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A STUDY ON COMPARISON OF OPC AND PSC WITH PARTIAL REPLACEMENT OF DIFFERENT ADMIXTURES

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ABSTRACT

The cement and concrete industries due to their large size are unquestionably feasible scope for economic and safe disposal of millions of tonnes of industrial by products such as fly ash, microsilica, slag, rice husk ash. Due to their properties, byproducts can be used in certain amount such as cement replacement material than in the practice today. In fact, these mixes replaced by 15% of by-products have shown high strength and durability at relatively early ages. This development has removed one of the strong objections to the use of high volume of by products in mortar cubes. In this study we discussed PSC with 10% replacement of mineral admixtures like fly ash, ground granulated blast furnace slag, with superplasticizer, PSC with 10% replacement of all admixtures with and without SP the percentage change in compressive strength, Significant loss in compressive strength is observed in PSC and PSC with replacement of mineral admixtures with and without superplasticizer when the samples are tested in acid, alkali and sulphate solutions.

INTRODUCTION

1.1. GENERAL

The greatest challenge before the construction industry is to serve the two pressing needs of human society namely the protection of the environment and meeting the infrastructure requirement of our growing population and consequentially needs of industrialization and urbanization in the past. The concrete industry has met these needs very well. However for a variety of reasons, the situation has been changed now.

The cement and concrete industries due to their large size are unquestionably feasible scope for economic and safe disposal of millions of tonnes of industrial by products such as fly ash, microsilica, slag, rice husk ash. Due to their properties, byproducts can be used in certain amount such as cement replacement material than in the practice today. In fact, these mixes replaced by 15% of by-products have shown high strength and durability at relatively early ages. This development has removed one of the strong objections to the use of high volume of by products in mortar cubes.

Therefore, it should be obvious that certain scale cement replacement with industrial by products is highly advantageous from the stand point of cost, economy, energy efficiency, durability and overall ecological and environmental benefits.

The advantageous in concrete technology method of construction and type of construction have paved the way to make the best use of locally available materials by judicious mix proportioning and proper workmanship so as to result in a construction industry satisfying the performance requirements. Proper design of mixes is intended to obtain such proportioning of ingredients that will produce of high durability during the designed life of a structure.

High performance does not necessarily require high strength, it is proportioning of mixes, which has low permeability, as possible for particular use that determines the long-term high strength performance behaviour of a structure.

1.2. ADMIXTURES

This publication provides information on the types and functions of admixtures that have been, or are being, standardized in Europe for implementation in national standards in CEN member countries. It also provides guidance on the circumstances when it may be necessary to specify an admixture to a concrete producer.

Admixtures are materials other than cement, aggregate and water that are added to concrete either before or during its mixing to alter its properties, such as workability, curing temperature range, set time or color. Some admixtures have been in use for a very long time, such as calcium chloride to provide a cold-weather setting concrete. Others are more recent and represent an area of expanding possibilities for increased performance. Not all admixtures are economical to employ on a particular project. Also, some characteristics of concrete, such as low absorption, can be achieved simply by consistently adhering to high quality concreting practices.

Admixtures are now widely accepted as materials that contribute to the production of durable and cost-effective concrete structures. The contributions include improving the handling properties of fresh concrete making placing and compaction easier, reducing the permeability of hardened concrete, and providing freeze/thaw resistance.

TYPES OF ADMIXTURES

Admixtures vary widely in chemical composition, and many perform more than one function. Two basic types of admixtures are available:

1)Mineral admixtures.

2)Chemical admixtures.

All admixtures to be used in concrete construction should meet specifications; tests should be made to evaluate how the admixture will affect the properties of the concrete to be made with the specified job materials, under the anticipated ambient conditions, and by the anticipated construction procedures.

1)MINERAL ADMIXTURES

Mineral admixtures (fly ash, silica fume [SF], and slag) are usually added to concrete in larger amounts to enhance the workability of fresh concrete; to improve resistance of concrete to thermal cracking, alkali-aggregate expansion, and sulfate attack; and to enable a reduction in cement content.

(a)Fly Ash

(b)Silica Fume

(c)Ground Granulated Blast Furnace Slag

(d)Rice husk ash

2)CHEMICAL ADMIXTURES

Chemical admixtures are added to concrete in very small amounts mainly for the entrainment of air, reduction of water or cement content, plasticization of fresh concrete mixtures, or control of setting time.

