A Study on Compatibility of Super Plasticizers with GGBS Blended Cement Concrete using OPC 53-S

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Abstract
This paper presents the flow behavior of super plasticized ordinary Portland cement of specially graded (OPC 53-S) which is controlled by the dispersion of cement particles using super plasticizers. The blended special graded cement with ground granulated blast furnace slag (GGBS) is being used quite commonly instead of pure special cement due to later non availability of cement and to improve the durability of concrete. The flow behavior of cement paste with different chemical composition such as SP1 and SP2 of PCE (Polycarboxylic ether) based super plasticizer (SP) and dosage of super plasticizers is optimized by conducting marsh cone test. The evaluation of the effectiveness of plasticizers is also reviewed. The factor which controls the compatibility, the presence of minerals and chemical admixtures and the proportion of concrete were discussed clearly. This study also includes mechanism of concrete, reduced rate of strength gain, loss of workability, change in long term behavior and alternation of setting behavior are the specific issues of incompatibility. It is mainly observed that as the percentage of GGBS replacement increases, the optimum dosage of super plasticizer decreases to achieve the desired workability. The target mean strength of M40 grade concrete is achieved using 35% GGBS with PCE based super plasticizer.

Key Words: Super plasticizer, Marsh cone test, Saturation dosage, Setting time, Loss of slump

1. INTRODUCTION

Concrete has been recognized as a very important building material for sustainable infrastructure development in India. In the present situation, more time for construction is impossible and the results are expected in short time. Special cement such as OPC53-S has been introduced to attain high early strength and high performance concrete. This cement can be used for prestressed concrete elements, high raised buildings, and high strength concrete. Though high workability and high strength concretes are achieved by reducing the water- cement ratio, it directly affects the workability and compaction of concrete. The desired workability at low water-cement ratio is achieved by using Super Plasticizers [6].Super plasticizer constitutes a relatively new category and improved version of plasticizer, which permits the reduction of water to the extent upto 45% without reducing workability. Super plasticizers are classified to be under 3 generations namely

1. Lignosulphonates – 1st generation
2. Sulphonated melamine formaldehyde (SMF) and Sulphonated naphthalene formaldehyde (SNF)-2nd generation
3. Polycarboxylic ether (PCE)-3rd generation.[3]

In the present study, PCE (Polycarboxylic ether) third generation super plasticizer is used. The effectiveness of super plasticizer depends on various factors such as the chemical nature and molecular weight of the polymer, particle size distribution and composition of the binder. [8]PCEs are generally more effective than other generation of super plasticizers due to large number of long side chains with high molecular weight. Optimization of the dosage of super plasticizer is also essential since low dosage may affect loss of fluidity and high dosage could lead to segregation. Using Marsh cone test the optimum dosage of super plasticizer is determined. The use of super plasticizer is practiced for production of flowing, self-leveling, self-compacting and for the production of high strength and high performance concrete [1]. Ground granulated blast furnace slag is similar to ordinary cement along with fineness, setting time, soundness and strength. It is recognized that the rate of hardening of GGBS in mortar or concrete is somewhat slower than that of Ordinary Portland cement during first 28 days. But there after it increases the strength and become close to or even exceeds the Portland cement strength. The heat of GGBS is lower than that of ordinary Portland cement. So slag cement is to be used in mass concrete structures [2]. Therefore by blending these two materials the strength can be maintained in the early age and also in the later ages.

II. MATERIALS

I.OPC 53-S Cement:

Ordinary Portland cement of special graded OPC53-S cement is referred IRS-T40:1985 was adopted in the study. It is a very finely ground cement with high C_3S content designed to develop high early strength in the manufacture of concrete sleepers for Indian railways. The physical property of cement is presented in Table1.

II.GGBS:

Ground granulated blast furnace slag (GGBS) a mineral admixture is a by-product of iron and steel production Industry was used in the study. An experiment with various percentages of mineral Admixtures up to the permissible limit as given in IS 455:1989, used the chemical property of GGBS is presented in Table 2.

III. Aggregates:

Aggregates are classified as fine aggregate and coarse aggregate: As per IS 383- 1970, fine aggregate is defined as the aggregate most of which passes through 4.75 mm and retained on 75µ IS sieves, and the coarse aggregate is those most of which will retain 4.75 mm and passes through 80m IS sieves; In

Construction works, 20mm size coarse aggregate is commonly used. The physical properties of aggregates are presented in Table3.

