COMPARATIVE STUDY OF PROPERTIES OF DIFFERENT TYPES OF BINDER MIXES MODIFIED WITH SILICA FUME

A PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
in
Civil Engineering

By

SRINIVAS GUTHA

Department of Civil Engineering
National Institute of Technology, Rourkela
May 14, 2010

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Under the guidance of
Prof. Asha Patel

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Rourkela

CERTIFICATE

This is to certify that the thesis entitled "**COMPARATIVE STUDY OF PROPERTIES OF DIFFERENT TYPES OF BINDER MIXES MODIFIED WITH SILICA FUME"** submitted by Mr. Srinivas Gutha in partial fulfillment of the requirements of the award of Bachelor of Technology Degree in civil Engineering at the National Institute of Technology, Rourkela is an authentic work carried out by him under our supervision and guidance. To the best of our knowledge, the matter embodied in the thesis has not been submitted to any other university/institute for the award of any degree or diploma.

Date: 14/05/2010

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Date: SRINIVAS GUTHA

CONTENTS

Abstract

The benefits of using Portland Pozzolanic Cement are fairly established. They offer benefits with respect to the cost of manufacturing of cement because pozzolona are by-products or waste materials replacing a part of Portland clinker, hence fewer primary energy and row materials are required in production of cement. This leads to more efforts towards the use of waste materials with lower environmental impact The PSC Portland slag cement contains ground granulated blast furnace slag as constituent of cement . The Fly ash cement contains fly ash as cement constituent. In India slag cement has main share (about 60%) of the cement market. It is used for almost all types of concrete structures, while it is exclusive material for structures in marine environments. Whereas the Fly ash cement is not that appreciated in the market. The quality of fly ash cement depends on nature and amount of fly ash added to the clicker during manufacturing of the cement and the its fineness. Deficiency associated with the use of Fly ash cement is its low strength specially in early age. Similarly research papers show that slag cement gain strength at early stage but rate of gain of strength is low leading to comparatively less ultimate strength. Research studies indicate that inclusion of Silica Fume in binder mix positively improves the strength of the matrix and its chemical resistance but can create increase in water demand, placing difficulties, plastic shrinkage etc. However, all these materials have certain shortfalls but a proper combination of them can compensate each other’s drawbacks which may result in a good matrix product with enhance overall quality.

The aim of the present work is to make a comparative study of properties of these two types of cements mixed in different proportions. In addition study is made to determine the effect of addition of different proportions of silica fume to these binder mixes. All these studies are made on mortar mix of proportion 1:3 with one part of binder mix and three parts of sand. Performance of the mortar mixes will be studied and compared in terms of compressive strength, capillary absorption and porosity tests.

CHAPTER 1

1 INTRODUCTION

1.1 GENERAL

Global warming and environmental destruction have become manifest problems in recent years, heighten concern about global environmental issues, and a change over from the mass-production, mass-consumption, mass-waste society of the past to a zero-emission society is now viewed as important. Preventing the exhaustion of natural resources and enhancing the usage of waste materials has become a significant problem of the modern world. Million tons of waste materials come into existence as a result of industrialization and a lot of studies have been carried out concerning the protection of natural resources, prevention of environmental pollution and contribution to the economy by using these waste materials. The world needs an environmentally friendly construction material. Concrete is basically made of aggregates glued by a cement paste which is made of cement and water. Each one of the primary constituents of concrete to some extent, has an environmental impact and gives rise to different sustainability issues. The current concrete construction practice is unsustainable because, not only it consumes enormous quantities of natural resources like stones, sand, and drinking water, but also one billon ton a year of cement, which is not an environment friendly material. The production of cement is characterized by huge consumption of energy and emission of large quantities of CO_2 gas. Alternatively, by-products and solid wastes of industries can be used in concrete mixes as aggregates or cement replacement, depending on their chemical and physical characteristics after giving adequate treatment. In India, the annual production of fly ash is about 130 million tones, but about 35 percent of total is being utilized, which is very low. Similarly, the steel industry in India is producing about 24 million tones of blast furnace slag and 12million tones of steel making slag. These slags are composed of calcium and magnesium silicates.

The use of the slag and flyash offers benefits with respect to the costs of manufacturing of concrete, because they are waste materials used as raw materials in making of cement involves fewer primary energy and natural raw materials..The same conclusion applies to the effect on the environment .

Slag cement and fly ash are the two most common SCMs used in concrete. Most concrete produced today includes one or both of these materials. For this reason their properties are frequently compared to each other by mix designers seeking to optimize concrete mixture.

1.2 AIM OF THE PRESENT WORK

The aim of the present work is to make a comparative study of properties of these two types of cements mixed in different proportions. In addition study is made to determine the effect of addition of different proportions of silica fume to these binder mixes. All these studies are made on mortar mix of proportion 1:3 with one part of binder mix and three parts of sand. Performance of the mortar mixes will be studied and compared in terms of compressive strength, capillary absorption and porosity tests

2 LITERATURE REVIEW

Many works have been done to explore the benefits of using pozzolanic materials in making and enhancing the properties of concrete. M.D.A.Thomus,M.H.Shehata[1] et.al.have studied the ternary cementitious blends of Portland cement,silica fume, and fly ash offer significant advantages over binary blends and even greater enhancements over plain Portland cement. Sandor Popovics[2] have studied the Portland cement-fly ash –sislica fume systems in concrete and concluded several beneficial effects of addition of silica fume to the flyash cement mortar in terms of strength, workability and ultra sonic velocity test results.Jan Bijen[3] have studied the benefits of slag and fly ash added to concrete made with OPC in terms of alkali-silica rection ,sulphate attack. L. Lam, Y.L. Wong, and C.S. Poon[4] in their studied entitled Effect of fly ash and silica fume on compressive and fracture behaviors of concrete had concluded enhancement in strength properties of concrete by adding different percentage of fly ash and silica fume.Tahir Gonen and Salih Yazicioglu[5] studied the influence of binary and ternary blend of mineral admixtures on the short and long term performances of concrete and concluded many improved concrete properties in fresh and hardened states. Mateusz Radlinski,Jan Olek and Tommy Nantung[6] in their experimental work entitled Effect of mixture composition and Initial curing conditions on the scaling resistance of ternary concrete have find out effect of diffent proportions of ingradients of ternary blend of binder mix on scaling resistance of concrete in low temperatures. S.A.Barbhuiya,J.K.Gbagbo,M.I.Russeli,P.A.M.Basheer[7] studied the properties of fly ash concrete modified with hydrated lime and silica fume concluded that addition of lime and silica fume improve the early days compressive strength and long term strength development and durability of concrete.

This review covers details of all materials that are being used in this experimental investigation

2.1 FLY ASH CEMENT

Fly ash cement is manufactured by intimately mixing together cement clinker and fly ash of good quality. Generally up to 30% of cement clinker is replaced by fly ash. Both the ingradients are ground together in ball mill to make a fine and uniform mixture.It is gray in colour

2.2 SLAG CEMENT

Slag, is a glassy granular material formed when molten blast-furnace slag is rapidly chilled . It is a non-metallic product, consisting of silicates and aluminosilicates of calcium and other bases is by product of blast furnace. It is used as a cementitious material in cement by grinding together the cement clinker and slag to a fine and uniform mixture.