Seven types of chemical admixtures are specified in ASTM C 494, and AASHTO M 194 [06], depending on their purpose or purposes in PCC. Air entraining admixtures are specified in ASTM C 260 and AASHTO M 154[05]. General and physical requirements for each type of admixture are included in the specifications.

(a) Air-Entrainment agents.

(b) Water-Reducers.

(c) Set-Retarders.

(d) Accelerators.

(e) Superplasticizers.

REVIEW OF LITERATURE

2.1. GENERAL

This chapter deals with the properties of cement and its constituents, their phase relationship, physical aspects of the setting and hardening process, Materials for cement substitutes such as fly ash, ground granulated blast furnace slag, micro silica, rice husk ash and super plasticizers and their properties, durability tests such as acid, alkaline and sulphate attack. Water and its quality, standards of water quality for mix, employed in the present investigation and high light the papers related the mineral and chemical admixtures

2.2. CEMENT AND ITS CONSTITUENTS

Cement is an extremely pulverized material having adhesive and cohesive properties, which provide a binding media for the discrete ingredients. Cement is obtained by burning, in definite proportion, a mixture of naturally occurring argillaceous (containing alumina) and calcareous (containing calcium carbonate or lime) materials to a partial fusion at high temperate about 1450°C. The solid matrix obtained on burning, called clinker, is cooled and ground to the required fineness to produce a material known as cement. The common calcareous materials are limestone, chalk, oyster shells and marl. The argillaceous materials are clay, shale, slate and selected blast furnace slag.

Since the raw materials consist mainly of Lime (CaO), Silica (Si02), Alumina (AI2O3) and Ferric oxide (Fe203), these form the major constituents of cement. Magnesium oxide (MgO), Sulphuric trioxide (SO3), Gypsum (CaSO^, Alkalis (K2O,

Na20), Constituents on ignition and insoluble reside are present in minor quantities in the composition of cement.
The influence of the chemicals present in the raw materials on the properties of cement is explained in brief. Calcium oxide (CaO) or lime is the important ingredient of all the cements. Slaking of cement when water is added is due to the presence of lime alone. A higher quantity of CaO makes the cement unsound and causes expansion and thereby leads to disintegration. Low content of CaO lowers the compressive strength of cement and simultaneously makes the cement to set quickly. Hence the optimum of CaO is very much required (Orchard, 1976).
Silicon dioxide Or Silica (Si02) is the major constituent of cement. It is completely insoluble in water and is not attacked by acids except by hydrofluoric acid. It imparts strength to cement by forming Di calcium and Tri calcium silicates. Even though excess silica imparts strength to cement, it prolongs the setting time. It reacts with lime and water to form lime-silica gel.
Pure Aluminum Oxide (AI2O3), commonly known as Alumina is useful in cement as it reacts with lime and water to form gel like products.
Ferric oxide (Fe203), is also an important ingredient of cement though it is required in small quantity for cement production. It behaves like a fluxing agent in the process of clinker burning.
Magnesium oxide (MgO), is present in small quantities in Portland cement. It is derived from magnesium carbonate present in original limestone in the form of Dolomite (CaC03 MgCOj). It has distinct hydraulic properties. It is the main agent, which imparts gray colour to cement.
Sulphuric trioxide (SO3), is also an important constituent of cement. It is mainly derived from (CaS04). It imparts soundness to cement. Higher quantity of (SO3), makes the cement unsound during hardening of cement in the presence of excess moisture.
Gypsum (CaS04) has great significance is regulating the setting time of cement. A limited quantity of gypsum present in cement has extreme importance, as it is capable of preventing final setting of cement. A higher quantity of gypsum will cause expansion during subsequent hardening in the presence of moisture ultimately leading to unsoundness of cement.
The two-alkali (K2O, Na20) compounds viz., potassium oxide and sodium oxide are invariably associated with raw materials of cement described above. They have been found to react with some aggregates, the products of these action causes disintegration of the concrete, and have also been observed to affect the rate of again of strength of cement (Neville, A.M., 1959 & Gambhir, 1986 [47]).
The components lost of ignition are only a minor fraction. Ignition loss is defined as the percentage of weight loss suffered by a simple of cement after heating to 1000°C. This ignition loss in cement is due to the expulsion of carbon dioxide and water from free lime and free magnesia from cement at higher temperature. (Czernin and Wolfgang 1962 [11])
A certain degree of moisture absorption cannot be avoided during the manufacturing process of cement. Clinkers absorb moisture from the atmosphere during storage. Finally the Gypsum (CaSC>4, 2H2O) added to cement during grinding of clinkers contains over 18% of chemically bound water, which is additional to the moisture associated with gypsum in the dry condition. BS 12: 1978[09] limits the ignition loss of commercial grade Ordinary Portland Cement to 3% in temperature climate and 4% for cements in the tropics. Higher ignition loss may have adverse effects on the hardening properties of cement and the rate of hardening.
The insoluble representing the fraction of cement, which is insoluble in hydrochloric acid, is a measure of adulteration of cement, largely arising from impurities in gypsum. This quantity can be determined only after reaction of all minerals, present in clinker, with hydrochloric acid and become soluble. BS 12:1978[09] limits this insoluble residue to 1.5% of the weight of the cement. Its content shall be less than 2% as per BIS recommendations. The ASTM specifications give the upper limit as 2.5% (ASTM C-150-78a, 1955[04]).
Based on the variety of raw materials used in the manufacture of cement, the oxide composition of ordinary Portland cement is presented in Table 2.1.
Most of the standard specifications specified the percentage of constituents with the following ratios, which were defined by Kuhl (1929) [36].