IV. Mix Proportioning of Concrete:

Mix proportioning of concrete was carried out as per IS10262-2009. The design mix proportions for M40 grade concrete is presented in Table VI.

V. Super plasticizers:

In this study PCE based super plasticizer confirming to IS 9103:1999.is adopted with two different chemical compositions and their chemical properties are given in Table V.

TABLE I. Physical Properties of Cement Mixture

Properties	OPC 53-S	OPC53-S&25% of GGBS	OPC53-S& 35% of GGBS	OPC53-S&45% of GGBS
Residue	1%	1%	1%	1%
Consistency	35%	35%	35%	34%
IST(min)	66	66	72	88
FST(min)	330	330	395	495
Specific gravity	3.1	-	-	-
Soundness (mm)	2	1	1	1

TABLE II. Chemical Properties of GGBS (Courtesy From Rashtriya Ispat Nigam Limited-Vizag)

Sample	GGBS
Cao	35%
SiO_2	38%
Al_2O_3	19%
MgO	10%
FeO	5%
MnO	2%
moisture	12%

TABLE III. Physical properties of Fine and Coarse Aggregate

S.No	Properties	Fine aggregate	Coarse aggregate
1	Particle shape andsize	Round&4.75 mm down	Angular&20mm
2	Fineness modulus	3.23	6.87
3	Silt content	1.67%	-
4	Specific gravity	2.53	2.76
5	Water absorption	-	0.55%

Table 4.Mix propo

TABLE IV.Mix Proportioning for M40 Concrete

S.No	Cement	Fine Aggregate	Coarse Aggregate	SP1	SP2	W/C ratio Without SP	W/C ratio With SP
For $1m^3$ concrete	400kg	663kg	1309kg	2lit	2.8lit	200lit	140lit
In ratios	1	1.657	3.27	0.5%	0.7%	0.5%	0.35%

TABLE V. Chemical Properties of PSC Based Super Plasticizers

Properties	SP1	SP2
Appearance	Light yellow colored liquid	Light brown liquid
pH	Minimum 6	5-7
Volume mass@20^0	1.09kg/liter	1.09+(or) 0.01kg/liter
Chloride content	≤0.2%	<0.2%
Alkali content	≤1.5 g	≤3 g
Normal dosage	0.4 to 3liter/100kg	0.2 to 1.5 liter/100kg

III. EXPERIMENTAL INVESTIGATIONS

Marsh cone test is a simple method for optimization of super plasticizer with cement. It consist of 152mm across and 305mm in height to the apex which is fixed with a tube of 8 mm internal diameter and with length 60 mm. Measure 500g of cement, take (W/C) in the ratio of 0.5 and Mix it in a mechanical mixer.200ml of Cement paste was taken in the measuring jar and pour through the cone. While pouring cement paste, the finger was kept at bottom of the cone and once the finger removed, time taken for release of pour was observed using stopwatch. The observations were made with varying percentages of super plasticizers; and same is designated as marsh cone time. The optimum dosage of super plasticizers was identified when the constant time is observed even though increase in percentage of super plasticizer in cement paste

3.2Optimum Dosage of PCE based Super plasticizer

The Marsh cone test conducted using various combinations of cement with different chemical compositions of PCE based SP, to determine the optimum dosage of each combination of cement by graphical representation of dosage of SP with logarithmic time taken to discharge the cement paste is indicated in Table7 and shown in Figure 1 and Figure 2.

TABLE VI. Experimental Test Results

CODE	C1	C2	C3	C4
Type of cement	OPC - 53S	Pozzolanic slag cement(PSC)	Pozzolanic slag cement(PSC)	Pozzolanic slag cement(PSC)
GGBS (%)	0	25	35	45
Slump(mm)	60	67	75	90

COMPRESSIVE STRENGTH IN “Mpa”

