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Combined Effect of Ground Granulated Blast Furnace Slag and Metakaolin on Mechanical Properties of Self Compacting Concrete

J.M.Srishaila[1], Basawakiran.B.M[2], K.N.Vishwanath[3], P.Prakash[4]
Associate Professor[1,3], PG Student[2], Professor[4]
Dayananda Sagar College of Engineering, Bangalore

ABSTRACT: *This study investigates the combined effect of Ground Granulated Blast Furnace Slag (GGBS) and Metakaolin on the properties of self compacting concrete. The workability test for acceptance of self compacting concrete like slump test, V-funnel, and L-Box were carried out on fresh concrete. The compressive, split tensile, and flexural strength test of concrete with replaced GGBS plus Metakaolin at 5%,15%and 25% and 3%,6% and9% were examined after curing period of 28 and 56 days. RCPT test was also carried out on the hardened concrete after curing period 28 days to know the penetration of chloride ion. Ultra sonic pulse velocity was also conducted to known the grade of concrete.*

KEYWORDS: *Self Compacting Concrete, Ground Granulated Blast Furnace Slag (GGBS), Metakaolin, Compressive strength, Split tensile strength, Flexural strength.*

I. INTRODUCTION

The concrete is the man-made material which has the vastest utilization worldwide. This fact leads to important problems regarding its design and preparation to finally obtain an economic cost of the product on short and long time periods. The material has to be also "friendly with the environment" during its fabrication process and also its aesthetical appearance when it is used in the structures. Concrete's performances have continuously rise in order to accomplish the society needs. Many studies have been made concerning the use of additives and super–plasticizers in the concrete for passing the frontier of minimum water content for a good workability of a concrete. As a result of this, high performance concretes developed having a superior durability.

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. The hardened concrete is dense, homogeneous and has the same mechanical properties and durability as traditional concrete. SCC, was first introduced in the late 1980's to have no segregation and bleeding. Such concrete should have a relatively low yield value to ensure high flow ability, a moderate viscosity to resist segregation and bleeding, and must maintain its homogeneity during transportation, Japanese researchers, is highly workable concrete that can flow under its own weight through restricted sections placing and curing to ensure adequate structural performance and long term durability. The successful development of SCC must ensure a good balance between deformability and stability. For SCC, it is generally necessary to use super plasticizer in order to obtain high mobility. Adding a large volume of powdered material or viscosity modifying admixture segregation can be eliminated.The present study determines the properties of self compacting concrete with combined replacement of GGBS and Metakaolin to cement.

RESEARCH SIGNIFICANCE

For a newly developing material like SCC, studies on mechanical and durability is of paramount importance for instilling confidence among the engineers and builders. A comprehensive study which involves durability parameters like RCPT is not available for SCC. Hence, considering the gap in the existing literature, an attempt has been made to study on the durability parameters of SCC like Rapid Chlorine Penetration Test.
Also there are no much research are done on the SCC containing Metakaolin and GGBS as admixtures. Hence it's an opportunity to take this project and carrying out the work.

METHODOLOGY

The main aim of this work is to assess the feasibility of Self compacting concrete with the mineral admixtures such as Metakaolin and GGBS replacing OPC by a known percentage to understand the change in properties of SCC.

- The Ordinary Portland cement is replaced by (Metakaolin 3%+GGBS 5%,15%,25%), (Metakaolin 6%+GGBS 5%,15%.25%), (Metakaolin 9%+GGBS5%) percentage and superplasticizer is also added to get workability.
- Total seven mix designs are prepared and the properties are checked in fresh state and hardened state.
- The tests are conducted for 7,28,56,90 days for the hardened concrete.
- RCPT test was also conducted on the hardened cylinders to know the chloride resistance of the concrete.

II MATERIALS AND PROPERTIES

The materials used in the research are:

Cement

In this work ordinary Portland cement of 53 grade conforming to IS: 12269-1987 has been used and tested for physical and chemical properties as per IS: 4031 – 1988 and found to be conforming to various specifications as per IS: 12269-1987.

Table: 1 Physical properties of cement

Sl. No.	Properties		Values	IS:12269-1987
1	Standard Consistency		27%	28%
2	Fineness % (retained on 90μ sieve)		3%	≤ 10%
3	Soundness (by Le Chatelier)		3 mm	≤10mm
4	Initial setting time (min)		62	≥30 min
5	Final setting time (min)		370	≤ 600 min
6	Specific gravity		2.95	-----
7	Compressive Strength	7 days	45	≤ 37 N/mm2
		28 days	65	≤ 53 N/mm2
8	Temperature during testing		27.8°C	27° C ± 2°C

2. Fine aggregate

In the investigation fine aggregate is manufactured sand from quarry is used, are as per IS: 383-1997. The physical properties of fine aggregate like specific gravity, gradation and fineness modulus are tested in accordance with IS:2386.