The ternary diagram, shown in Figure 1shows that slag cement is more closely related to portland cement than fly ash.This is one reason why slag cement can be used in much larger amounts. Both are used as a replacement for a portion of the portland cement. Slag cement replaces as much as 50 percent in normal concrete (and up to 80 percent in special applications such as mass concrete). Fly ash is usually limited to 20 or 30 percent. Slag cement will provide lighter concrete with higher reflectivity than plain portland cement concrete.

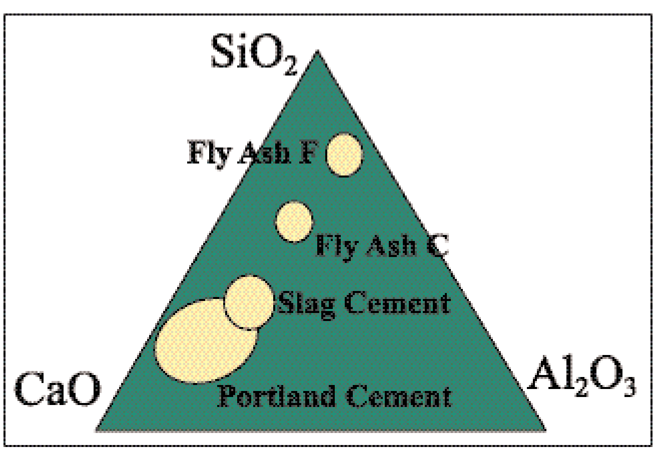


Fig 1

Slag cement is a more uniform product than fly ash. As a result, concrete made with slag cement will generally have more uniform properties than concrete made with fly ash.

2.3 SILICA FUME

Silica fume is a highly reactive pozzolanic material and is a byproduct from the manufacture of silicon or ferro-silicon metal. It is collected from the flue gases from electric arc furnaces. Silica fume is an extremely fine powder, with particles about 100 times smaller than a average cement grain. It is available as a densified powder or in a water slurry form. It is generally used at 5% to 12% by mass of cementitious materials for concrete structures that need high strength or significantly reduced permeability to water.

CHAPTER 3

3 EXPERIMENTAL PROGRAM

3.1 MATERIALS

The ACC brand of Fly ash cement and slag cement used in this investigation were purchased from the local market. Silica fume is supplied by Cornice India Private Limited. Preliminary test like specific gravity, water absorption of these materials are done in the structure lab. The chemical analysis of both the cements were done in the chemistry department of NIT Rourkela.The chemical analysis of Fly ash cement , Slag cement and silica fume are shown in Table 1.

Compound	Slag cement (%)	Fly ash cement (%)	Silica fume (%)
Sio_2	12	6	86.7
Cao	43	49	Not given
Mg_2	0.37	0.66	Not given
Fe_2o_3	12	15	Not given
Al_2o_3	26	16	Not given

3.2 METHODOLOGY

This experimental investigation was carried out for three different combinations of slag cement and flyash cement. In each combination three different proportion of silica fume had been added along with the controlled mix without silica fume.

Binders being used were different combinations of slag cement, fly ash cement in the proportions 1:0, 0:1 and 1:1 hence total three combinations. Further in each type of combination of binder mix 0%,5 %,10 % and 15 % percentage of silica fume had been added. Hence total 12 sets of mortar of

1:3 proportion were prepared by mixing one part of binder mix and three parts of naturally available sand.

To study the physical properties following tests were conducted:

3.2.1 Compressive Strength test

For each set six standard cubes were cast to determine 7-days and 28 day compressive strength after curing. The size of the cube is as per the IS 10086 – 1982.

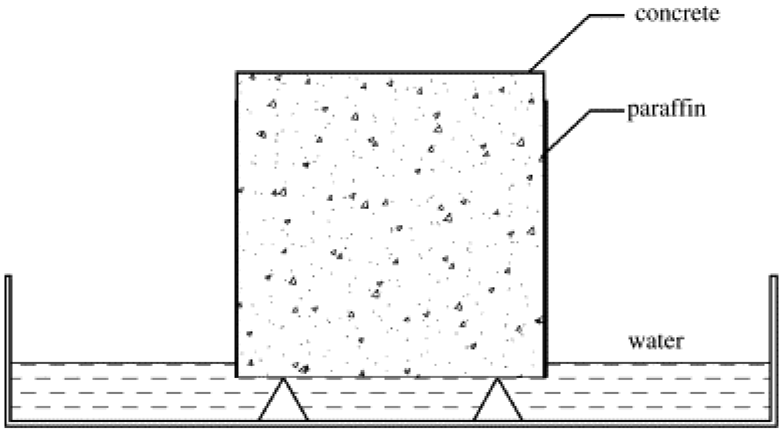
3.2.2 Capillary absorption Test

Two cube specimens were cast to determine capillary absorption coefficients after 7days and 28 days curing. This test is conducted to check the capillary absorption of different binder mix mortar matrices which indirectly measure the durability of the different mortar matrices[8].

Procedure

1) The specimen was dried in oven at about 105°C until constant mass was obtained.
2) Specimen was cool down to room temperature for 6hr.
3)The sides of the specimen was coated with paraffin to achieve unidirectional flow.
4) The specimen was exposed to water on one face by placing it on slightly raised seat (about 5 mm) on a pan filled with water .
5) The water on the pan was maintained about 5mm above the base of the specimen during the experiment as shown in the figure below.
6) The weight of the specimen was measured at 15 min and 30 min. intervals.
7) The capillary absorption coefficient (k) was calculated by using formula:

$k=Q/A^* \text{sqrt}(t)$ where Q is amount of water absorbed
A is cross sectional area in contact with water
t is time



fig

3.2.3 Porosity Test

Two cylindrical specimen of size 65 mm dia and 100 mm height for each mix were cast for porosity test after 7 days and 28 day of curing. This indirectly measures the durability of the mortar matrices

Procedure

1) The specimen was dried in oven at about 100^0C until constant mass W_{dry} was obtained.
2) The specimens were placed in a desiccators filled with distilled water under vacuum for 3 hrs.
3) Weight of the saturated specimen W_{sat} in distilled water is taken.
4) The specimens are taken out and its weight is taken in air ie. W_{wat}
5) The vacuum saturated porosity is calculated by the formula:

$$P =((W_{sat} - W_{dry}) / (W_{sat} - W_{wat}))*100$$

where, p = vacuum saturation porosity (%)

W_{sat} = the weight in air of saturated sample

W_{wat} = the weight in water of saturated sample

W_{dry} = the weight of oven dried sample

CHAPTER 4

4 RESULTS AND DISCUSSIONS

4.1 NORMAL CONSISTENCY

Normal consistency of different binder mixes were determined using the following procedure referring to IS 4031: part 4 (1988) :

