AN EXPERIMENTAL STUDY ON EFFECT OF SILICA FUME & FLY ASH IN SLAG CONCRETE

A P LAKSHMI 1*, B BEERAIAH 2*, M V NARASAIAH 3*, Dr. Y RAMESH BABU 4*

1. *Student, Dept of CIVIL, VELAGA NAGESWARA RAO COLLEGE OF ENGINEERING.*
2. *Asst Prof, Dept of CIVIL - VELAGA NAGESWARA RAO COLLEGE OF ENGINEERING.*
3. *HEAD-Dept of CIVIL - VELAGA NAGESWARA RAO COLLEGE OF ENGINEERING.*
4. *Principal - VELAGA NAGESWARA RAO COLLEGE OF ENGINEERING.*

ABSTRACT

Concrete is the most versatile construction material because it can be designed to withstand the harshest environments while taking on the most inspirational forms. Engineers are continually pushing the limits to improve its performance with the help of innovative chemical admixtures and supplementary cementations materials. Nowadays, most concrete mixture contains supplementary cementations material which forms part of the cementations component. These materials are majority byproducts from other processes. The main benefits of SCMs are their ability to replace certain amount of cement and still able to display cementations property, thus reducing the cost of using Portland cement. The fast growth in instralisation has resulted in tons and tons of byproduct or waste materials, which can be used as SCMs such as fly ash, silica fume, ground granulated blast furnace slag, steel slag etc. The use of these byproducts not only helps to utilize these waste materials but also enhances the properties of concrete in fresh and hydrated states. 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 mixtures. Perhaps the most successful SCM is silica fume because it improves both strength and durability of concrete to such extent that modern design rules call for the addition of silica fume for design of high strength concrete. To design high strength concrete good quality aggregates is also required. Steel slag is an industrial byproduct obtained from the steel manufacturing industry. This can be used as aggregate in concrete. It is currently used as aggregate in hot mix asphalt surface applications, but there is a need for some additional work to determine the feasibility of utilizing this industrial byproduct more wisely as a replacement for both fine and coarse aggregates in a conventional concrete mixture. Replacing all or some portion of natural aggregates with steel slag would lead to considerable environmental benefits. Steel slag aggregate generally exhibit a propensity to expand because of the presence of free lime and magnesium oxides hence steel slag aggregates are not used in concrete making.

In the present work a series of tests were carried out to make comparative studies of various mechanical properties of concrete mixes prepared by using ACC brand Slag cement , Fly ash cement and their blend (in 1:1 proportion). These binder mixes are modified by 10% and 20% of silica fume in replacement. The fine aggregate used is natural sand comply to zone II as per IS 383-1982.The coarse aggregate used is steel making slag of 20 mm down size. The ingredients are mixed in 1: 1.5: 3 proportions. The properties studied are 7days, 28days and 56 days compressive strengths, flexural strength, porosity, capillary absorption.

The main conclusions drawn are inclusion of silica fume increases the water requirement of binder mixes to make paste of normal consistency. Water requirement increase with increasing dose of silica fume. Water requirement is more with fly ash cement than slag cement. The same trend is obtained for water binder ratio while making concrete to achieve a target slump of 50-70 mm. The mortar strength (1:3) increases with increasing percentage of silica fume. Comparatively higher early strength gain (7-days) is obtained with fly ash cement while later age strength (28 days) gain is obtained with slag cement. Their blended mix shows comparatively moderate strength gain at both early and later ages. Mixing of silica fume had made concrete sticky i.e. more plastic specifically with fly ash cement. The porosity and capillary absorption tests conducted on mortar mixes show decrease in capillary absorption and porosity with increase in silica fume percentage with both types of cements. The decrease is more with fly ash cement than slag cement. But the reverse pattern is obtained for concrete i.e. the results show decrease in 7days,28 days and 56 days compressive strength of concrete due to inclusion of silica fume in the matrix. The increasing dose of silica fume show further decrease in strength at every stage. Almost same trend is obtained for flexural strength also. The specimens without silica fume had fine cracks which are more visible in concrete made with slag cement than fly ash cement.