Table: 2 Physical properties of fine aggregate

Sl.No.	Property	Value
1	Specific gravity	2.62
2	Water absorption	3.8%
3	Max size(mm)	4.75mm
4	Fineness Modulus	3.60

3. Coarse aggregate

Coarse aggregate crushed granite of 12.5 mm maximum size and retained on IS 4.75 sieve has been used as coarse aggregate. The physical properties of coarse aggregate like specific gravity, gradation and fineness modulus are tested in accordance with IS: 2386.

Table: 3 Physical properties of coarse aggregate

Sl.No.	Property	Value
1	Specific gravity	2.7
2	Water Absorption	0.8%
3	Max size(mm)	12.5
4	Flakiness Index	22.6%
5	Elongation Index	24%

4. Mineral admixtures

a) Metakaolin

In the present investigation work, the metakaolin used is obtained from Gujarat India. Specific gravity being 2.42. Chemical Properties of Metakaolin is given in the below table.

Table: 4 Chemical properties of metakaolin

Sl.No.	Parameter	Quantity (% wt)
1	Silicon Dioxide(SiO_2)	52
2	Alumina(Al_2O_3)	42.2
3	Iron oxide(Fe_2O_3)	0.7
4	L.O.I.	0.3%
5	Oil Absorption	56.5
6	Moisture	0.1
7	pH	6.55
8	Brightness	83.4

b) Ground Granulated Blast Furnace Slag (GGBS)

Ground Granulated Blast Furnace Slag (GGBS) is a highly efficient pozzolonic material and has considerable potential for use in concrete and it is obtained from steel works at Bellary. Specific gravity being 2.62.

Table: 5 Chemical properties of GGBS

Sl.No.	Parameter	Quantity (% wt)
1	Insoluble residue	0.83
2	Manganese Oxide	0.25
3	Magnesium oxide	10.13
4	Sulphide sulphur	0.75
5	$CaO+MgO+1/3Al_2O_3$ $SiO_2+2/3Al_2O_3$	1.10
6	$CaO+MgO+ Al_2O_3 SiO_2$	1.84

5. Chemical admixture

Super plasticizer -Master Glenium sky-8233 is used. The properties of superplasticizer are given in below table.

Table: 6 Properties of Super plasticizer

Aspect	Light Brown liquid
Relative density	1.08 ± 0.01at 25˚c
pH	≥ 6
Chloride ion content	< 0.2%

6. Water

This is the least expensive universally available material, but most important ingredient of concrete. The water used for making concrete and for curing, should be clean and free from harmful impurities such as oil, alkali, acid, etc.

Table:7 Physical and Chemical properties of Water

Mix No.	Cement Kg/m^3	GGBS Kg/m^3	MK Kg/m^3	Fine Agg Kg/m^3	Coarse Agg Kg/m^3	W/C	Super Plas. Kg/m^3
Mix 1 (5%GGBS+3%MK)	**514.52**	**24.835**	**13.764**	**880.94**	**714.42**	**0.343**	**4.42**
Mix 2 (5%GGBS+6%MK)	**497.74**	**24.835**	**27.527**	**880.94**	**714.42**	**0.345**	**4.4**
Mix 3 (5%GGBS+9%MK)	**480.97**	**24.835**	**41.291**	**880.94**	**714.42**	**0.347**	**4.37**
Mix 4 (15%GGBS+3%MK)	**458.60**	**74.505**	**13.764**	**880.94**	**714.42**	**0.347**	**4.37**
Mix 5 (15%GGBS+6%MK)	**441.82**	**74.505**	**27.527**	**880.94**	**714.42**	**0.349**	**4.35**
Mix 6 (15%GGBS+9%MK)	**425.04**	**74.505**	**41.291**	**880.94**	**714.42**	**0.351**	**4.32**
Mix 7 (25%GGBS+3%MK)	**402.67**	**124.176**	**13.764**	**880.94**	**714.42**	**0.351**	**4.32**

III. MIX PROPORTION

The proposed study is being carried out to develop self compacting concrete using GGBS and Metakaolin in varying combinations for use in the Indian conditions. Following guidelines of EFNARC for rheological properties of concrete in fresh state and using Japanese method of mix design as reference, mix design was carried to form concrete at coarse aggregate content of 45% by volume of concrete and fine aggregate content of 47% by volume of mortar in concrete and cement volume was kept varying based on the percentage of mineral mixtures. The dosage of superplasticizer was estimated to be 0.8 % of cement. Slump flow test, V- funnel, L box test satisfies the limits laid by EFNARC. Now 5%, 15%, 25% weight of GGBS is replaced with equal weight of cement and cement is also replaced with 3%,6%,and 9% by weight of metakaolin and self compacting concrete is prepared which satisfied rheological properties. The mix proportions are given in below table no 8.