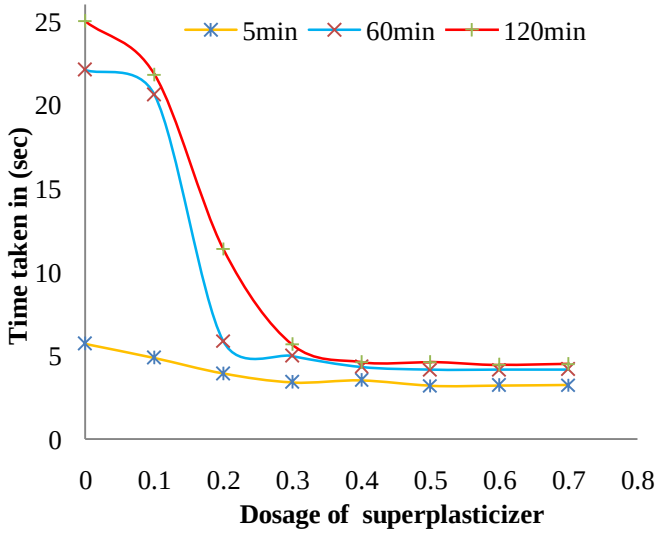
CODE	C1	C2	C3	C4
3days	24.10	22.70	19.75	16.20
28 days	50.46	48.48	48.14	43.50

3.1Mix Proportioning for concrete

M40 grade concrete mix proportioning for the study arrived based on the properties of ingredients with the water-cement ratio of 0.35 using optimum dosage for different chemical composition of PCE based SP. The cement content has been replaced with different percentage of GGBS cement mixture prepared for the study. In this study, the trials were conducted using different combinations of cement mixture as mentioned in Table 6 along with two different chemical compositions of PCE based Super plasticizer. Through Marsh cone test, the optimum dosage and slump retention are determined at various intervals is at 5min, 60min, 120min, 180min.Also observed slump and strength of concrete with optimum dosage of SP at the different ages.

TABLE VII. Effect of Dosage of PCE Based Super Plasticizer

Dosage of SP (%)	**Marsh cone value T in(sec) for SP1super plasticizer**				**Marsh cone value T in(sec) for SP2super plasticizer**			
	5 min	**60 min**	**120 min**	**180 min**	**5 min**	**60 min**	**120 min**	**180 min**
0	5.71	22.1	25.00	60.00	5.71	22.10	25.00	60.00
0.1	4.86	20.60	21.80	49.20	5.40	21.50	23.70	57.40
0.2	3.92	5.88	11.40	19.00	4.90	6.00	12.70	19.94
0.3	3.40	4.98	5.67	7.20	4.34	5.44	5.80	8.40
0.4	3.53	4.32	4.61	5.36	4.15	4.50	5.20	5.43
0.5	3.20	4.16	4.61	5.33	3.67	3.91	4.61	5.35
0.6	3.21	4.16	4.46	5.33	3.65	3.90	4.33	4.60
0.7	-	-	-	-	3.57	3.90	4.30	4.60
0.8					3.55	3.80	4.33	4.60