INTRODUCTION

Concrete is a mixture of cement, sand, coarse aggregate and water. Its success lies in its versatility as can be designed to withstand harshest environments while taking on the most inspirational forms. Engineers and scientists are further trying to increase its limits with the help of innovative chemical admixtures and various supplementary cementitious materials SCMs.

Early SCMs consisted of natural, readily available materials like volcanic ash or diatomaceous earth. The engineering marvels like Roman aqueducts, the Coliseum are examples of this technique used by Greeks and Romans. Nowadays, most concrete mixture contains SCMs which are mainly byproducts or waste materials from other industrial processes.

SUPPLEMENTARY CEMENTITIOUS MATERIAL

More recently, strict environmental – pollution controls and regulations have produced an increase in the industrial wastes and sub graded byproducts which can be used as SCMs such as fly ash, silica fume, ground granulated blast furnace slag etc. The use of SCMs in concrete constructions not only prevents these materials to check the pollution but also to enhance the properties of concrete in fresh and hydrated states.

The SCMs can be divided in two categories based on their type of reaction : hydraulic and pozzolanic. Hydraulic materials react directly with water to form cementitious compound like GGBS. Pozzolanic materials do not have any cementitious property but when used with cement or lime react with calcium hydroxide to form products possessing cementitious prosperities.

GROUND GRANULATED BLAST FURNACE SLAG S: It is hydraulic type of SCM.

Ground granulated blast furnace slag (GGBS or GGBFS) is obtained by quenching molten iron slag ,a by-product of iron and steel making from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder.

Ground granulated blast furnace slag (GGBFS) has been utilized for many years as an additional cementitious material in Portland cement concretes, either as a mineral admixture or as a component of blended cement. Granulated blast furnace slag typically replaces 35–65% Portland cement in concrete. The use of GGBFS as a partial replacement of ordinary Portland cement improves strength and durability of concrete by creating a denser matrix and thereby increasing the service life of concrete structures. It has a higher proportion of the strength-enhancing calcium silicate hydrates (CSH) than concrete made with Portland cement only, and a reduced content of free lime, which does not contribute to concrete strength.

Fly ash: It is pozzolanic SC material.

Fly ash is one of the residues generated in the combustion of coal. Fly ash is generally captured from the chimneys of coal-fired power plants, and is one of two types of ash that jointly are known as coal ash; the other, bottom ash, is removed from the bottom of coal furnaces. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO2) (both amorphous and crystalline) and calcium oxide (CaO). Fly ash is classified as Class F and Class C types.

The replacement of Portland cement with fly ash is considered to reduce the greenhouse gas "footprint" of concrete, as the production of one ton of Portland cement produces approximately one ton of CO2 as compared to zero CO2 being produced using existing fly ash. New fly ash production, i.e., the burning of coal, produces approximately twenty to thirty tons of CO2 per ton of fly ash. Since the worldwide production of Portland cement is expected to reach nearly 2 billion tons by 2010, replacement of any large portion of this cement by fly ash could significantly reduce carbon emissions associated with construction.

It has been used successfully to replace Portland cement up to 30% by mass, without adversely affecting the strength and durability of concrete. Several laboratory and field investigations involving concrete containing fly ash had reported to exhibit excellent mechanical and durability properties. However, the pozzolanic reaction of fly ash being a slow process, its contribution towards the strength development occures only at later ages. Due to the spherical shape of fly ash particles, it can also increase workability of cement while reducing water demand.

Silica Fume: It is also a type of pozzolanic material.

Silica fume is a byproduct in the reduction of high-purity quartz with coke in electric arc furnaces in the production of silicon and ferrosilicon alloys. Silica fume consists of fine particles with a surface area on the order of 215,280 ft^2/lb (20,000 m^2/kg) when measured by nitrogen adsorption techniques, with particles approximately one hundredth the size of the average cement Because of its extreme fineness and high silica content, silica fume is a very effective pozzolanic material particle.