Silica Ratio: Silica Ratio is the ratio of percentage by weight of silica to that of the sum of the Alumina and Ferric Oxide. Mathematically it is expressed as

3. SCOPE AND OBJECTIVES

The present investigation is aimed at using of waste material like fly ash, Microsilica, slag, rice husk ash, which is otherwise hazardous to environment. This may be used as partial replacement of cement. This leads to economy, utilization of industrial waste in useful manner and environmental reduction of pollution to great extent.

Initial and final setting times, compressive strength of cement mortars 1:3 (made from Portland Slag Cement and Ordinary Portland Cement) and soundness of cement were the factors considered which are likely to be influenced by the partial replacement of cement by admixtures.

In order to facilitate the analysis, interpretation of results is carried out at each phase of the experimental work. In this investigation, the replacement of cement by admixtures will effect the strength development of cube.

This interpretation of results obtained is based on the current knowledge as available in the literature as well as on the standards specified by codes (Standards specified by IS 456-2000[22] are considered).

1.The averages of both setting times of at least three cement samples prepared with mineral and chemical admixtures are compared with those of the cement specimens prepared with ordinary cements. If the difference is less than 30 minutes, the change is considered to be negligible or insignificant and if the difference is more than 30 minutes, the change is considered to be significant.

2.The average soundness test results of three samples prepared with different admixtures under consideration are compared with that of samples made with ordinary cements. The unsoundness of the specific sample, made with mixing mineral admixtures of particular percent, is significant if the result of the Le- chatelier's test is more than 10 mm.

3.Average compressive strength of at least three cubes prepared with mineral and chemical admixtures under consideration is compared with that of three similar cubes prepared with ordinary cements. If the variation in the strength is less than 10%, it is considered to be insignificant and if it is greater than 10%, it is considered to be significant.

The principal objectives of the present investigations are:

1.To study the effect of replacement of cement by various admixtures like fly ash, ground granulated blast furnace slag, microsilica, rice husk ash when they are mixed with superplasticizer and without superplasticizer on initial and final setting times of cements both the Portland Slag Cement and the Ordinary Portland Cement.

2.To examine the effects of these substances with 10 percent replacement of cement mortar cubes on short term and long term strength development.

3.To find the strengths of cement mortar cubes after conducting various durability tests like acid, alkaline and sulphate test.

CHAPTER 4

EXPERIMENTAL INVESTIGATION

4.1. GENERAL

In the present chapter, the physico-chemical properties of cement, sand and water used in the investigation were analyzed based on and also the standard experimental procedure laid down in the standard codes, like IS, ASTM and BS codes. These standard experimental procedures were adopted for the determination of normal consistency, initial and final setting times, and soundness of cement and compressive strength of cement mortar cubes. In establishing these requirements, careful consideration of properties of locally available materials has to be accounted for.

4.2. MATERIALS

The materials used in the experimental investigation include:

- Portland Slag Cement (PSC)
- Ordinary Portland Cement (OPC)
- Fly Ash
- Ground Granulated Blast Furnace Slag (GGBS)
- Microsilica
- Rice Husk Ash (RHA)
- Superplasticizers
- Fine aggregate
- Water

The properties of these materials are given in the following sub-sections

4.2.1. CEMENT

There are many types of cement in the market to suit every need. Out of them some are included in the initial experiments like initial setting time, final setting time, compressive strength and soundness test on mortar cubes were conducted on various grades of cement.