1) 300 gms of sample coarser than 150 micron sieve is taken.
2) Approximate percentage of water was added to the sample and was mixed thoroughly for 2-3 minutes.
3) Paste was placed in the vicat's mould and was kept under the needle of vicat's apparatus.
4) Needle was released quickly after making it touch the surface of the sample.
5) Check was made whether the reading was coming in between 5-7 mm or not and same process was repeated if not
6) The percentage of water with which the above condition is satisfied is called normal consistency

Normal consistency of different binder mixes were tabulated below in table 2:

TABLE 2

Mix	Description	Cement (grams)	Silica fume (grams)	Consistency (%)
SC0	SC	300	00	31.5
SC5	SC with 5% SF	285	15	33
SC10	SC with 10% SF	270	30	35
SC15	SC with 15% SF	255	45	37
FC0	FC	300	00	37.5
FC5	FC with 5% SF	285	15	42.5
FC10	FC with 10% SF	270	30	47
FC15	FC with 15% SF	255	45	52
SFC0	SC:FC (1:1)	150 each	00	36.5
SFC5	SC:FC (1:1) with 5% SF	142.5 each	15	39
SFC10	SC:FC (1:1) with 10% SF	135 each	30	41.5
SFC15	SC:FC (1:1) with 15% SF	127.5 each	45	44

Where, SC = slag cement
FC = fly ash cement
SF = silica fume
SFC = slag and fly ash cement.

From the above table we can conclude that water requirement increases with increase in percentage of replacement by silica fume and fly ash cement consumes more water due to its fineness.

4.2 COMPRESSIVE STRENGTH

Compressive Strength of different mortars after 7 days and 28 days were tabulated in table 3 :

TABLE 3

Type of cement	% of SF replaced	7 days	28 days
Slag cement (SC)	0	19.61	29.43
	5	22.35	31.72
	10	27.47	35.09
	15	32.12	39.24
Fly ash cement (FC)	0	15.72	27.57
	5	21.58	29.43
	10	27.47	31.74
	15	31.39	34.34
Slag and fly ash cement blend (1:1) (SFC)	0	16.63	33.57
	5	17.66	34.30
	10	22.58	38.59
	15	24.85	38.58

From the above table, we can conclude that early or 7 days strength and 28 days strength increases with increase in percentage of replacement by silica fume. Early gain of strength is more in case of fly ash cement and gain of strength at later stages is more in case of slag cement. the reason for early gain of strength in fly ash cement could be fast reaction between fly ash and silica fume particles due to fine nature. as slag particles are coarser than fly ash, reaction rate is relatively slow and hence gain of early strength is not that much but at later stages gain of strength is more.

4.3 CAPILLARY ABSORPTION

Coefficients of capillary absorption of different mortars after 7 days and 28 days of curing were tabulated in table 4:

TABLE 4

Type of cement	% of SF replaced	7 days ($k*10^{-3}$ cm/s)	28 days ($k*10^{-3}$ cm/s)
Slag cement	0	1.262	1.03
	5	1.14	0.905
	10	0.85	0.79
	15	0.67	0.56
Fly ash cement	0	0.916	0.835
	5	0.752	0.732
	10	0.62	0.574
	15	0.58	0.565
Slag and fly ash cement blend (1:1)	0	1.102	1.01
	5	0.937	0.87
	10	0.862	0.66
	15	0.65	0.61

From the above table, we can conclude that capillary absorption decreases with increase in percentage of replacement by silica fume. The reason could be the inclusion of silica fume to the different cements actually forms denser matrices thereby improve resistance of the matrices against water ingress which is one of the most important reasons that increases the deterioration of concrete.

4.4 POROSITY

Porosity of different mortars after 7 days and 28 days of curing were tabulated in table 5:

TABLE 5

Type of cement	% of SF replaced	7 days (%)	28 days (%)
Slag cement	0	10.13	7.99
	5	9.98	7.14
	10	8.56	6.84
	15	7.34	6.13
Fly ash cement	0	7.23	6.32
	5	6.85	5.99
	10	6.28	5.42
	15	5.87	4.85
Slag and fly ash cement blend (1:1)	0	8.82	7.85
	5	8.16	7.10
	10	7.63	6.12
	15	7.20	5.96

From the above table, we can conclude that porosity decreases with increase in percentage of replacement by silica fume. The reason could be the inclusion of silica fume to the different cements actually forms denser matrices thereby improve resistance of the matrices against water ingress which is one of the most important reasons that increases the deterioration of concrete.