Silica fume is added to Portland cement concrete to improve its properties, in particular its compressive strength, bond strength, and abrasion resistance. These improvements stems from both the mechanical improvements resulting from addition of a very fine powder to the cement paste mix as well as from the pozzolanic reactions between the silica fume and free calcium hydroxide in the paste. Addition of silica fume also reduces the permeability of concrete to chloride ions, which protects the reinforcing steel of concrete from corrosion, especially in chloride-rich environments such as coastal regions .When silica fume is incorporated, the rate of cement hydration increases at the early hours due to the release of OH ÿ ions and alkalis into the pore fluid. The increased rate of hydration may be attributable to the ability of silica fume to provide nucleating sites to precipitating hydration products like lime, C±S±H, and ettringite. It has been reported that the pozzolanic reaction of silica fume is very significant and the non-evaporable water content decreases between 90 and 550 days at low water /binder ratios with the addition of silica fume.

During the last decade, considerable attention has been given to the use of silica fume as a partial replacement of cement to produce high-strength concrete.

STEEL SLAG:

The Steel slag, a byproduct of steel making, is produced during the separation of molten steel from impurities in steel making furnaces. This can be used as aggregate in concrete. Steel slag aggregate generally exhibit a propensity to expand because of the presence of free lime and magnesium oxides that have not reacted with the silicate structure and that can hydrated and expand in humid environments. This potentially expansive nature (volume changes up to 10 percent or more attributable to the hydration of calcium and magnesium oxides) could cause difficulties with products containing steel slag, and is one reason why steel slag aggregate are not used in concrete construction. Steel slag is currently used as aggregate in hot mix asphalt surface applications, but there is a need for some additional work to determine the feasibility of utilizing this industrial by-product more wisely as a replacement for both fine and coarse aggregates in a conventional concrete mixture. Most of the volume of concrete is aggregates. Replacing all or some portion of natural aggregates with steel slag would lead to considerable environmental benefits. Steel slag has high specific gravity, high abrasion value than naturally available aggregate apart from the drawbacks like more water absorption, high alkalis. Therefore with proper treatments it can be used as coarse aggregate in concrete.

The production of a HSC may be hampered if the aggregates are weak. Weak and marginal aggregates are widespread in many parts of the world and there is a concern as to the production of HSC in those regions. Incorporation of silica fume is one of the methods of enhancing the strength of concrete, particularly when the aggregates are of low quality.

LITERATURE SURVEY:

Many works have been done to explore the benefits of using pozzolanic materials in making and enhancing the properties of concrete. M.D.A. Thomas, M.H.Shehata. 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 have studied the Portland cement-fly ash – silica fume systems in concrete and concluded several beneficial effects of addition of silica fume to the fly ash cement mortar in terms of strength, workability and ultra sonic velocity test results. Jan Bijen has studied the benefits of slag and fly ash added to concrete made with OPC in terms of alkali-silica reaction, sulphate attack.

L. Lam, Y.L. Wong, and C.S. Poon 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 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 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 different proportions of ingredients 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 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.

Susan Bernal, Ruby De Gutierrez, Silvio Delvasto, Erich Rodriguez carried out Research work in Performance of an alkali-activated slag concrete reinforced with steel fibers. Their conclusion is that The developed AASC present higher compressive strengths than the OPC reference concretes. Splitting tensile strengths increase in both OPCC and the AASC concretes with the incorporation of fibers at 28 curing days.

Hisham Qasrawi , Faisal Shalabi, Ibrahim Asi carried out Research work in Use of low CaO unprocessed steel slag in concrete as fine aggregate.Their conclusion is That Regarding the compressive and tensile strengths of concrete steel slag is more advantageous for concretes of lower strengths.

O. Boukendakdji, S. Kenai, E.H. Kadri, F. Rouis carried out Research work in Effect of slag on the rheology of fresh self- compacted concrete. Their conclusion is that slag can produce good self-compacting concrete.

Shaopeng Wu, Yongjie Xue, Qunshan Ye, Yongchun Chen carried out Research work in Utilization of steel slag as aggregates for stone mastic asphalt (SMA) mixtures. Their conclusion is that The test roads shows excellent performances after 2-years service, with abrasion and friction coefficient of 55BPN and surface texture depth of 0.8 mm.

Tahir Gonen,Salih Yazicioglu carried out research work in the influence of mineral admixtures on the short and long term performance of concrete, hence concluded that silica fume contributed to both short and long term properties of concrete, where as fly ash shows its beneficial effect in a relatively longer time. As far as the compressive strength is concerened, adding of both silica fume and fly ash slightly increased compressive strength, but contributed more to the improvement of transport properties of concrete.

