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Compatibility assessment of commercial cements and superplasticizers

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***Abstract*: -** Nowadays different type of cements and superplasticizers are available commercially. It creates a lot of confusion to the users in selecting the type of cement and superplasticizers which are compatible to each other. To eliminate this confusion, the Information on compatibility of superplasticizers and cements are very much needed. In the present study, the compatibility between two types of commercially available blended cements and two types of superplasticizers are experimented for each combination. The optimum dosage of the superplasticizers is identified using marsh cone test and mini slump test for each of the combinations. The strength properties of concrete made with each combination were tested through compressive test, splitting tensile test and flexural test and reported. The best compatibility is found between the polymer based superplatizer and slag blended cement.

Keywords: - cement, superplasticizers, marsh cone test, mini slump test, compressive strength, split tensile strength, flexural strength, saturation point and retention time.

I. Introduction

Nowadays different type of cements and superplasticizers are available commercially. It creates a lot of confusion to the users in selecting the type of cement and superplasticizers which are compatible to each other. The term compatibility describes to the desired effect on performance when a specific combination of cement and superplasticizers is used in concrete. Common problems occurred are delayed setting, flash setting time, rapid slump loss, improper strength gain, cracking etc. which are due to the incompatibility between cement and superplasticizers. It also affects the hardened concrete properties. In present days, ready mixed concrete, high performance concrete, high strength concrete and self-compacting concretes are being used. For these concretes, use of super plasticizers is mandatory to gain workability. At the same time, knowing the compatibility of it with the type of cement used is also essential. The compatible combination of cement and superplatizer results in the optimum dosage of the superplastizer which otherwise lead to use higher dosage and other sequential problems like delayed setting etc. The optimum dosage superplasticizers are chosen for each cement by testing their compatibility by recommended tests like marsh cone test and mini slump test.

II. EXPERIMENTAL PROGRAM

A. Materials

Cements

Portland pozzolana cement (PPC), Portland slag cement (PSC) were used in the study. Portland pozzolana cement is a blended cement with fly ash while Portland slag cement contain Granulated Blast furnace Slag. These are commercially available from DALMIA and JSW Cement Ltd., respectively.

Fly ash is a waste product obtained from combustion which is fine powdered coal obtained from the fuel chamber. Particle size of fly ash is finer than that of cement. It is used in higher constructions like retaining walls, dams etc. In market, fly ash blended Portland pozzolana cements are easily available. PPC blended with fly ash gives higher ultimate strength compared to that of OPC cement.

TABLE-I: PHYSICAL PROPERTIES OF CEMENTS

s.no	Physical properties	PPC	PSC
1	Specific gravity	2.93	2.88
2	Standard consistency	66%	32%
3	Initial setting time	30 min	160 min
4	Final setting time	130 min	250 min
5	Soundness	0 mm	0 mm

TABLE-II: CHEMICAL PROPERTIES OF CEMENTS

S.NO	Chemical properties	PPC	PSC
1	Loss on Ignition	1.05%	0.50%
2	Silica (SiO_2)	61.02%	35%
3	Iron (Fe_2O_3)	4.48%	0.50%
4	Alumina (Al_2O_3)	27.76%	16%
5	Calcium Oxide (CaO)	1.26%	40%
6	Magnesium (MgO)	0.56%	8%
7	Sulphate (SO_3)	0.19%	-
8	Sodium Oxide (Na_2O)	0.90%	-
9	Potassium Oxide (K_2O)	0.06%	-

GGBS is a non-metallic product obtained from steel manufacturing plants. PSC is manufactured with a combination of up to 45% – 50% clinker, 45- 50% slag, and 3-5% gypsum. PSC has been voted as the most suitable cement for higher constructions as it gives Ultimate compressive strength, excellent resistance to Chloride & Sulphate attacks, Low risk of cracking, improved workability and better compatibility with all types of admixtures.

Superplasticizers

Superplasticizers are available in four forms in the market namely, Sulfonated Naphthalene Formaldehyde (SNF), Sulfonated Melamine Formaldehyde (SMF), modified lignosulfonates and Poly Carboxylic Ether (PCE). In this study, SNF and PCE are used.

B. Mix proportion for cement paste

In this work, preparation of cement paste with the following quantity of material and water cement ratio were used.

