portland Cement

S. No	Property	Test Results
1.	Normal Consistency	30%
2.	Specific gravity	2.9
3.	Initial setting time Final setting time Final setting time	99 minutes 207 minutes
4.	Fineness	1.3%
5.	Soundness	2 mm

3.1.2 Aggregates

The fine aggregate used was locally available river sand without any organic impurities and the coarse aggregate were used, which was bought from the nearby quarry. Aggregates of 10 mm were chosen for the experiment which is clean and free from deleterious materials used was conforming to IS: 383 –1970. The physical properties of fine aggregate and coarse aggregate was shown in Table 2. [9]

Table 2: Physical properties of fine aggregate and Coarse aggregate

S. No	Property	Fine Aggregate	Coarse Aggregate
1.	Specific gravity	2.42	2.6
2.	Bulk Density Loose	1545.69 kg/m^3	1400 kg/m^3
3.	Bulking	4% w c	--
4.	Flakiness Index	--	8%
5.	Elongation Index	--	0%
6.	Fineness Modulus	2.64	--

3.1.3 Metakaolin

Metakaolin differs from other supplementary cementitious materials (SCMs), like silica fume, fly ash, slag. For this work metakaolin was obtained from 20 microns Ltd, Mumbai

Table: 3 Physical properties of Metakaolin

S.No	Description of physical properties	Units	Results
1	Color		1Close To Std
2	Appearance		1 OFF whitePowder
3	Bulk Density	Gm/liter	356
4	Specific gravity		2.63

3.1.4 Super Plasticizer

The chemical admixture GLENIUM B233 was used a super plasticizer. The normal dosage of GLENIUM B233 is between 0.5 and 1.5 liters per 100 kg cementitious material. Dosages outside this range are permissible subjected to trial mixes.

Table: 4 Properties of Super plasticizer

S. No	Property	Results
1.	Form or state	Liquid
2.	Color	Brown
3.	Specific Gravity	1.09 at 30°C

3.1.5 Water

As per recommendation of IS: 456 -2000, the water used for mixing and curing must be clean and free from substances that may be deleterious to concrete or steel The pH value of water shall be not less than 6. In the present investigation, tap water is used for both mixing and curing purposes.[10]

3.2 Mix Proportions For M40 SCC (Metakoalin % Variable)

SCCMK 20: Cement replaced by 20% of Metakaolin
SCCMK 22: Cement replaced by 22% of Metakaolin
SCCMK 24: Cement replaced by 24% of Metakaolin
SCCMK 26: Cement replaced by 26% of Metakaolin
SCCMK 28: Cement replaced by 28% of Metakaolin
SCCMK 30: Cement replaced by 30% of Metakaolin
SCCMK 32: Cement replaced by 32% of Metakaolin
SCCMK 34: Cement replaced by 34% of Metakaolin
SCCMK 36: Cement replaced by 36% of Metakaolin
SCCMK 38: Cement replaced by 38% of Metakaolin

Table: 5 Mix Proportions for M40 SCC

MIX (%)	Cement (kgs)	Mk (kgs)	Powder (kgs)	Coarse Agg (kgs)	Fine Agg (kgs)	Water (lts)	Sp (lts)	Total (kgs)
SCCMK 20	399.1	68.9	468	766	916	172	8.5	2330.5
SCCMK 22	392.21	75.79	468	766	916	172	8.5	2330.5
SCCMK 24	385.32	82.68	468	766	916	172	8.5	2330.5
SCCMK 26	378.43	89.57	468	766	916	172	8.5	2330.5
SCCMK 28	371.54	96.46	468	766	916	172	8.5	2330.5
SCCMK 30	364.65	103.35	468	766	916	172	8.5	2330.5
SCCMK 32	357.76	110.24	468	766	916	172	8.5	2330.5
SCCMK 34	350.87	117.13	468	766	916	172	8.5	2330.5
SCCMK 36	344.51	122.96	468	766	916	172	8.5	2330.5
SCCMK 38	338.20	129.79	468	766	916	172	8.5	2330.5

IV. Results And Discussion

Test methods include the tests of fresh concrete mix for workability and hardened concrete specimens for compressive and split tensile strength, flexural strength test. Various tests were conducted on the trail mixes to ensure the requirement of filling ability, passing ability, segregation. The test mentioned in Table 6 was conducted to assess whether the mixes meet the workability requirements of SCC. The results of tests conducted on fresh concrete are given in Table 6.