IV. RESULTS AND DISCUSSION

Table :8 **Mix Proportions**

Sl.No.	Contents	Units
1	Ph	7.72
2	Acidity	NIL
3	Specific conductance	835 micro/mhos
4	Total hardness	274 mg/litre
5	Chloride	105 mg/litre
6	Turbidity	1 NTU
7	Alkalinity	260 mg/litre
8	TDS	500 mg/litre

4.1Fresh Properties Result

The workability of the concrete was measured in terms of passing ability, filling ability and segregation resistance as per EFNARC guide lines and limits are given in Table 9.

Table: 9 Results of fresh properties

Sl.No	Methods	Units	Min	Max	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6	Mix 7
1	Slump flow	mm	650	800	690	687	680	709	695	692	720
2	T50 cm Slump flow	Sec	2	5	2.9	3.3	3.9	2.7	3.1	3.7	2.6
4	V-funnel	Sec	6	12	7	9.2	10	6.5	10	11.1	6.2
5	L-box (h2/h1)	--	0.8	1	0.90	0.88	0.87	0.91	0.90	0.88	0.93
6	Temperature	(^{0}C)			24	25	24	23	26	25	24

From the above obtained results we can say that the increase in content of metakaolin decreases the passing and Filling ability of the self compacting concrete. The temperature of the concrete tends to increase with the increase in the percentage of metakaolin.

4.2Mechanical Properties Result

The mechanical properties of self compacting concrete includes the various strength parameters like compressive strength, split tensile strength, flexural strength and density of the concrete. The obtained values are presented in below table.

Table: 10 Results of mechanical properties

Mix	Density (Kg/m^3)	pH	Compression Strength (N/mm^2)		Split Tensile Strength (N/mm^2)		Flexural Strength (N/mm^2)	
			28 days	56 days	28 days	56 days	28 days	56 days
Mix 1	2472	11.48	45.23	53.24	4.57	4.88	10	11.75
Mix 2	2526	11.50	50.2	60.77	4.58	4.98	11.5	12.3
Mix 3	2550	11.63	52.7	68.79	4.71	5.55	13	13.5
Mix 4	2470	11.8	53.36	69.8	5.06	5.85	13.5	14
Mix 5	2480	11.94	63.9	76.85	5.72	5.85	14.5	16.5
Mix 6	2510	11.70	60.95	73.95	4.78	4.84	15.75	16.25
Mix 7	2480	11.4	58.78	68.62	4.72	4.80	15.25	16

4.2.1 NDT test

Ultra sonic pulse velocity

Ultrasonic pulse velocity testing of concrete is based on the pulse velocity method to provide information on the uniformity of concrete,cavities,cracks and defects.The pulse velocity in a material depends on its density and its elastic properties which in turn are related to the quality and the compressive strength of the concrete.It is therefore possible to obtain information about the properties of components by sonic investigations.The test is carried according to **IS 13311 (Part 1):1992.**

Table: 11 Result of Ultrasonic Pulse Velocity test

Mix	Average Pulse Velocity(Km/Sec)	Pulse Velocity by Cross Probing(Km/Sec)	Concrete Quality Grading as per IS:13311(part1):1992
Mix 1	6.6	Above 4.5	Excellent
Mix 2	6.7		
Mix 3	6.6	3.5 to 4.5	Good
Mix 4	6.8		
Mix 5	6.9	3.0 to3.5	Medium
Mix 6	6.8		
Mix 7	6.7	Below 3.0	Doubtful

4.3Durability Properties Results

4.3.1 Rapid Chloride Penetration Test

The data on the resistance of the high performance self-compacting concrete mixture to chloride ion penetration determined in accordance with **ASTM C 1202-1994.** Accelerated chloride permeability tests were conducted on standard cylindrical specimens after curing period of 28 days.