4.2.1.1- Ordinary Portland Cement

Even though only Ordinary Portland Cement is graded according to strength, the other cements too have to gain a particular strength. 33, 43 and 53 grade in OPC indicates the compressive strength of cement after 28 days when tested as per IS: 4031-1988[25], eg, 33 Grade means that 28 days of compressive strength is not less than 33 N/mm2 (MPa) . Similarly for 43 grade and 53 grade the 28 days compressive strength should not be less than 43 and 53 MPa respectively. 43 and 53 grade are also being introduced in PPC and PSC shortly by the Bureau of Indian Standards (BIS). The compressive strength of cement when tested as per IS code shall be minimum 43 MPa. Cement used in the present investigation is Zuari 43 Grade. The physical and chemical properties of this cement are given in the table no.4.2 (a) below.

Table 4.2(a): The Physical and Chemical properties of OPC

	Fineness	Soundness by		Setting Time		Compressive Strength in MPa			
IS CODE	(Sq.m/ Kg) Min	Lechatlier (mm)	Auto clave Max (%)	Initial (min)	Final (min)	3Day MPa	7Day MPa	28 Day MPa	90 Day MPa
(IS 8112-1989)	225	0.77	0.8	123	218	28.33	37.60	44.00	49.40

CHEMICAL CHARACTERISTICS OF 43 GRADE OPC						
IS CODE	Lime Saturation Factor	Alumina Ratio Min.	Insoluble Residue (%) Max	MgO (%)	Sulphuric anhydride	Loss on Ignition (%)
(IS 12269-1987)	0.8 Min 1.02 Max	0.66	3	6	2.5% Max when C3A is 5 or less 3% Max when C3A is greater than 5	5

4.2.1.2. Portland Slag Cement

PSC is obtained by mixing blast furnace slag, cement clinker and gypsum **and** grinding them together to get intimately mixed cement. The quantity of slag varies from 30-70%. The gain of strength of PSC is somewhat slower than OPC. **Roth** PPC and PSC will give more strength than that of OPC at the end of 12 **months.** PPC and PSC can be used in all situations where OPC is used, but are **preferred** in mass construction where lower heat of hydration is advantageous or in marine situations and structures near seacoast or in general for any structure where extra durability is desired. Cement used in the present investigation is ultratech (PSC).The physical and chemical properties of this cement are given in the table no.4.2 (b) below.

Table 4.2(b): The Physical and Chemical properties of PSC

S. No.	Physical Properties	Result	IS: 455-1989
1	Specific gravity	3.01	3.15
2	Normal consistency	36%	Not specified
	Setting times (minutes)		
3	a) Initial	133	Not less than 30
	b) Final	257	Not more than 600
	Compressive strength (MPa)		
A	a) 3 days	24.30	Not less than 16
t	b) 7 days	33.32	Not less than 22
	c) 28 days	44.50	Not less than 33

S. No.	Chemical Properties	Test results	Requirements of IS: 455-1989
1	Magnesia (% by mass)	3.53	8.0 max
2	Sulphur trioxide(%by mass)	2.24	3.0
3	Sulphide sulphur	0.26	1.5
4	Total loss on ignition	1.02	5.0
5	Insoluble residue	0.94	4.0
6	Chloride	0.005	0.1

4.2.2. Fly Ash

All Indian fly ashes tested at CANMET correspond to the category of ASTM class C fly ashes: Typically all fly ashes had very low lime (CaO < 1.5%), low alkali (Na_20 < 1.34%) and Sulphur ($S0_2$ < 0.01 %) contents. The physical properties of most of the fly ashes are found to be excellent. Most of them are better than Canadian Sundance fly ash. The workability of the fresh concrete made with cement and fly ash are found to be the best. Despite the increased water content used in some concretes to obtain the necessary workability, these concretes exhibited high strengths, an indication of the reactivity of the fly ashes. Most of the concretes have satisfactory early and later age strengths. They ranged from 8 to 22 MPa at one day and from 45 to 55 MPa at 28 days. All concretes had excellent resistance to chloride - ion penetration as determined by ASTM C 1202 with coulomb values below 1000 in each case.

The investigation is included with fly ash is produced from Ennore thermal power station, Chennai. It is conformed to gradel of IS: 3812-1981. The physical and chemical properties of this cement are given in the table no.4.2 (c) below.