M. Maslehuddin, Alfarabi M. Sharif, M. Shameem, M. Ibrahim and M.S Barry carried out experimental work on comparison of properties of steel slag and crushed limestone aggregate concretes, finally concluded that durability characteristics of steel slag cement concrete were better than those of crushed limestones aggregate concrete. Some of physical properties were better than of crushed lime stones concrete.

J. G. Cabrera and P. A. Claisse carried out experimental work on Oxygen and water vapour transport in cement pastes, hence concluded that the flow of oxygen is described by the Darcy equation, but the flow of water vapour is not. The different mechanisms of transmission cause the transmission rates for oxygen to be spread over a far greater range than those for water vapour with some of the SF samples almost impermeable to oxygen.

MATERIALS AND METHODOLOGY

MATERIALS

Silica Fume

Silica fume is a byproduct in the reduction of high-purity quartz with

coke in electric arc furnaces in the production of silicon and ferrosilicon alloys. Silica fume consists of fine particles with a surface area on the order of 215,280 ft²/lb (20,000 m²/kg) when measured by nitrogen adsorption techniques, with particles approximately one hundredth the size of the average cement Because of its extreme fineness and high silica content, silica fume is a very effective pozzolanic material particle.

Silica fume is added to Portland cement concrete to improve its properties, in particular its compressive strength, bond strength, and abrasion resistance. These improvements stems from both the mechanical improvements resulting from addition of a very fine powder to the cement paste mix as well as from the pozzolanic reactions between the silica fume and free calcium hydroxide in the paste. Addition of silica fume also reduces the permeability of concrete to chloride ions, which protects the reinforcing steel of concrete from corrosion, especially in chloride-rich environments such as coastal regions .When silica fume is incorporated, the rate of cement hydration increases at the early hours due to the release of OH ÿ ions and alkalis into the pore fluid. The increased rate of hydration may be attributable to the ability of silica fume to provide nucleating sites to precipitating hydration products like lime, C±S±H, and ettringite. It has been reported that the pozzolanic reaction of silica fume is very significant and the non-evaporable water content decreases between 90 and 550 days at low water /binder ratios with the addition of silica fume.

Physical Properties of silica fume.

The properties of silica fume were determined in laboratory. Specific gravity analysis is given below.

Materials	Specific gravity
Silica fume	2.27

Chemical Analysis of silica fume

The primary components of iron and steel slag are limestone (CaO) and silica (SiO2). Other components of blast furnace slag include alumina (Alsub>2O3) and magnesium oxide (MgO), as well as a small amount of sulfur (S), while steelmaking slag contains iron oxide (FeO) and magnesium oxide (MgO). In the case of steelmaking slag, the slag contains metal elements (such as iron) in oxide form, however because the refining time is short and the amount of limestone contained is large, a portion of the limestone auxiliary material may remain undissolved as free CaO.

These components exist in the natural world in places such as the Earth's crust, natural rock, and minerals and chemical composition in similar to that of ordinary portland cement. The shape and physical charecterstics of iron and steel slag are similar to ordenary crushed stone and sand, however due to differences such as the chemical components and cooling processes, it is possible to provide different types of slag with a wide variety of unique properties. For example, there are some types of slag that harden when alkali stimulation occurs. Maney applications utilizing the physical and chemical characteristics of slag have been developed and are being put to use in a broad range of fields.

Components	Blast furnace slag	Converter slag	Electric arc slag		Andesite (for reference)	Ordinary cement
			Oxidizing slag	Reducing slag		
Cao	41.7	45.8	22.8	55.1	5.8	64.2
Sio_2	33.8	11.0	12.1	18.8	59.6	22.0
T-Fe	0.4	17.4	29.5	0.3	3.1	3.0

Componens	Blast furnae slag	Convertr slag	Electric arc slag		Andesite (for referenc)	Ordinay cement
			Oxidizig slag	Reducig slag		
Mgo	7.4	6.5	4.8	7.3	2.8	1.5
Al_2O_3	13.4	1.9	6.8	16.5	17.3	5.5
S	0.8	0.06	0.2	0.4	-	2.0
P2O3	<0.1	1.7	0.3	0.1	-	-
Mno	0.3	5.3	7.9	1.0	0.2	-

The chemical analysis of silica fume is given below It is also compared with ASTM