Cement weight	Water cement ratio	Superplasticizers dosage
2 kg	**0.45**	**0.3, 0.6, 0.9, 1.2, 1.5…**

After mixing the cement paste, One liter cement paste was used to conduct the marsh cone test and mini slump test with 5min, 30min and 60min time intervals. Marsh cone test is used to find the saturation dosage and optimum dosage of superplasticizers. Mini slump cone test is used to find out the saturation dosage and spread area of the cement paste.

III. METHODOLOGY

For different kinds of mixes of cement pastes workability, compatibility and strength properties of concrete were tested by using marsh cone test, mini slump cone test, compressive strength, split tensile strength and flexural strength.

A. Marsh cone test

Marsh cone test is used to find the workability. This test varies from country to country. But the principles of marsh cone test remains the same. To find out the properties of materials, we recorded the flow time of the cement pastes with different intervals of time. Marsh cone test is the best approach to know about the cement paste behavior. Marsh cone test is used to find the saturation point and optimum dosage of superplasticizer with different types of cement materials.

B. Mini slump cone test

Mini-slump cone is a small sized truncated cone type mould similar in relative dimensions to Abram's slump cone used for concrete slump test. It was developed by Kantro and is used by many researchers for paste studies. It is also used to find the spread area of different cements pastes. By using mini slump test, we measured the spread area of different cement mixes.

C. Compressive strength

It is the measure of extent till which a given concrete can withstand compression which gives concrete its grade. It is in fact the most important test performed on concrete as we know that concrete is mainly used to withstand compression. We used UTM to carry out the compressive strength test.

The final strength achieved can be calculated as: Load at Breakage / The Surface Area of Cube.

D. Tensile strength

The ability of concrete to withstand the tension (pull) is its tensile strength. Concrete is very weak in withstanding tension because of it being brittle compared to its compression. Usually, the tensile strength will be nearly 10% of the compressive strength.

Split tensile strength was calculated using: $f_t = \frac{2P}{\pi DL}$

Where, f_t is the tensile strength
P is the compressive load at failure
L is the length of cylinder
D is the diameter of cylinder.

E. Flexural strength

It is the ability of concrete to sustain the deformation in the presence of bending moment. It is also regarded as bending strength. It is mainly affected by the specimen size; as the size of specimen increases, strength decreases.

Flexural strength was calculated using: $\sigma = \frac{3FL}{2bd^2}$

Where, σ is the flexural strength
F is the load at fracture point
L is length of supporting span
b is the width, d is the thickness

IV. RESULT AND DISCUSSIONS

We observed saturation dosage, saturation point, retention time using two commercially available cements PPC, PSC with two brands of superplasticizer for each combination. Flow time and flow spread were found using marsh cone test and mini slump cone test respectively.

A. FLY ASH BASED BLENDED PORTLAND POZZOLANA CEMENT WITH SNF, PCE BASED SUPERPLASTICIZERS

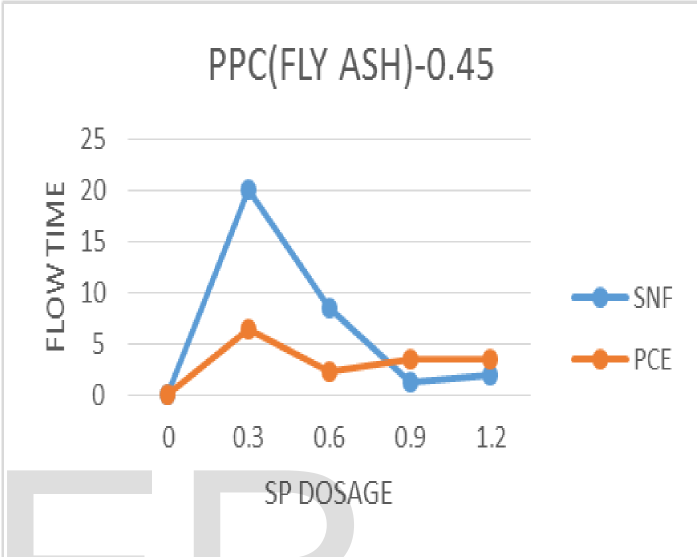
TABLE-III: SPERAD AREA AND FLOW TIME OF SNF BASED SUPERPLASTICIZER WITH FLY ASH BASED PPC CEMENT

Dosage of super plasticizer (%)	SPREAD (cm)			FLOW TIME (min)		
	5min	30min	60min	5min	30 min	60min
0	–	–	–	–	–	–
0.3	20	19.5	19	20	18	18
0.6	21.5	21.3	20.5	8:54	8:10	8
0.9	42.14	39.3	38.5	***1:30***	***1:15***	***1:09***
1.2	34.5	34	34	2:05	1:50	1:45