Table 4.2(c): The Physical and Chemical properties of fly ash

S. No.	Physical Characteristics	Percentage
1	Silica SiO_2	49-67
2	Alumina Al2O3	16-28
3	Iron oxide Fe_2O_3	4-10
4	Lime CaO	0.7-3.6
5	Magnesia MgO	0.3-2.6
6	Sulphur trioxide SO3	0.1-2.1
7	Loss on ignition	0.4-0.9
8	2/1 Surface area m /kg	230-600

S.No.	Chemical Characteristics	Requirement	Composition of fly ash used
1	Silica + alumina + iron oxide % by mass	70 (min)	94.2
2	Silicon dioxide % by mass	35 (min)	53.0
3	Magnesium oxide % by mass	5 (max)	1.19
4	Sulphur trioxide % by mass	2.75 (max)	0.04
5	Available alkalies as sodium oxide % by mass	1.5 (max)	0.46
6	Loss on ignition	12 (max)	0.34

4.2.3. Ground Granulated Blast Furnace Slag (GGBS)

In the production of cast iron, also called pig iron, if the slag is cooled slowly in air, the chemical components of slag are usually present in the form of crystalline melelite (C3 AS-C2 MS2 solid solution), which does not react with at ordinary temperature. The granulated slag when finely ground and combined with Portland cement has been found to have excellent cementitious properties. GGBS has an inherent ability to reduce heat evolved during exothermic reaction of cement and water. It has been observed that GGBS has the largest potential to replace cement due it's in built cementitious property. Hence a high volume replacement of cement by GGBS is an attractive option; usually for every tones of pig iron produced about 1.0 to 1.5 tonnes of slag is discarded as a waste material. It is estimated that India alone produces about 8 million tone of slag every year. The disposal of such slag as a waste fill is a problem and may cause serious environmental hazard. Such that it is produced from Lanco steel plant, Sri Kalasatri. The physical and chemical properties of this cement are given in the table no.4.2 (d) below.

Table 4.2(d): The Physical and Chemical properties of GGBS

Sl. No.	Physical Characteristics	Properties of Slag used
1	Specific gravity	2.91
2	Fineness m^2/kg	330
3	Glass content percent	93
4	Bulk density Kg/m^3	1100
5	Color	Dull white

S. No.	Compound	Chemical Requirement (BS 6699)	Properties of Slag used
1	SiO_2	32-42	33.2
2	Al_2O_3	7.16	18.3
3	CaO	32-45	41.0
4	Fe_2O_3	0.1-1.5	1.3
5	MgO	14 max	11.6
6	SO_3	2.5 max	1.0
7	CaO/ SiO_2	1.4 max	1.23
8	Loss on ignition	3 max	0.5

CHAPTER 5
TEST RESULTS AND DISCUSSIONS
5.1. GENERAL

The results of the present investigation are presented both in tabular and graphical forms. In order to facilitate the analysis, interpretation of the results is carried out at each phase of the experimental work. This interpretation of the results obtained is based on the current knowledge available in the literature as well as on the nature of result obtained. The significance of the result is assessed with reference to the standards specified by the relevant I S codes.

1.The averages of both the initial and final setting times of three cement samples prepared with PSC/OPC and compared with those of the cement specimen prepared with different admixtures. If the difference is less than 30 minutes, the change is considered to be negligible or insignificant and if it is more than 30 minutes, the change is considered to be significant.

2.The average compressive strength of at least three cubes prepared with PSC/OPC under consideration is compared with that of three similar cubes prepared with different admixtures. If the difference in the strength is less than 10%, it is considered to be insignificant and if it is greater than 10%, it is considered to be significant.

3.The average soundness test results of three samples prepared with PSC/OPC under consideration are compared with those with different admixtures. The unsoundness of the specific sample, made with admixtures, is significant if the result of Le-Chatelier's test is more than 10 mm.

Test results of initial and final setting times, soundness and percentage change in compressive strengths and durability tests regarding compressive strength t>f different types of cement mortar cubes with replacement of mineral and chemical admixtures are reported in the Tables 5.1 to 5.3.

Though all the samples made with different types of cements (i.e. PSC and OPC) by replacement of chemical and mineral admixtures either accelerate or retard significantly the setting process. The limits for significance criteria in setting times of all these samples under consideration are within the range of standards specified in IS 8112:1989[30], The IS code specifies initial setting time should not be less than 30 minutes and final setting time should not be more than 600 minutes.

Soundness test results of the samples made with different types of cements are presented in the Tables 5.1 to 5.2. The IS 269:1976[21] code specifies the limit for soundness as per the Le-Chatelier's test result should not be more than 10 mm for Ordinary Portland Cements. The Le-Chatelier's test results of soundness of different types of cements vary proportionately with the concentration of the cement.