Silica fume	ASTM-C-1240	Actual Analysis
SiO_2	85%min	86.7%
LOI	6%max	2.5%
Moisture	3%	0.7%
Pozz Activity Index	105%min	129%
Sp Surface Area	>15 m2/gm	22 m2/gm
Bulk Density	550 to 700	600
+45	10%max	0.7%

Table:3.3 chemical properties

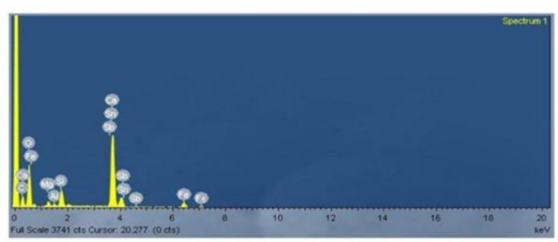

Figure 3.1 XRD Analysis of Steel Slag

3.1.3 Fly ash cement

RESULTS AND DISCUSSIONS

EXPERIMENTAL STUDY ON MORTAR.

Here we prepared mortar with ratio 1:3 from different types of cement + silica fume replacement as binder mix and sand as fine aggregate. Then its physical properties like capillary absorption consistency, compressive strength and porosity was predicted. These test results both in tabular form and graphical presentation are given below.

Normal Consistency for Mortar.

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

1)300 gm 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.

Where,SC = Slag cement

FC = Fly ash cement

SF = Silica fume

SFC = slag and fly ash cement

SC0 = Slag cement with 0% silica fume replacement

SC10 = slag cement with 10% silica fume replacement

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

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

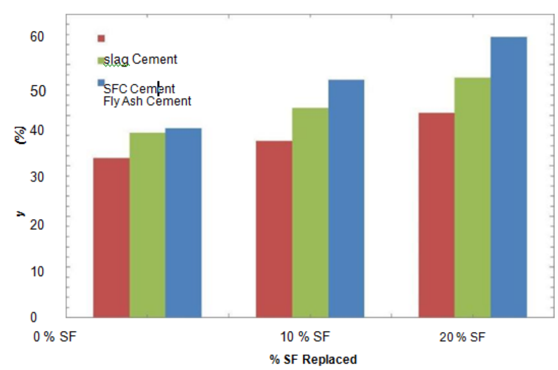

Figure.4.1 Consistency of Mortar.

Compressive Strength of Mortar

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. All binder mixes shows that up to 20% replacement of cement with silica fume the Compressive strength increases with increasing dose of silica Fume. 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. 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

Type of cement	% of SF replaced	7 days	28 days
Slag cement	0	18.91	29.43
(SC)	10	25.97	35.09
	20	34.13	42.12
Fly ash cement	0	14.82	26.57
(FC)	10	27.07	31.74
	20	31.43	37.23
Slag and fly ash	0	15.73	32.57
cement blend (1:1)	10	22.58	37.69
(SFC)	20	27.89	40.12

Table No. 4. 1 Compressive Strength of different mortars after 7 days and 28 days

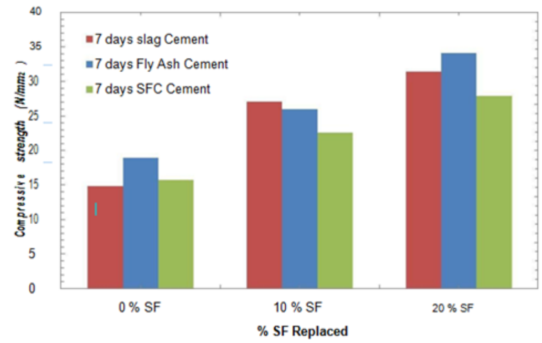

Figure.4.2 Compressive strength for mortar for 7 days

Porosity Test of Mortar

Porosity of different mortar after 7 days and 28 days of curing were tabulated in Table No.4.5.

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. All binder mixes shows that up to 20% replacement of cement with silica fume the durability in terms of decreases with increasing dose of silica Fume. Porosity decreases to about 16 % in slag cement, about 17 % in Fly ash cement and about 17% in blended binder mix with 20% addition of silica fume between 7days to 28 days of curing.