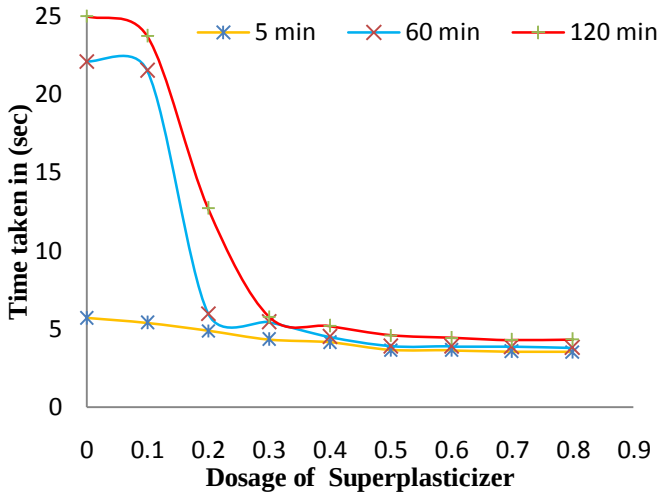


Fig 1: Marsh cone flow curve for SP1

Fig 2:.Marsh cone flow curve for SP2

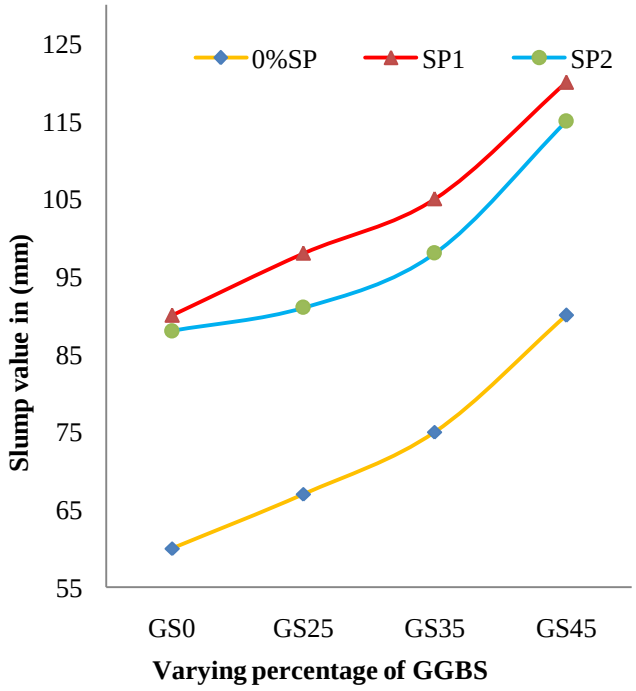


Fig 3: Slump retention of concrete

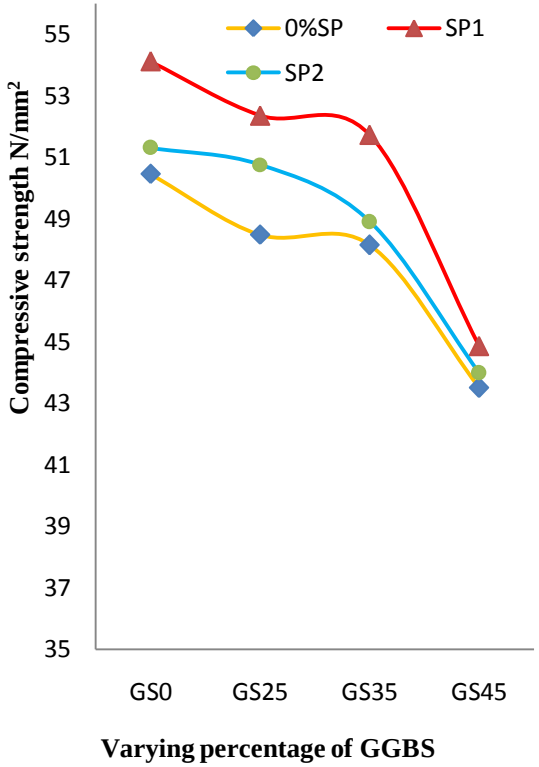


Fig 5: Compressive strength results for 28-days

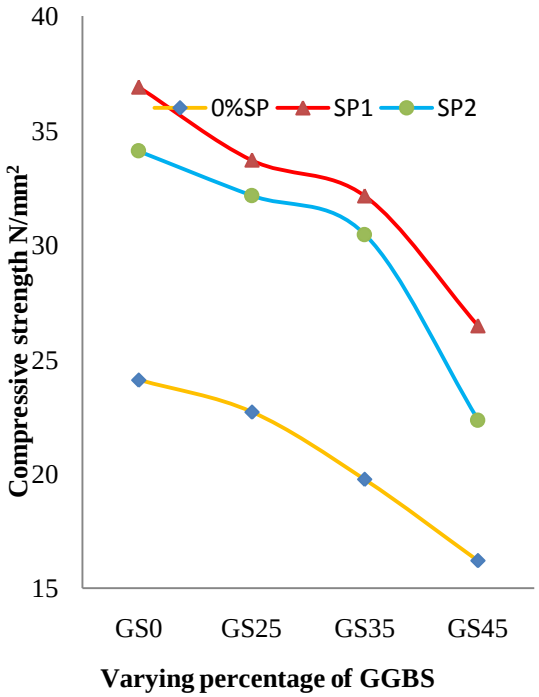


Fig 4: Compressive strength results for 3-days

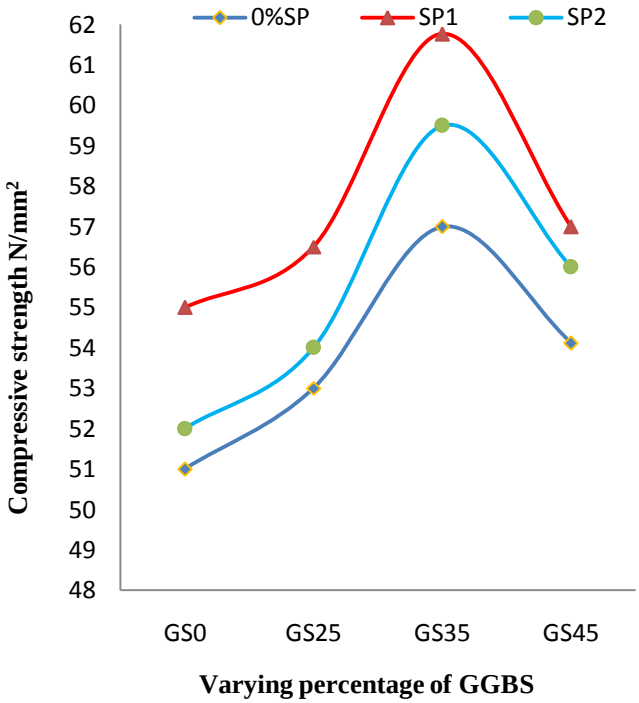


Fig 6: Compressive strength results for 91-days

IV. RESULTS AND DISCUSSION

The selected OPC 53-S cement is replaced with GGBS upto 45% to determine the optimum dosage of two different chemical composition of PCE based super plasticizers. From the above study, the slump value is nearly equal even after slump retention period of 1hr and compressive strength of concrete for 3, 28 and 91 days are tested simultaneously which is given in Table 8. It is observed that SP1optimized at a value of 0.5% with good slump retention which is minimum compared to SP2 at a value of 0.7% as shown in Figure 1 and 2. The compressive strength of SP1 is more compared to SP2 with same varying percentage of GGBS which is shown in Figure 5 and 6. As the percentage of GGBS increased in the concrete, the workability of concrete also increases linearly from above observation which is shown in Figure 3.

TABLE VIII. Comparison of Test Results between Two Different Chemical Compositions of PCE Based SP with Various Combinations of GGBS Blended Concrete

Sample code	Without SP				SP1					SP2				
	slump (mm)	compressive strength(MPa)			Slump (mm)	Optimum dosage (%)	compressive strength(MPa)			slump (mm)	Optimum dosage (%)	compressive strength(MPa)		
		3 days	28 days	91 days			3 days	28 days	91 days			3 days	28 days	91 days
C1	60	24.10	50.46	51.00	90	0.6	36.89	54.12	55.00	88	0.8	34.1	51.31	52.00
C2	67	22.70	48.48	53.00	98	0.5	33.71	52.36	56.50	91	0.7	32.15	50.76	54.00
C3	75	19.75	48.14	57.00	105	0.5	31.22	51.73	61.70	98	0.7	30.45	48.90	59.50
C4	90	16.20	43.50	54.12	120	0.5	26.47	44.86	57.00	115	0.7	22.34	43.98	56.00