But this increase in variation is very meager and less than the significant value, i.e., 10 mm and hence, there is no appreciable change in the volume of the samples.

Table 5.1: Initial and final setting times, soundness of cement, compressive strength and percent change in compressive strength of cement mortar cubes at different ages made with 10% replacement of mineral admixtures with and without superplasticizer in Portland Slag Cement.

Sl. No	Cement + Admixture	Initial setting time (min)	Final setting time (min)	Soundness (mm)	Compressive strength MPa				Percent change in compressive strength			
					3 day	7 day	28 day	90 day	3 day	7 day	28 day	90 day
1	PSC	133	257	0.25	24.30	33.12	44.50	50.00	0	0	0	0
2	PSC+10% MS	127	265	0.00	23.20	30.21	40.60	49.20	-4.54	-9.21	-8.76	-1.15
3	PSC + 10% FA	155	190	1.10	24.33	32.24	42.20	51.33	0.12	-1.24	-5.17	3.04
4	PSC+10% RHA	190	211	0.00	23.00	30.12	42.20	47.20	-5.35	-9.00	-5.17	-7.69
5	PSC + 10% GGBS	170	282	1.50	23.33	31.33	39.40	48.40	0.12	-5.76	-11.46	-3.33
6	PSC+ SP	180	260	0.25	25.40	36.20	47.50	54.30	4.53	5.64	6.74	8.89
7	PSC + 10% MS + SP	130	185	3.50	24.89	34.22	46.20	52.50	2.06	2.48	3.82	5.05
8	PSC + 10% FA + SP	155	270	0.25	22.60	29.67	45.70	52.34	-7.00	-10.55	2.70	3.01
9	PSC + 10% RHA + SP	51	142	0.00	22.67	34.00	43.67	44.33	-6.71	2.04	-1.87	-12.78
10	PSC+10% GGBS + SP	160	206	1.00	22.67	32.00	42.16	49.00	-6.71	-1.86	-5.33	-0.33

Note:SP = Superplasticizer, GGBS = Ground Granulated Blast Furnace Slag, PSC = Portland Slag Cement\ RHA= Rice Husk Ash

Table 5.2: Initial and final setting times, soundness of cement, compressive strength and percent change in compressive strength of cement mortar cubes at different ages made with 10% replacement of mineral admixtures with and without superplasticizer in Ordinary Portland Cement.

Sl. No	Cement + admixture	Initial setting time (min)	Final setting time (min)	Soundness (mm)	Compressive strength MPa				Percent change in compressive strength			
					3 day	7 day	28 day	90 day	3 day	7 day	28 day	90 day
1	OPC	123	218	0.77	23.13	37.00	44.08	49.00	0	0	0	0
2	OPC + 10% MS	113	168	1.20	16.42	29.00	38.08	44.00	-46.01	-21.31	-12.64	-10.83
3	OPC + 10% FA	130	224	0.25	23.02	28.60	42.98	47.10	-18.74	-22.76	-3.41	-4.19
4	OPC + 10% RHA	85	200	0.80	21.14	26.00	31.96	42.67	-20.11	-29.04	-27.36	-11.62
5	OPC + 10% GGBS	90	210	1.30	24.56	30.00	41.88	44.33	-13.3	-18.09	-4.95	-10.26
6	OPC + SP	120	340	0.50	21.00	30.00	38.75	47.88	-20.54	-18.75	-11.37	-3.24
7	OPC + 10% MS + SP	180	260	0.46	21.43	27.80	36.88	40.67	-24.41	-25.00	-16.23	-17.07
8	OPC + 10% FA + SP	186	316	0.60	24.16	27.00	40.88	46.09	-14.04	-26.88	-7.09	-6.00
9	OPC + 10% RHA + SP	85	300	0.50	19.74	20.40	31.28	34.33	-44.41	-44.81	-28.9	-30.91
10	OPC+10% GGBS +SP	168	280	0.90	23.00	31.00	40.68	41.33	-18.87	-16.19	-7.51	-12.20

Note: SP=Superplasticizer, GGBS =Ground Granulated Blast Furnace Slag, OPC=Ordinary Portland Cement, RHA= Rice Husk Ash

Table 5.3(a) Durability Tests of the Portland Slag Cement made with 10% replacement of mineral admixtures with and without superplasticizer on the compressive strength