Types of cement	% silica fume replace	28 days($k*10^{-3}$ cm/s)	56 days($k*10^{-3}$ cm/s)
Slag cement	0	1.232	1.093
	10	0.811	0.783
	20	0.624	0.518
Fly ash cement	0	0.886	0.795
	10	0.637	0.598
	20	0.538	0.485
Slag and fly ash cement blend (1:1)	0	0.982	0.871
	10	0.842	0.638
	20	0.593	0.541

Table No. 4.2 Coefficients of capillary absorption

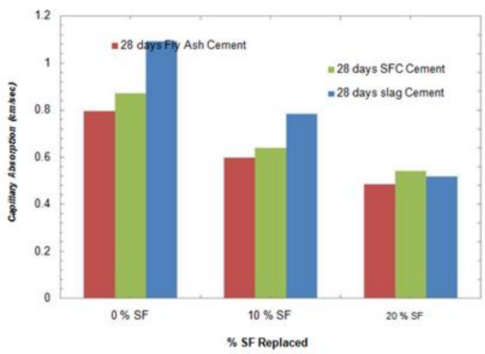

Figure.4.5 Capillary Absorption for mortar for 28 days

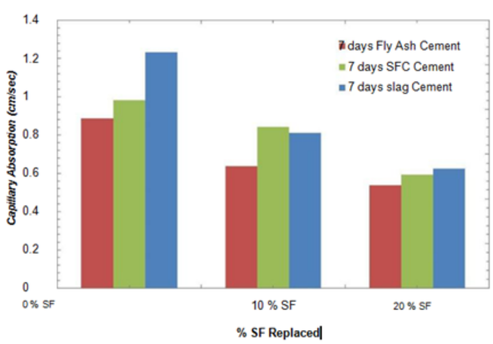

Figure.4.4 Capillary Absorption for mortar for 7 days

EXPERIMENTAL STUDY ON CONCRETE CUBE.

Here we prepared concrete with ratio 1:1.5:3 from different types of cement + silica fume replacement as binder mix, sand as fine aggregate and steel slag as coarse aggregate. Then its physical properties like capillary absorption, water/cement ratio, compressive strength, porosity, flexural strength, and wet-dry test was predicted. These test results both in tabular form and graphical presentation are given below.

Water /Cement Ratio and Slump.

The water–cement ratio is the ratio of the weight of water to the weight ofcementused in aconcretemix and has an important influence on the quality of concrete produced. A lower water-cement ratio leads to higher strength and durability, but may make the mix more difficult to place. Placement difficulties can be resolved by usingplasticizers or super-plasticizers

Often, the water–cement ratio is characterized as the water to cement plus pozzolan ratio, w/(c+p). The pozzolan is typically a fly ash, orblast furnaceslag. It can include a number of other materials, such as silica fume, rice husk ash or natural pozzolans. The addition of pozzolans will influence the strength gain of the concrete.

The concept of water–cement ratio was developed by Duff A. Abrams and first published in 1918, seeconcrete slump test.

The water cement ratio and slump of steel slag concrete with different binder mix with silica fume replacement is given below.

Type of cement	% of SF replaced	W/C Ratio	Slump in (mm)
Fly ash cement	0	0.51	52
	10	0.58	52
	20	0.591	58
Slag cement	0	0.47	63
	10	0.518	50
	20	0.581	55
Slag and fly ash cement blend (1:1)	0	0.489	60
	10	0.543	53
	20	0.544	52

Table No. 4.4 Water /Cement Ratio and Slump

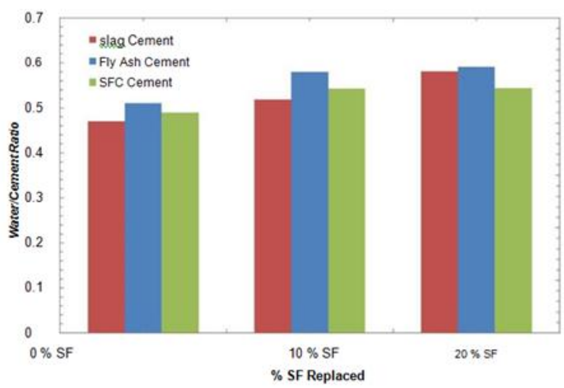

Figure.4.8 Water Cement Ratio for steel slag concrete

CONCLUSION:

1.Inclusion of silica fume improves the strength of different types of binder mix by making them more denser.