Different trail mixes are conducted using various combinations of cement with GGBS and PCE based Super-plasticizer at optimum dosage to observe the slump performance. It has been observed that there is no significant change in the slump value of 100 mm upto 1hour using various percentages of GGBS with two different chemical composition of PCE based super plasticizers. The compressive strength of concrete is determined by using 150mm cubes specimen for various combination of cement with GGBS and PCE based Super plasticizers. It is observed that the Target compressive strength of 48MPa is achieved by replacement of 35% GGBS using PCE based Super plasticizer at optimum dosage. The strength of the concrete linearly decreased as the GGBS percentage increased for 3, 28 days but gradually the strength is achieved after 91days for the maximum replacement of GGBS

V. CONCLUSIONS

i. The optimum dosage of super plasticizer for concrete mix is slightly higher than the optimum dosage for cement paste due to additional increase in materials (coarse aggregate and fine aggregate)

ii. As the percentage of replacement of GGBS increases, the workability of concrete is found to be increased linearly with a difference of 5-10mm.

iii. For 3, 28 days the compressive strength results decreases linearly with replacement of 25%, 35% and 45% of GGBS for concrete mix

iv. High strength results are obtained for M40 grade concrete when replaced 35% GGBS to the cement in 91days

v. For M40 grade concrete, cement replaced with GGBS dosage of 45% to failed to achieve the Target compressive strength of 48Mpa at optimum dosage of PCE based super plasticizer

vi. It is observed that the change in super plasticizer is affecting behavior of concrete while keeping the C.A, F.A and W/C ratio constant. SP1 shows better strength, workability and incompatibility issues also less than compared to SP2

vii. M40 grade concrete made with SP1, retains a slump 100 mm up to 60 minutes compared to 45 minutes retention by SP2

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