4.5 Graphical representation of results are displayed in the following figures

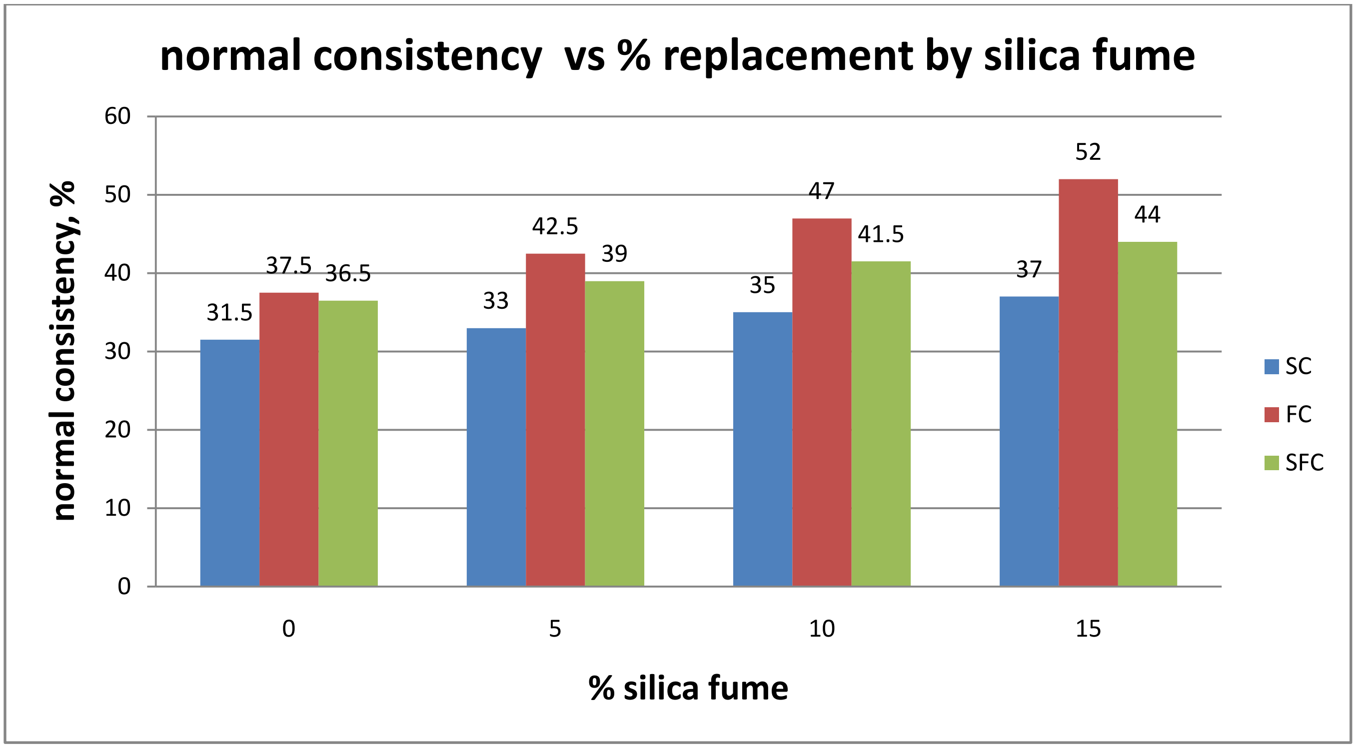


fig 1

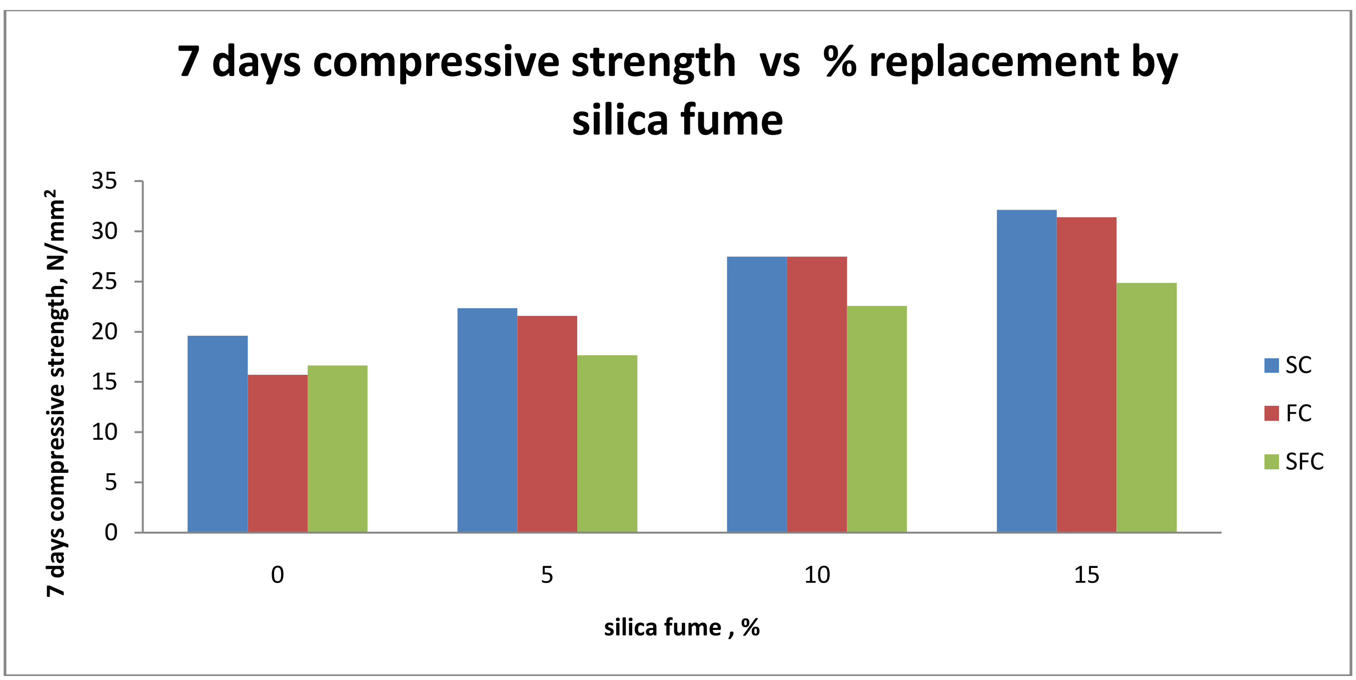


fig 2

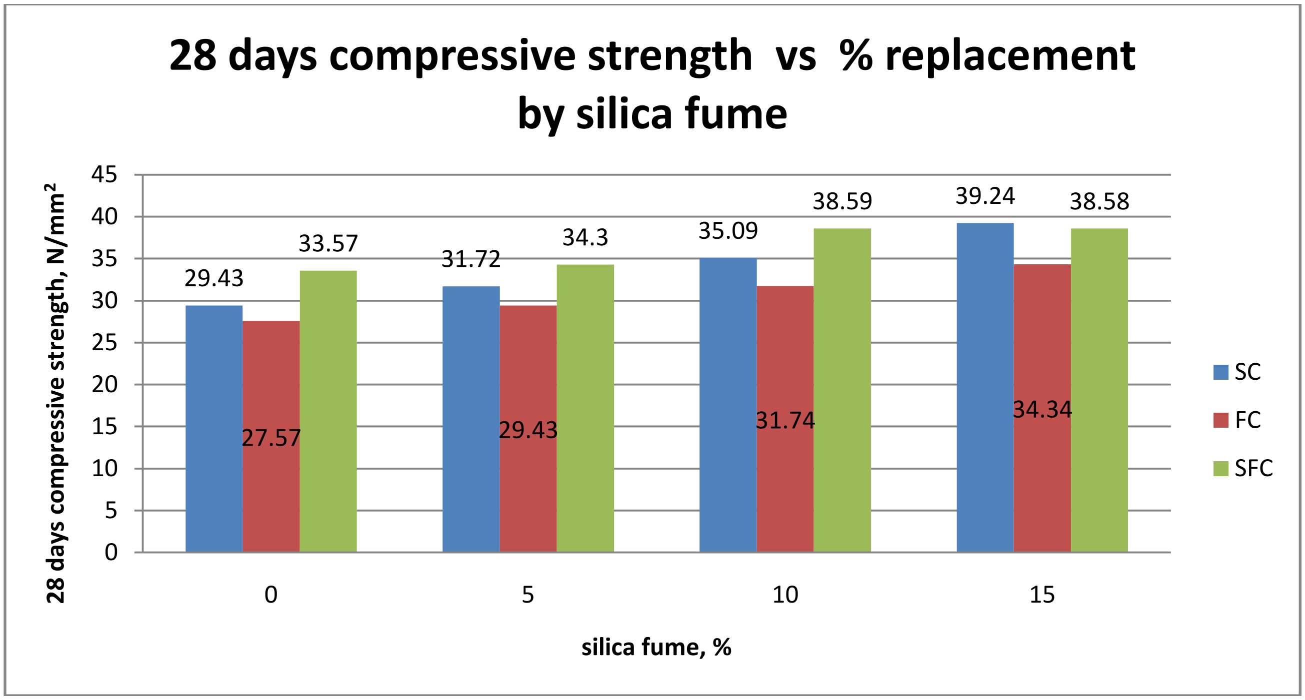

28 days compressive strength vs % replacement by silica fume
28 days compressive strength, N/mm²
45
40
35
30
25
20
15
10
5
0
29.43
27.57
33.57
31.72
29.43
34.3
35.09
31.74
38.59
39.24
34.34
38.58
0
5
10
15
silica fume, %
SC
FC
SFC