2.Addition of silica fume improves the early strength gain of fly ash cement whereas it increases the later age strength of slag cement.

3.The equal blend of slag and fly ash cements improves overall strength development at any stage.

4.Addition of silica fume to any binder mix reduces capillary absorption and porosity because fine particles of silica fume reacts with lime present in cement and form hydrates dancer and crystalline in composition.

5.The capillary absorption and porosity decreases with increase dose up to 20% replacement of silica fume for mortar.

6.Addition of silica fume to the concrete containing steel slag as coarse aggregate reduces the strength of concrete at any age.

7.This is due to the formation of voids during mixing and compacting the concrete mix in vibration table because silica fume make the mixture sticky or more cohesive which do not allow the entrapped air to escape. The use of needle vibrator may help to minimize this problem.

8.The most important reason of reduction in strength is due to alkali aggregate reaction between binder matrix and the steel slag used as coarse aggregate. By nature cement paste is alkaline. The presence of alkalis Na_2O, K_2O in the steel slag make the concrete more alkaline. When silica fume is added to the concrete, silica present in the silica fume react with the alkalis and lime and form a gel which harm the bond between aggregate and the binder matrix. This decrease is more prominent with higher dose of silica fume.

9.Combination of fly ash cement and silica fume makes the concrete more cohesive or sticky than the concrete containing slag cement and silica fume causing formation of more voids with fly ash cement. Therefore the concrete mixes containing fly ash and silica fume show higher capillary absorption and porosity than concrete mixes containing slag cement and silica fume.

10.The total replacement of natural coarse aggregate by steel slag is not recommended in concrete. A partial replacement with fly ash cement may help to produce high strength concrete with properly treated steel slag.

11.The steel slag should be properly treated by stock piling it in open for at least one year to allow the free CaO & MgO to hydrate and thereby to reduce the expansion in later age.

12.A thorough chemical analysis of the steel slag is recommended to find out the presence of alkalis which may adversely affect to the bond between binder matrix and the aggregate.

REFERENCES

1.Thanongsak, N., Watcharapong, W., and Chaipanich. A., (2009), "Utilization of fly ash with silica fume and properties of Portland cement–fly ash–silica fume concrete". Fuel, Volume 89, Issue 3, March 2010, Pages 768-774.

2.Patel, A, Singh, S.P, Murmoo, M. (2009), "Evaluation of strength characteristics of steel slag hydrated matrix" Proceedings of Civil Engineering Conference-Innovation without limits (CEC-09), 18th - 19th September‟ 2009.

3.Li Yun-feng, Yao Yan, Wang Ling, "Recycling of industrial waste and performance of steel slag green concrete", J. Cent. South Univ. Technol.(2009) 16: 8−0773, DOI: 10.1007/s11771-009-0128-x.

4.Velosa, A.L, and Cachim, P.B.," Hydraulic lime based concrete: Strength development using a pozzolanic addition and different curing conditions" ,Construction and Building Materials ,Vol.23,Issue5,May2009,pp.2107-2111.

5.Barbhuiya S.A., Gbagbo, J.K., Russeli, M.I., Basheer, P.A.M. "Properties of fly ash concrete modified with hydrated lime and silica fume", aCentre for Built Environment Research, School of Planning, Architecture and Civil Engineering, Queen‟s University Belfast, Northern Ireland BT7 1NN, United Kingdom Received 28 January 2009; revised 1 June 2009; accepted 3 June 2009. Available online 15 July 2009.

6.Gonen,T. and Yazicioglu,S. " The influence of mineral admixtures on the short and long term performances of concrete" department of construction education, Firat University, Elazig 23119, Turkey.2009.

7.Mateusz R.J. O. and Tommy N. " Effect of composition and Initial Curing Conditions of Scaling Resistance of Ternary(OPC/FA/SF) concrete", Journal of Materials in Civil Engineering © ASCE/October 2008, PP 668-677.

8.Chang-long,W QI, Yan-ming,He Jin-yun, "Experimental Study on Steel Slag and Slag Replacing Sand in Concrete", 2008, International Workshop on Modelling, Simulation and Optimization.