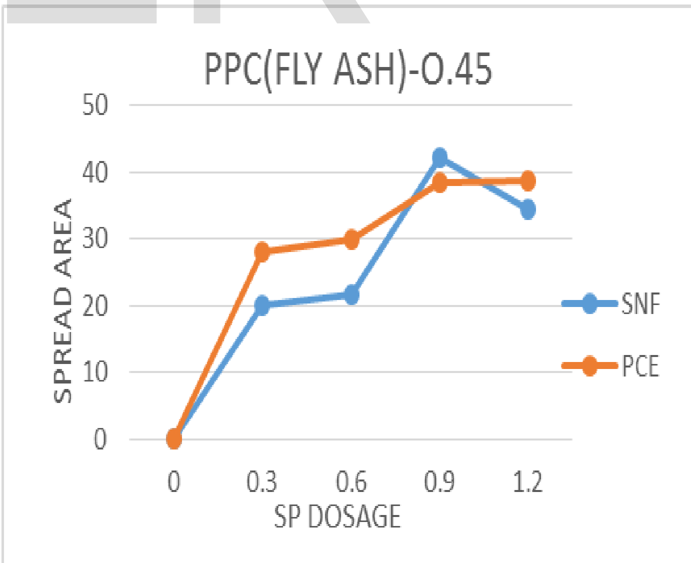
TABLE-IV: SPERAD AREA AND FLOW TIME OF PCE BASED SUPERPLASTICIZER WITH FLY ASH BASED PPC CEMENT

Dosage of super plasticizer (%)	SPREAD (cm)			FLOW TIME (min)		
	5min	30min	60min	5min	30 min	60min
0	–	–	–	–	–	–
0.3	28	30	29.3	6:50	5:57	5:45
0.6	30	39.6	39.3	***2:25***	***1:30***	***1:25***
0.9	38.34	38	38.7	3:47	1:45	1:40
1.2	38.6	38.34	38	3:51	2:49	2:46

GRAPH 1&2



GRAPH-1. B/W FLOW TIME AND SP DOSAGE



GRAPH-2. B/W SPREAD AREA AND SP DOSAGE

Following TABLES III&IV and GRAPHS 1&3 represents the flow time and spread area by using fly ash based blended PPC cement with SNF, PCE based superplasticizers. SNF based superplasticizer obtained saturation point at 0.9% of superplasticizer dosage. PCE based superplasticizer obtained saturation point at 0.6% of superplasticizer dosage.

B. GGBS BASED BLENDED PORTLAND SLAG CEMENT WITH SNF, PCE BASED SUPERPLASTICIZERS

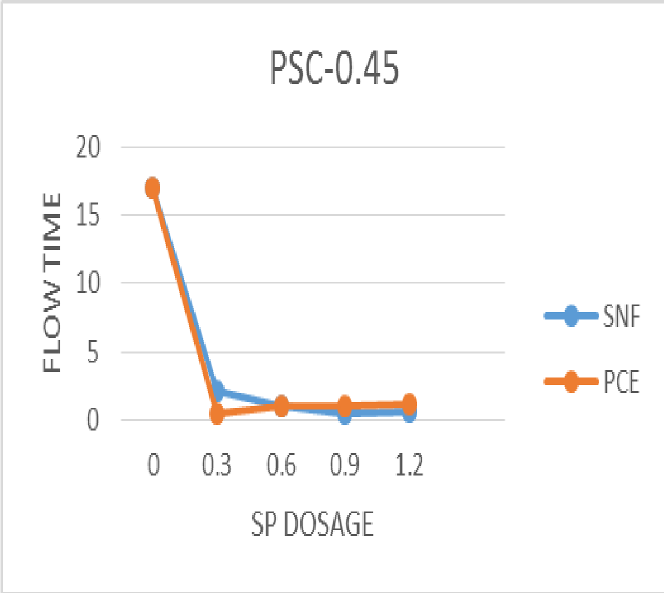
TABLE-V: SPERAD AREA AND FLOW TIME OF SNF BASED SUPERPLASTICIZER WITH GGBS BASED PSC CEMENT