4.1 Workability Tests

Table 6: Fresh properties of M40 SCC

Concrete Mixes	Slump Flow		V-Funnel		L-Box	U-Box
	Dia(mm)	T500 (Sec)	Sec	T_5 (Sec)	h2/h1	mm
SCCMK 20	638	4.2	11.2	14.4	0.68	3
SCCMK 22	657	4.56	11.85	14.63	0.76	4
SCCMK 24	669	4.9	12.2	15.54	0.81	5
SCCMK 26	685	5.2	12.54	15.69	0.87	6
SCCMK 28	697	5.5	12.74	15.87	0.93	7
SCCMK 30	700	6	12.9	16.06	0.96	8
SCCMK 32	698	5.93	12.63	15.84	0.9	7
SCCMK 34	695	5.78	12	15.75	0.85	6
SCCMK 36	680	5	11.67	14.8	0.78	5
SSCMK38	675	4.6	11.3	14.2	0.71	4

4.2 Compressive Strength Tests

In this investigation, the cube specimens of size 100 mm x 100 mm x 100 mm are tested in accordance with IS: 516 – 1959 [Method of test for strength of concrete]. The testing was done on a compression testing machine of 200 tons capacity. The machine has been calibrated to the required standards. Compressive strength tests were conducted on 100 mm size cubes of SCC in a compression testing machine at 7 and 28 days. The results are given in Table 7 and plotted in Fig.1.[11]

Table: 7 Compressive Strength Results

Type Of Mix	Compressive Strength (N/mm2)	
	7days	28days
SCCMK 20	33.82	48.31
SCCMK 22	34.66	49.52
SCCMK 24	35.32	50.46
SCCMK 26	35.65	51.08

SCCMK 28	36.28	51.84
SCCMK 30	36.91	52.74
SCCMK 32	35.67	50.95
SCCMK 34	34.95	49.94
SCCMK 36	33.76	47.68
SCCMK 38	31.74	44.81