Sl. No	Cement + Admixture	Compressive Strength (Mpa)	Acid Test(Mpa)	Alkaline Test (Mpa)	Sulphate Test (Mpa)	% Loss in Compressive Strength in Acid Test	% Loss in Compressive Strength in Alkaline Test	% Loss in Compressive Strength in Sulphate Test
1	PSC	59.58	15.08	15.60	14.00	63.25	59.82	62.34
2	PSC +10% MS	48.28	9.50	12.16	8.00	71.50	61.52	76.80
3	PSC +10% FA	51.33	12.03	19.05	16.33	69.82	52.28	59.06
4	PSC +10% RHA	47.28	14.23	17.19	17.00	63.85	56.60	56.50
5	PSC +10% GGBS	45.68	13.11	16.88	17.67	64.44	54.22	52.97
6	PSC+ SP	54.18	19.17	22.16	22.50	61.16	54.73	54.39
7	PSC + 10% MS + SP	42.13	16.16	17.75	17.67	61.24	57.82	56.06
8	PSC + 10% FA + SP	52.13	17.67	17.40	18.00	53.00	54.60	51.04
9	PSC +10% RHA + SP	44.32	13.67	13.33	14.00	58.89	60.81	58.80
10	PSC +10% GGBS + SP	49.08	14.84	15.33	17.00	58.81	57.42	52.76

Note: SP = Superplasticizer, GGBS = Ground Granulated Blast Furnace Slag, PSC = Portland Slag Cement, RHA= Rice Husk Ash

Table 5.3(b) Durability Tests of the Ordinary Portland cement made with 10% replacement of mineral admixtures with and without superplasticizer on the compressive strength

Sl No.	Cement + Admixture	Compressive Strength (Mpa)	Acid Test(MPa	Alkaline Test (Mpa)	Sulphate Test (Mpa)	% Loss in Compressive Strength in Acid Test	% Loss in Compressive Strength in Alkaline Test	% Loss in Compressive Strength in Sulphate Test
1	OPC	49.40	10.73	28.08	19.00	68.06	58.51	61.39
2	OPC +10% MS	48.00	18.00	18.77	17.87	59.00	55.07	50.30
3	OPC +10% FA	47.33	17.33	18.47	18.25	63.38	60.55	61.40
4	OPC +10% RHA	42.67	16.17	18.10	17.00	62.18	57.04	58.75
5	OPC +10% GGBS	41.33	18.55	22.53	20.71	58.11	49.18	51.21
6	OPC + SP	47.80	12.34	17.67	13.33	78.02	68.00	70.02
7	OPC + 10% MS + SP	40.67	14.47	15.07	17.93	63.93	62.99	60.83
8	OPC + 10% FA + SP	40.80	15.70	18.57	16.77	55.65	48.11	52.65
9	OPC + 10% RHA + SP	34.33	14.00	14.58	14.67	58.22	57.78	57.27
10	OPC + 10% GGBS + SP	43.33	17.33	28.03	20.17	68.00	55.93	53.47

Note:SP-Superplasticizer, GGBS=Ground Granulated Blast Furnace Slag, PSC = Ordinary Portland Cement,RHA=Rice Husk Ash

5.2 ADMIXTURES

Fly ash, Ground granulated blast furnace slag, Microsilica and Rice husk ash as mineral admixtures and superplasticizer as chemical admixture are used in the present work.

5.2.1 Effect of different admixtures on Portland Slag Cement 5.2.1.1 Effect of admixtures without Superplasticizer.

The effect of different admixtures without superplasticizer on the Portland Slag Cement is presented in Table 5.1 and the graphical representation is presented in Fig 5.1(a), 5.1(c) and 5.1(d)

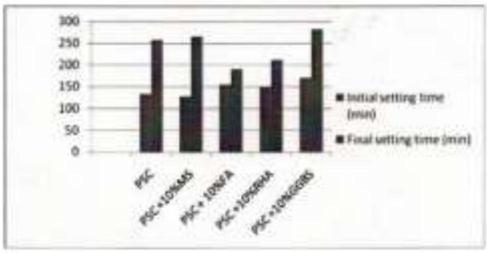

Fig. 5.1(a) Variation of initial and final setting times in the Portland slag cement with the replacement of different admixtures without superplasticizer

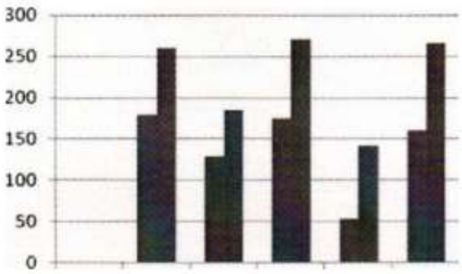

Fig. 5.1(b) Variation of initial and final setting times in the Portland slag cement with the replacement of different admixtures with superplasticizer

5.2.1.1.1 Effect of 10% Fly ash Replacement

The effect of Fly ash on the initial and final setting times is shown in Fig. 5.1(a). Both initial and final setting times got accelerated by replacing 10% of fly ash in the Portland Slag Cement. For the Fly ash replacement (10%), the initial is 22 minutes more and final setting time is 67 minutes less than that of Portland Slag Cement. The change in final setting times is observed to be significant.