Table: 12 Result of RCPT test

Mix	28 days Chloride Ion Permeability (Coulombs)	Charge Passing (Coulombs)	Chloride Permeability Rating
Mix 1	1853.1	Greater than 4000	High
Mix 2	1855.9		
Mix 3	1859.3	2001 to 4000	Moderate
Mix 4	1861.5		
Mix 5	1865.7	1001 to 2000	Low
Mix 6	1870.6		
Mix 7	1873.8	100 to 1000	Very low

FIGURES

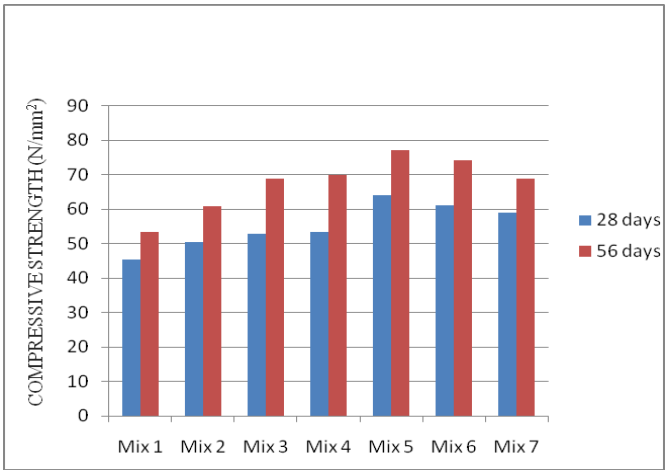

Figure: 1 Compressive Strength of Concrete in relation to different mix proportion.

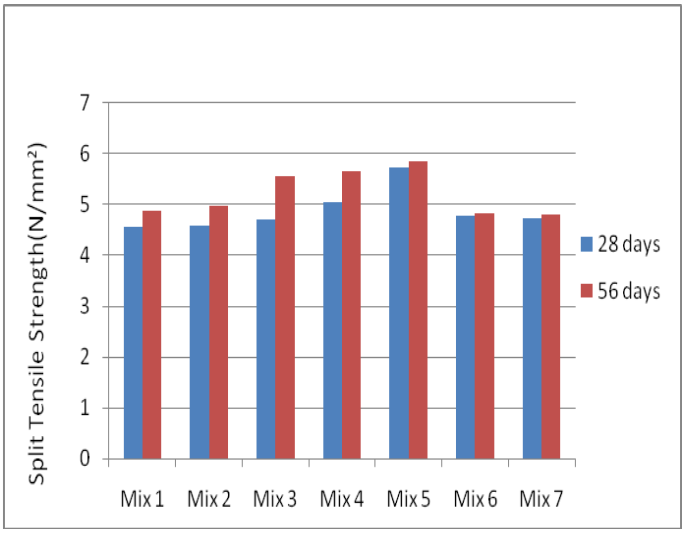

Figure: 2 Split tensile Strength of Concrete in relation to different mix proportion.

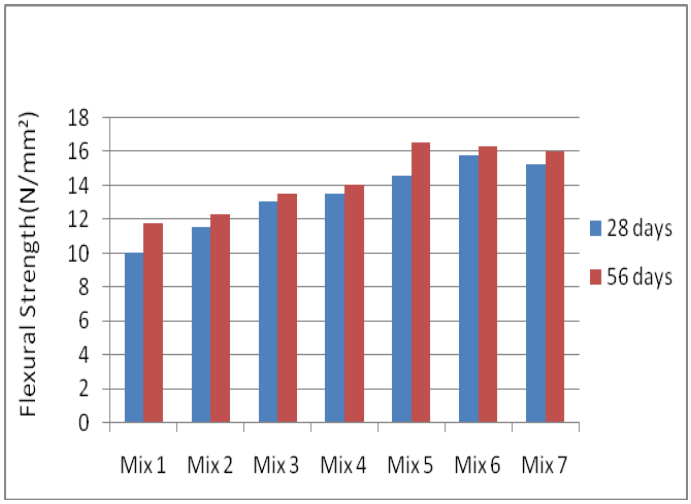

Figure: 3 Flexural Strength of Concrete in relation to different mix proportion.

V CONCLUSION

Based on the experimental results the following conclusion are drawn

- Fresh property results show us that as the percentage of Metakaolin increases the filling and flowing ability of the concrete decreases.
- The temperature of the concrete increased with the increase in percentage of Metakaolin.
- The compressive, split tensile, flexural strength is maximum for the mix proportion Metakaolin 6% and GGBS 15% and is higher by 44% with respect to first mix.
- The Ultrasonic Pulse Velocity test values show that the concrete compaction is good without any external vibration.
- An RCPT value shows that as the percentage of GGBS and Metakaolin increases the chloride ion permeability will be low.
- 56 days compressive strength is higher by 13%if compared to 28 days strength of all mixes.

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