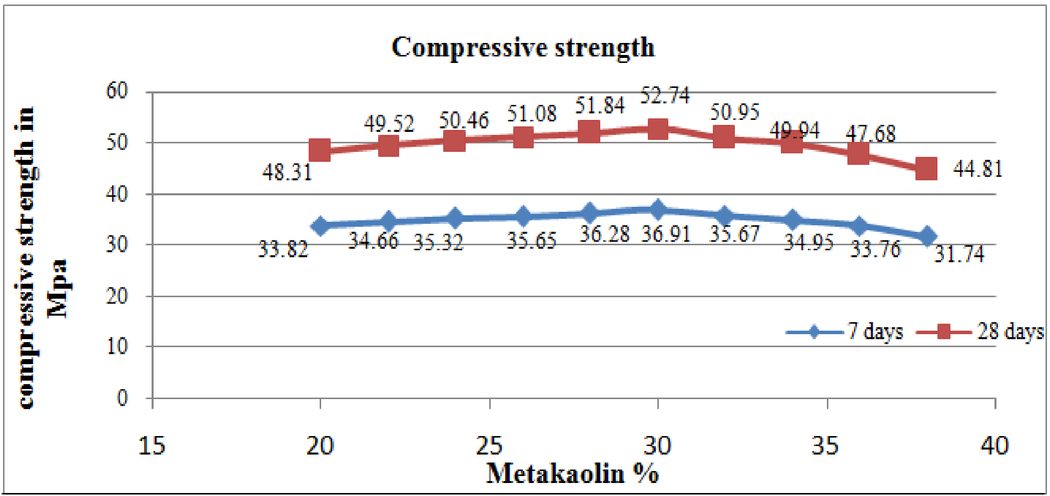

Figure 1 metakaolin% vs compressive strength

4.3 Split Tensile Strength Tests

Splitting tensile strength tests were conducted on cylindrical specimens of 150 mm diameter and 300 mm height at 7 and 28 days in accordance with BIS specifications and procedures. The results are given in Table 8.

Table 8 Split Tensile Strength results

Type Of Mix	Split tensile strength (N/mm^2)	
	7days	28days
SCCMK 20	3.42	4.16
SCCMK 22	3.49	4.23
SCCMK 24	3.53	4.3
SCCMK 26	3.58	4.38
SCCMK 28	3.61	4.41
SCCMK 30	3.65	4.49
SCCMK 32	3.58	4.39
SCCMK 34	3.53	4.34
SCCMK 36	3.46	4.28
SCCMK 38	3.34	4.08

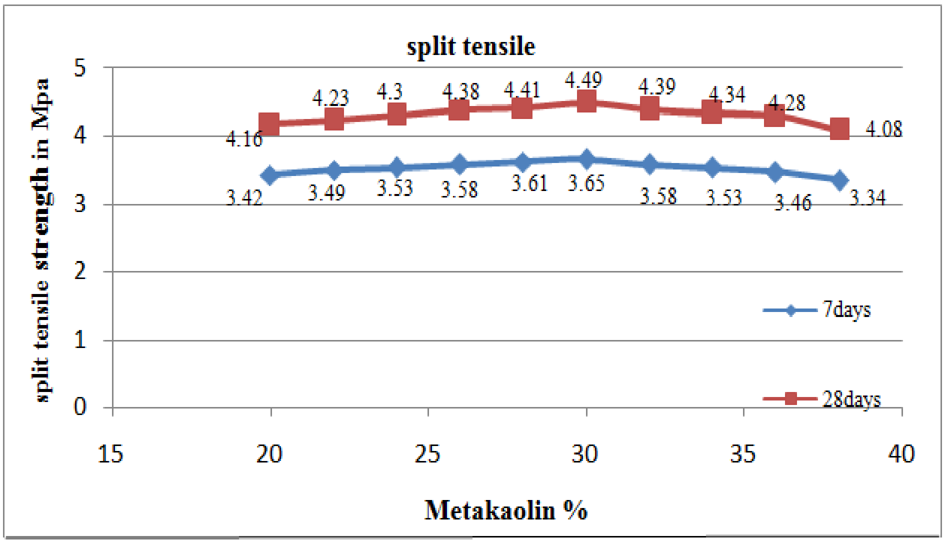

Figure 2 Metakaolin% Vs Split tensile strength

4. 4 Flexural Strength Tests
Flexural tests were conducted on beams of size of 100 mm x 100mm X 500 mm subjected to two point loading at 28 days in UTM and the results were given in Table 9. These results are plotted in Fig.3.

Table: 9 Flexural Strength Results

Type Of Mix	Flexural strength (N/mm^2)	
	7days	28days
SCCMK 20	4.07	4.86
SCCMK 22	4.11	4.92
SCCMK 24	4.16	4.97
SCCMK 26	4.18	5.0
SCCMK 28	4.21	5.04
SCCMK 30	4.25	5.1
SCCMK 32	4.20	4.99
SCCMK 34	4.13	4.94
SCCMK 36	4.06	4.83
SCCMK 38	3.94	4.68