Dosage of super plasticizer (%)	SPREAD (mm)			FLOW TIME (sec)		
	5min	30min	60min	5min	30min	60min
0	19.5	19	18.7	17	15:30	15:24
0.3	20.66	19.30	18.7	2:16	2:09	2:04
0.6	27.7	27	26.3	1:06	1:03	1:02
0.9	33	32	31.5	***0:46***	***0:45***	***0:43***
1.2	33.5	32.5	31	0:58	0:55	0:53

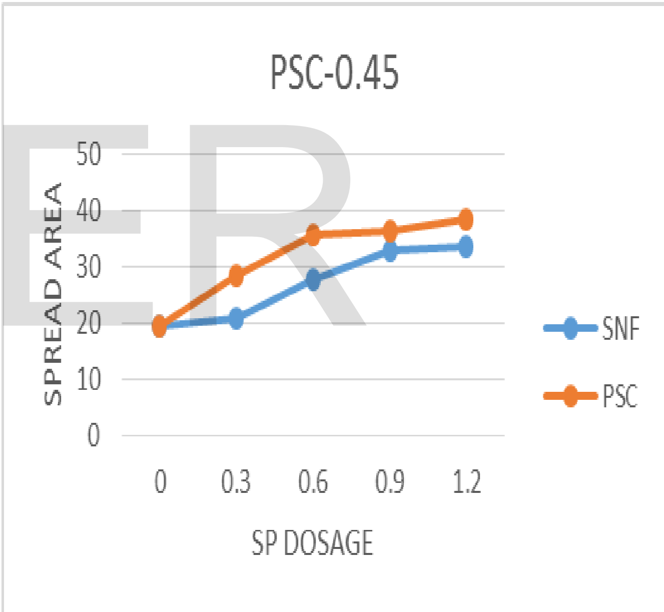
TABLE-VI: SPERAD AREA AND FLOW TIME OF PCE BASED SUPERPLASTICIZER WITH GGBS BASED PSC CEMENT

Dosage of super plasticizer (%)	SPREAD (mm)			FLOW TIME (sec)		
	5min	30min	60min	5min	30min	60min
0	19.5	19	18.7	17	15:30	15:24
0.3	28.5	28.2	27.8	***0:48***	***0:46***	***0:45***
0.6	35.6	35	34.7	1:08	1:06	1:03
0.9	36.34	36	35.7	1:10	1:09	1:07
1.2	38.41	38.28	38	1:16	1:11	1:09

GRAPH 3&4



GRAPH-3. B/W FLOW TIME AND SP DOSAGE



GRAPH-4. B/W SPREAD AREA AND SP DOSAGE

Following TABLES V&VI and GRAPHS 3&4 represents the flow time and spread area by using GGBS based blended PSC cement with SNF, PCE based superplasticizers. SNF based superplasticizer obtained saturation point at 0.9% of superplasticizer dosage. PCE based superplasticizer obtained saturation point at 0.3% of superplasticizer dosage.

TABLE-VII: COMPRESSION STRENGTH VALUES OF PPC&PSC

Sn.no	Type of cement	Compressive strength at 28 days (N/mm^2)
1	PPC	30.6
2	PSC	39.4

TABLE-VIII: SPLIT TENSILE STRENGTH VALUES OF PPC&PSC

Sn.no	Type of cement	Split tensile strength at 28 days (N/mm^2)
1	PPC	2.28
2	PSC	2.85

TABLE-IX: FLEXURAL STRENGTH VALUES OF PPC&PSC

Sn.no	Type of cement	Flexural strength at 28 days (N/mm^2)
1	PPC	5.48
2	PSC	8.10

FIG: - SPLIT TENSILE& FLEXURAL STRENGTHS

FIG:- COMPRESSIVE STRENGTH

The TABLES XII,XIII &XI represents the compressive strength, split tensile strength and flexural strength. According to the obtained results, PSC cement gives more strength compared to PPC cement.

CONCLUSION

The following conclusions were made from the above results and discussions.

1) Optimum dose of superplasticizer varies with the type of the superplasticizers as well as type of cement.
2) The reaction between JSW cement PSC with PCE based superplasticizer is less time consuming as compared to the reaction between DALMIA cement PPC and SNF based superplasticizer, for 5 minutes retention.
3) For 30 minutes retention as well as 60 minutes retention, the reaction between JSW cement PSC with PCE based superplasticizer is similar in behavior as compared to the reaction between DALMIA cement PPC and SNF based superplasticizer.
4) PCE based superplasticizer is more compatible than the SNF based superplasticizer.
5) The strength properties of PPC&PSC cement concrete results are obtained.
6) PSC cement gives more strength compared to PPC cement.

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