The effect of 10% fly ash replaced in the Portland slag cement on the compressive strengths and its percent changes at various ages is presented in Table 5.1 and depicted in Figs. 5.1 (c) & (d). The percentage change in compressive strength for the 3-day, 28-day and 90-day is insignificant.

5.2.1.1.1 Effect of 10% GGBS

At the GGBS replacement (10%), the variations of initial and final setting times are 33and 15 minutes respectively. The change in initial setting times is significant and final setting time is insignificant.

The effect of 10% GGBS replaced in the Portland slag cement on the compressive strengths and its percent changes at various ages is presented in Table 5.1 and depicted in Figs. 5.1 (c) & (d). The percentage change in compressive strength for the 3-day, 7-day and 90-day is insignificant.but for 28days it is significant.

5.2.1.1.2 Effect of 10% Micro silica

The effect of Micro silica on the initial and final setting times is shown in Fig. 5.1(a). In initial setting time got accelerated by replacing 10% of Micro silica in the Portland Slag Cement. But in final setting time retards. At the Micro silica replacement (10%), the initial setting time 6 minutes less and final setting time 8minutes more than those of Portland Slag Cement. The change in initial and final setting time is observed to be insignificant.

The effect of 10% Micro silica replaced in the Portland slag cement on the compressive strengths and its percent changes at various ages is presented in Table 5.1 and depicted in Figs. 5.1 (c) & (d). The percentage change in compressive strength for the 7- day, 28-day and 90-day is insignificant.

CONCLUSIONS AND SCOPE FOR FURTHER STUDY

6.1. CONCLUSIONS

Based on the results obtained in the present investigation in Chapter 5, the following conclusions can be drawn.

- PSC with 10% replacement of mineral admixtures like fly ash, ground granulated blast furnace slag, with superplasticizer retards the setting times significantly where as in the case of rice husk ash with and without superplasticizer accelerates both the initial and final setting times significantly.
- PSC with 10% replacement of all admixtures with and without SP the percentage change in compressive strength is meagre and further it is observed that the decrease in compressive strength is significant in the case of RHA with SP at lateral ages.
- Significant loss in compressive strength is observed in PSC and PSC with replacement of mineral admixtures with and without superplasticizer when the samples are tested in acid, alkali and sulphate solutions.
- OPC with 10% replacement of mineral admixtures like fly ash, ground granulated blast

furnace slag and microsilica with superplasticizer retards final setting time significantly, where as in the case of rice husk ash with and without superplasticizer accelerates both the initial and final setting times significantly.

- OPC with 10% replacement of fly ash, ground granulated blast furnace slag and microsilica with and without superplasticizer the percentage change in compressive strength is decreased significantly and further, it is observed that this decrease in strength slightly increases at lateral days.
- OPC with 10% replacement of mineral admixtures like fly ash, ground granulated blast furnace slag, microsilica and rice husk ash with and without superplasticizer, the loss in compressive strength in Acid Test, alkali and sulphate test is significant.
- From the test analysis it can be inferred that the PSC in all the cases performing well than that of the OPC. Hence it is preferable to use PSC.

6.2. SCOPE FOR FURTHER STUDY

The following aspects can be taken up for further investigation.

1.Similar studies can be carried out on admixture cement concrete to analyze the effect of various chemical and mineral admixtures on the compressive strength with a special attention on the durability of concrete beyond 2-years.

2.The effect of other similar substances present in water, which are not covered in this research, on the setting properties of cement and strength of cement mortar can be investigated.

3.The effect of substances located at various places containing unique compounds can be studied to develop standards and limitations on the use of such admixtures in cement construction.

4.Similar studies can be carried out on other engineering properties of cement mortar like tensile strength and shear strength.

Formation of lattice structures of hydrated cement compounds need to be investigated to study the reasons for changes occur due to mineral and chemical admixtures in cement mortar.

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