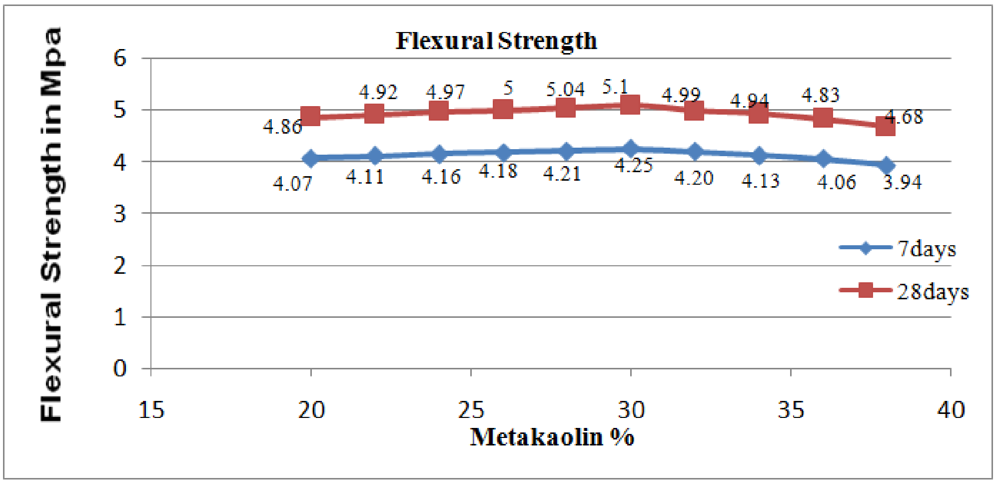

Figure 3 Metakaolin% Vs Flexural strength

4.5 Non Destructive Tests
The main objective of the present experimental investigations is to assess the quality, structural integrity and estimated compressive strength of metakaolin incorporated self compacting concrete of grade M40 using Rebound hammer and Ultrasonic pulse velocity measurements.

4.5.1 Rebound Hammer Test
Rebound hammer is the oldest technique used to assess the compressive strength of concrete indirectly and also to compare the various parts of structure. Schmidt rebound hammer is the instrument for this test. Schmidt rebound hammer shown in Fig1 is a simple, handy tool, which can be used to provide a convenient and rapid indication of the compressive strength of concrete. It consists of a spring controlled mass that slides on a plunger within a tubular housing. It works on the principle that the rebound of an elastic mass depends on the hardness of the surface against which the mass impinges.

Figure 4: Rebound hammer used

Table 10: Quality of concrete based on Average Rebound Hammer

Average rebound number	Quality of concrete
> 40	Very good hard layer
30 to 40	Good layer
20 to 30	Fair
< 20	Poor

4.5.2 Ultrasonic Pulse Velocity Test

Three reading of ultrasonic pulse velocity (USPV) were obtained for each cube. The cubes were then give a load of 7 N/mm2 (as specified by the IS code 13311) in the compression testing machine and the USPV were obtained. The cubes were then loaded upto their ultimate stress and the breaking load was obtained. The method starts with the determination of the time required for a pulse vibration at an ultrasonic frequency to travel through a concrete. Once the velocity is determined, an idea about quality, uniformity, condition and strength of the concrete tested can be attained. In the test, the time the pulses take to travel through concrete is recorded. Then the velocity is calculated as [12]

V = L/T

Where

V= Pulse Velocity, L = travel time in meters and

T = effective time in seconds

Table: 11 General Guidelines for Concrete Quality based on USPV

Pulse Velocity	Quality of concrete
4.0 km/s	Very good to excellent
3.5 to 4.0 km/s	Good to very good, slightly porosity may exist
3.0 to 3.5 km/s	Satisfactory but loss of integrity may exist
< 3.0 km/s	Poor and loss of integrity exist