fig 3

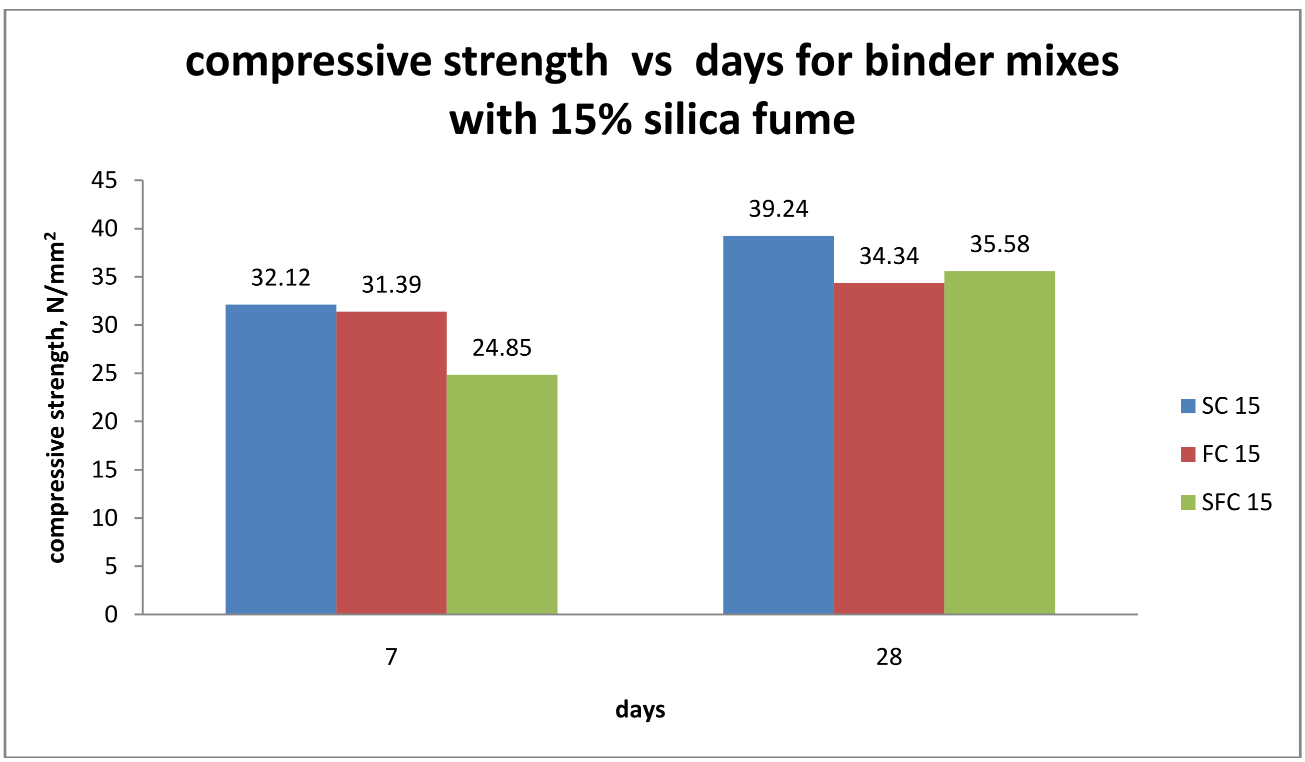

compressive strength vs days for binder mixes with 15% silica fume
compressive strength, N/mm²
45
40
35
30
25
20
15
10
5
0
32.12
31.39
24.85
39.24
34.34
35.58
7
28
days
SC 15
FC 15
SFC 15

fig 4

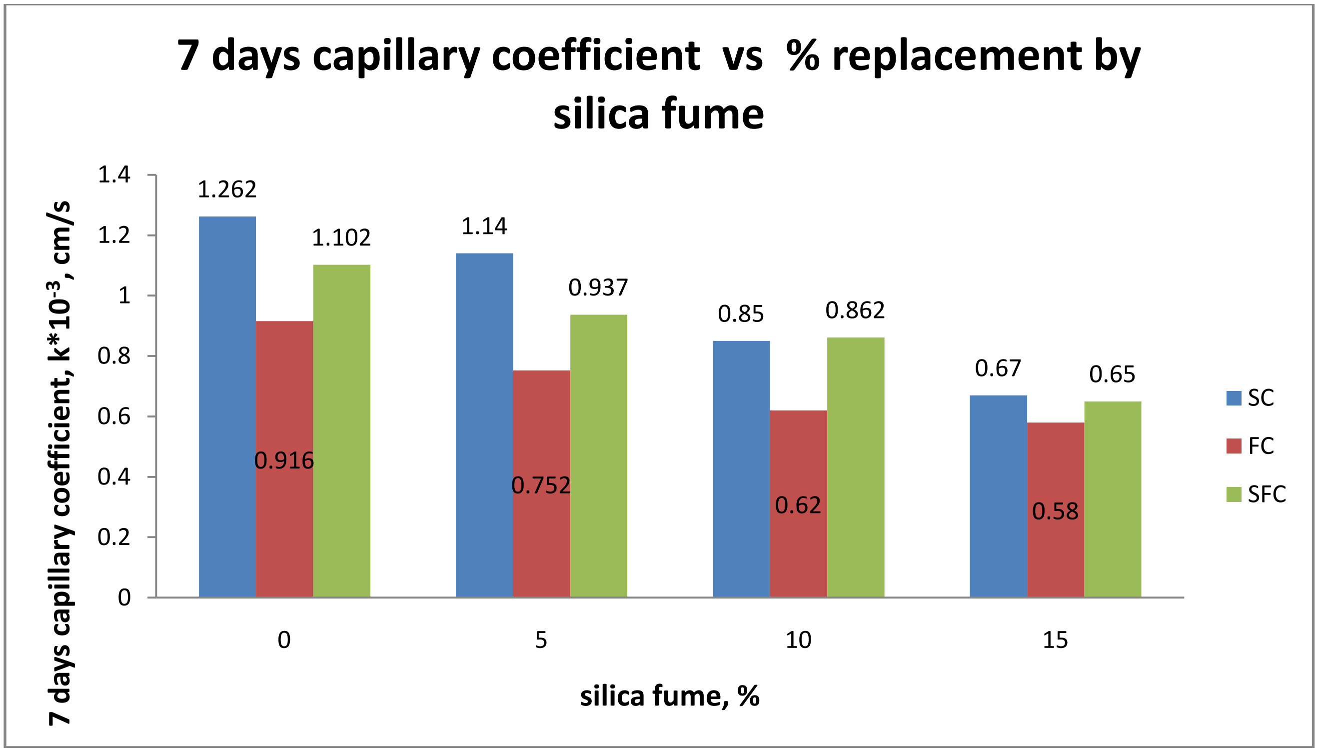

7 days capillary coefficient vs % replacement by silica fume
7 days capillary coefficient, k*10-3, cm/s
silica fume, %
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1.262
1.102
1.14
0.937
0.85
0.862
0.67
0.65
0.916
0.752
0.62
0.58
0
5
10
15
SC
FC
SFC

fig 5

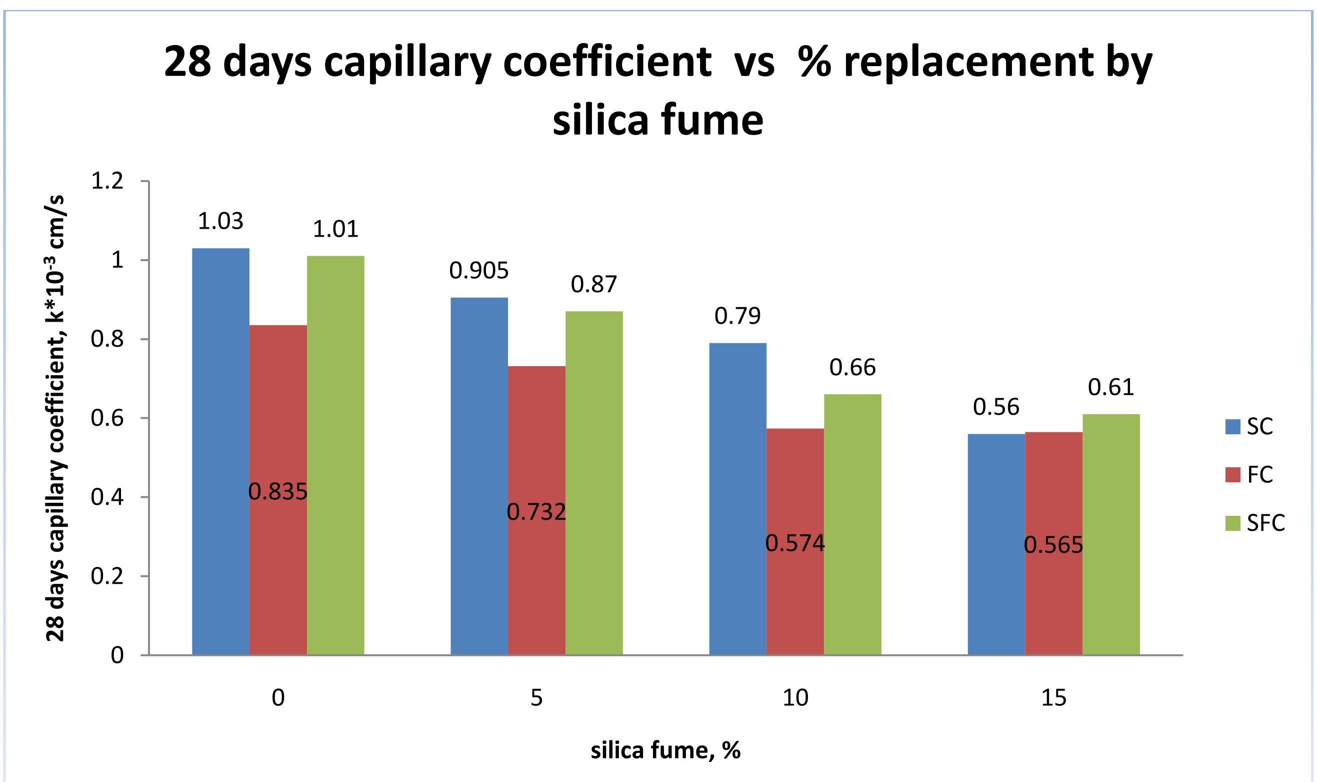
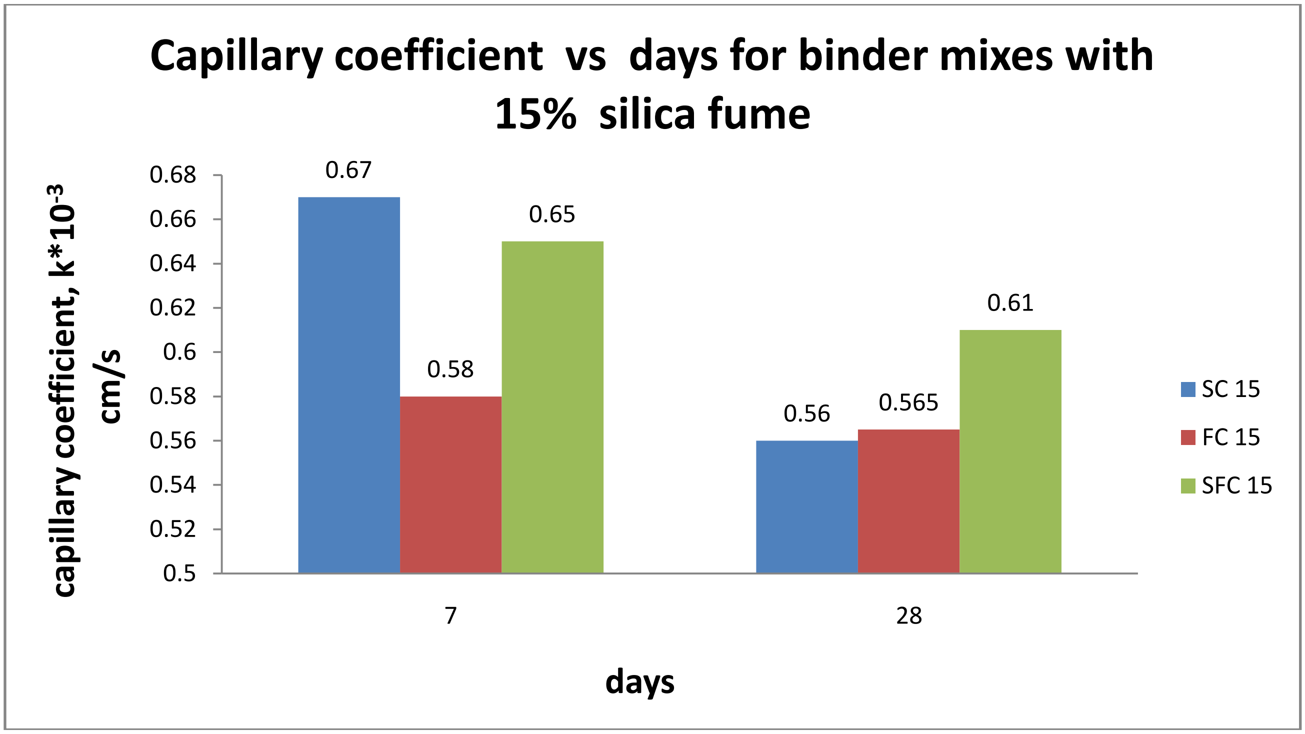
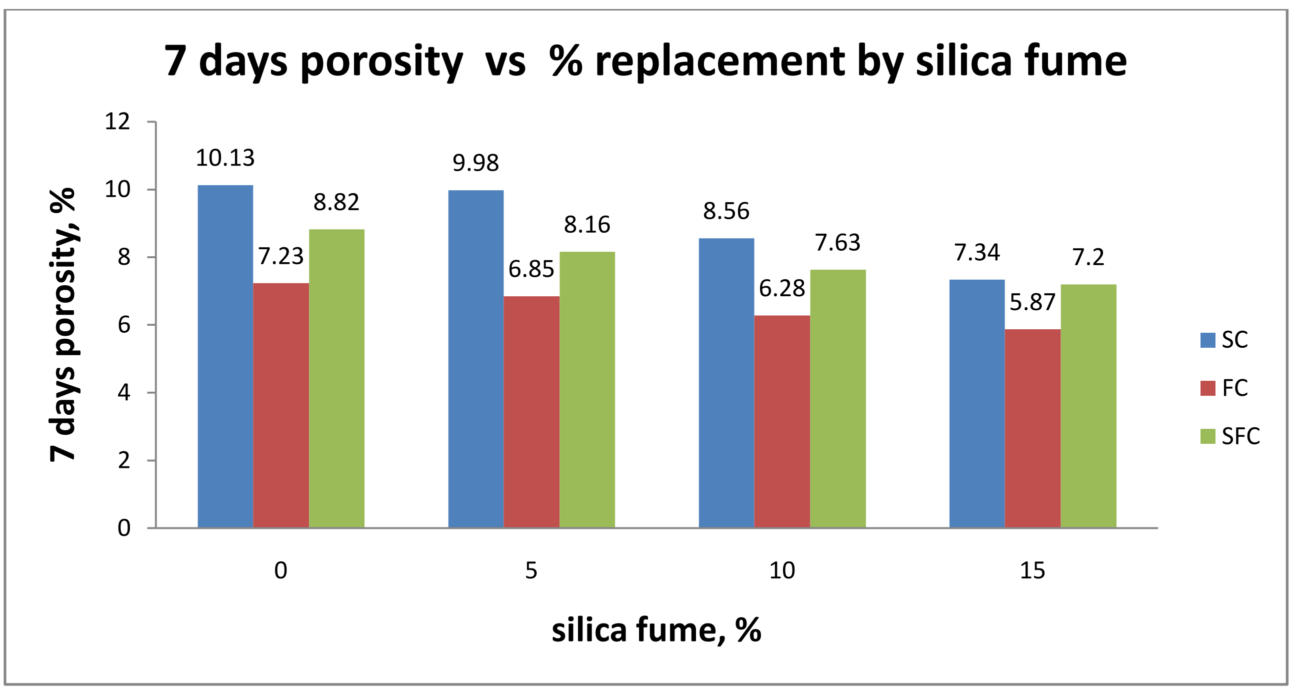