Figure 5: Ultrasonic Pulse Velocity used

Table: 12 Non-destructive test results of M40 grade SCC

%(MK)	Combined Rebound hammer and Ultrasonic Pulse Velocity Methods Results			
	M40 Concrete, Mpa			
	Mean Rebound Value	Mean Pulse Velocity km/sec	Compressive Strength N/mm2	Quality of Concrete
20%	29.6	2.83	23.3	Satisfactory
22%	31.9	2.98	26.5	Satisfactory
24%	34.2	3.08	30	Medium
26%	36.7	4.37	35.5	Good
28%	41.4	4.48	43.7	Good
30%	43.9	5.27	50.4	Excellent
32%	42.7	4.93	48.1	Excellent
34%	38.2	4.24	37.5	Good
36%	35.1	3.3	31.8	Medium
38%	32.5	2.37	24.9	Satisfactory

V. Conclusion

From the detailed experimental work done on SCC mix with an aim to study on properties of fresh and hardened self compacting concrete with varied percentages of metakaolin as mineral admixture for M40 grade (20%, 22%, 24%, 26%, 28%, 30%, 32%, 34%, 36% & 38%) the following conclusions are arrived.

The workability increases gradually as the percentage increases from 20% to 30% and decreases from 32% to 38%.

- The compressive strength, split tensile strength and flexural strength increased with the increase in the percentage of metakaolin from 20% to 30% & decreased from 32% to 38%.
- The optimum percentage of metakaolin is taken as 30% for w/c = 0.38.

- Based on the Non Destructive Tests it is concluded that quality of concrete,
  - For the mix with 30% & 32% metakaolin is excellent.
  - For the mix with 26%, 28% & 34% metakaolin is good.
  - For the mix with 24 & 36% metakaolin is medium.
  - For the mix with 20%, 22%, 38% metakaolin is satisfactory

References

[1] Okamura.H., and Ouchi.M., (2003) "Self-compacting concrete", Journal of Advanced Concrete Technology, 1[1], 5-15.
[2] Justice. J.M., Kennison. L.H., Mohr.B.J., Beckwith. S.L., McCormick. L.E., Wiggins. B., Zhang.Z. Z., and Kurtis. K.E., (2005) "Comparison of Two Metakaolins and a Silica Fume Used as Supplementary Cementitious Materials" International Symposium in Washington D.C. 20-24,
[3] Karjinni. Vilas V., Anadinni. Shrishail B., (2009) "Mixture Proportion Procedure for SCC" Indian Concrete Journal. 35-41.
[4] Sabir. B.B., wild. S, Bhai. J., (2001) "Metakaolin and calcined clays as a pozzolans for concrete: a review" cement and concrete composites 441-454.
[5] Subramanian .S., and Chatopadyay.D., (2002)"Experiments for mix proportions of Self Compacting Concrete", The Indian Concrete journal, 13-20
[6] Naveen Kumar C., Jagadish V., and Ranganath R.V., **(** 2006**)** "Self-Compacting Concrete with Fly Ash and Metakaolin", The Indian Concrete Journal, 33-39.
[7] Mallikarjuna Reddy .V., Seshagiri Rao. M.V., Srilakshmi. P., and Venkateswarlu. K., "Effect of Packing Factor on workability and Mechanical Properties of Self-Compacting Concrete of M70 Grade with Fly Ash and Micro Silica as filler Material".
[8] IS 12269:2013 Ordinary Portland Cement, 53 grade – specification (first revision), Bureau of Indian Standards, New Delhi
[9] IS: 383 (Specification for coarse and fine aggregates from natural sources for concrete), Indian Standard Code of Practice, 1970.
[10] IS: 456 – 2000 Plain and reinforced concrete – Code of practice (fourth revision), Bureau of Indian Standards, New Delhi
[11] IS: 516 – 1959 [Method of test for strength of concrete].
[12] IS13311 (Part1)- 1992 [method of test for ultrasonic pulse velocity]
[13] www.efnarc.org:European Specifications and guidelines for Production & Use of SCC, February and May 2005.
[14] EFNARC guidelines for Specifications and guidelines for Self-compacting concrete , February 2002
[15] www.basf-cc.co.in. (Gelenium).