28 days capillary coefficient vs % replacement by silica fume
28 days capillary coefficient, k*10-3 cm/s
silica fume, %
1.2
1
0.8
0.6
0.4
0.2
0
1.03
1.01
0.905
0.87
0.79
0.66
0.56
0.61
0.835
0.732
0.574
0.565
0
5
10
15
SC
FC
SFC

fig 6



Capillary coefficient vs days for binder mixes with 15% silica fume
capillary coefficient, k*10-3 cm/s
0.68
0.66
0.64
0.62
0.6
0.58
0.56
0.54
0.52
0.5
0.67
0.65
0.58
0.61
0.56
0.565
7
28
days
SC 15
FC 15
SFC 15

fig 7



7 days porosity vs % replacement by silica fume
7 days porosity, %
12
10
8
6
4
2
0
10.13
7.23
8.82
9.98
6.85
8.16
8.56
6.28
7.63
7.34
5.87
7.2
0
5
10
15
silica fume, %
SC
FC
SFC

fig 8

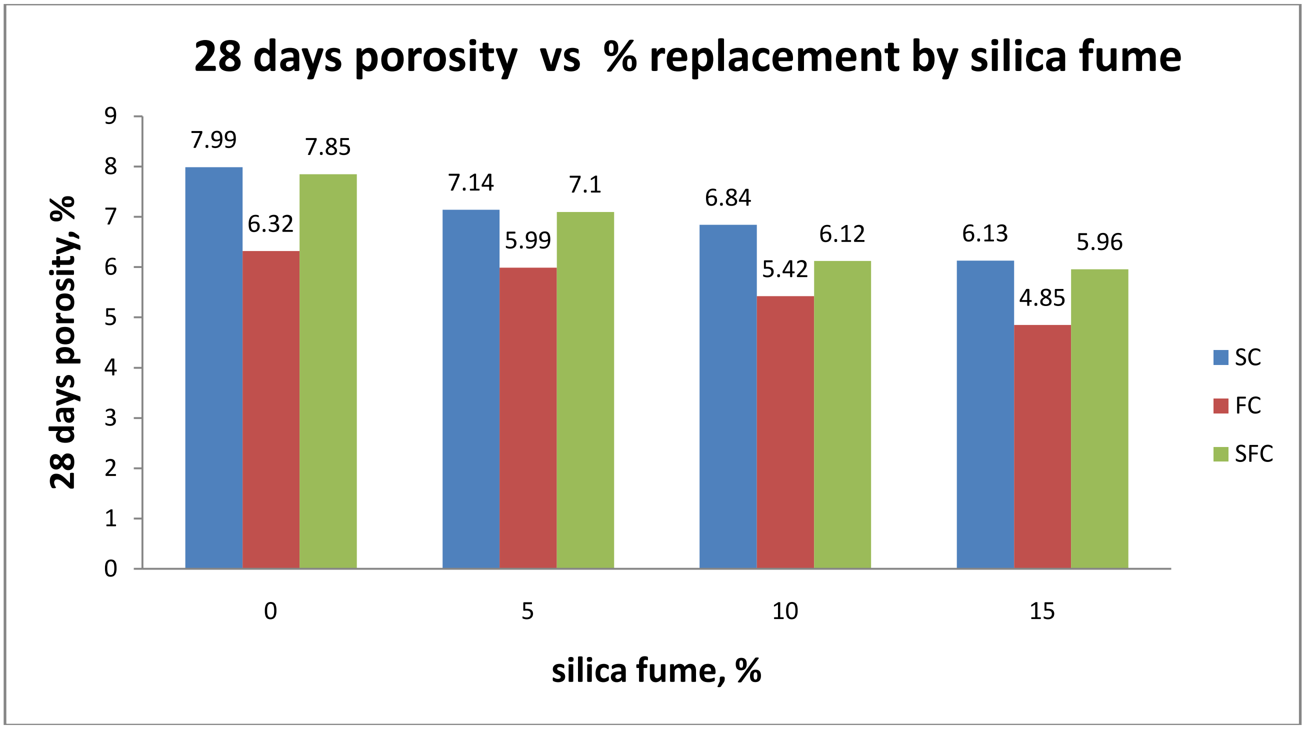

28 days porosity vs % replacement by silica fume
28 days porosity, %
9
8
7
6
5
4
3
2
1
0
7.99
6.32
7.85
7.14
5.99
7.1
6.84
5.42
6.12
6.13
4.85
5.96
0
5
10
15
silica fume, %
SC
FC
SFC

fig 9

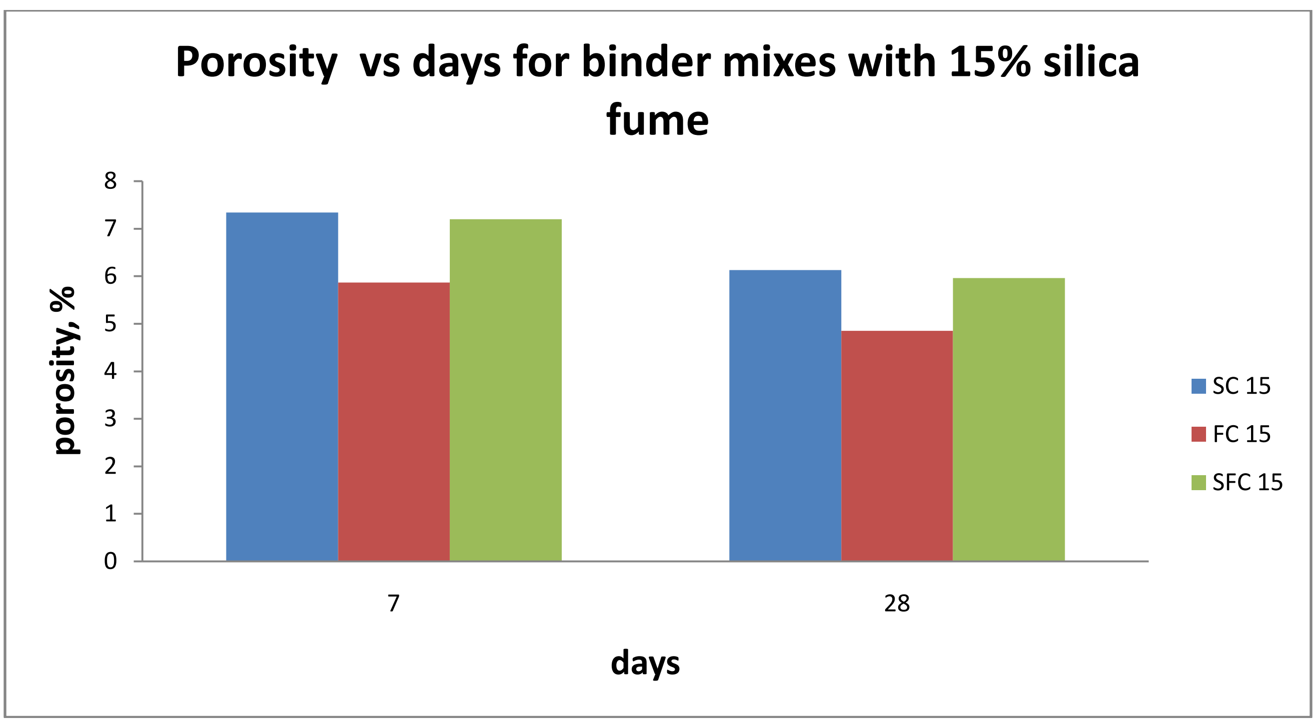

Porosity vs days for binder mixes with 15% silica fume
porosity, %
8
7
6
5
4
3
2
1
0
7
28
days
SC 15
FC 15
SFC 15

fig 10

CHAPTER 5

CONCLUSIONS

The following conclusions are drawn from the results of the investigation:

1) Water requirement or normal consistency of a binder mix increases with increment in percentage of silica fume replacement (fig 1).

2) Water requirement in case of fly ash cement binder mix is more because it is finer when compared to slag cement (fig 1).

3) All binder mixes shows that up to 15% replacement of cement with silica fume the Compressive strength increases with increasing dose of silica Fume (fig 2, fig 3, fig 4).

4) All binder mixes shows that up to 15% replacement of cement with silica fume the durability in terms of capillary absorption coefficients and porosity decreases with increasing dose of silica Fume (fig 5, fig 6, fig 7, fig 8, fig 9, fig 10).

5) Early strength in all binder mixes increases with 5% replacement by silica fume. The same is observed in case of 10% replacement. But amongst three types of binders, gain in fly ash cement is more (fig 2).

6) The early days strength increases remarkably by replacing any type of cement by silica fume up to 15%. This increase is more remarkable in fly ash cement (fig 2).

7) The 28 days strength increases by replacing any type of cement by silica fume up to 15%. This increase is more remarkable in slag cement (fig 3).

8) The 15% replacement of cement by silica fume increase 7 day compressive strength by 99% with Fly ash cement and 64% with slag cement . Whereas with blended binder mix (i.e one part of Fly ash cement and one part of Slag cement) the increase in compressive strength is 50 % (fig 2).

9) The reason for rapid increase in early strength could be the fine nature of fly ash cement and silica fume.

10) The 15% replacement of cement by silica fume increase 28 day compressive strength by 24% with Fly ash cement and 33% with slag cement. Whereas with blended binder mix (i.e one part of Fly ash cement and one part of Slag cement) the increase in compressive strength is 14% (fig 3).

11) The pozzalonic reaction between silica fume and slag is slow because slag particles are coarser than silica fume. therefore inclusion of silica fume doesn't effect early strength of slag cement mix much but in later stages gain of strength is more (fig 4).

12) Capillary absorption coefficient decreases with increasing % of silica fume up to 15% replacement. This indicates that inclusion of silica fume to the different cements actually forms denser matrices thereby improve resistance of the matrices against water ingress which is one of the most important reasons that increases the deterioration of concrete (fig 5, fig 6).

13) Decrease in capillary absorption coefficient between 7day to 28 day of curing is about 16% observed in slag cement with 15% silica fume and is about 3% observed in fly ash cement with 15% silica fume and is about 6% observed in blended binder mix with 15% silica fume (fig 7).

14) Porosity decreases to about 16 % in slag cement, about 17 % in Flyash cement and about 17% in blended binder mix with 15% addition of silica fume between 7days to 28 days of curing (fig 10).

15) The results on blended mix (i.e one part of Fly ash cement + one part of Slag cement) indicate the the same trends for compressive strength, capillary absorption and porosity

16) The use of silica fume with any type of cement improves both strength and other performance like absorption and porosity. It improves both early age and 28-days compressive strength of the matrices. The early age strength gain is more in fly ash cement whereas the 28 days strength gain is more in slag cement. this may be due to more percentage of lime in the fly ash cement than the slag cement used in the investigation.

17) Slag cement and fly ash are the two most common Supplementary Cementitious Materials used in concrete. Most concrete produced today includes one or both of these materials. For this reason their properties are frequently compared to each other by mix designers seeking to optimize concrete mixtures.

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