ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Effects of Using Silica Fume over Steel Slag Concrete for Construction

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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 cementitious materials. Nowadays, most concrete mixture contains supplementary cementitious material which forms part of the cementitious 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 cementitious property, thus reducing the cost of using Portland cement. The fast growth in industrialization 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. 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. Mixing of silica fume had made concrete sticky ie 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

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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.

I. 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.

A. 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 prevent 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.

1. Ground granulated blast furnace Slag: 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 shape of fly ash particles, it can also increase workability of cement while reducing water demand.

2. Fly ash: It is pozzalanic SC

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 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 compared to zero CO2 being produced using existing fly New fly ash production, i.e., the burning of coal, produces approximately twenty to thirty tons of CO2 per 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

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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.

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B. 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 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. 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.

II. 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.

III. MATERIALS

A. Silica Fume

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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

B. Steel Slag

Steel slag is the residue of steel production process and composed of silicates and oxides of unwanted elements in steel chemical composition. Fifty million tons per year of LD slag were produced as a residue from Basic Oxygen Process (BOP) in the world. In order to use these slags in cement, its hydraulic properties should be known. Chemical composition is one of the important parameters determining the hydraulic properties of the slags. In general, it is assumed that the higher the alkalinity, the higher the hydraulic properties. If alkalinity is> 1.8, it should be considered as cementitious material. Investigations were carried out also on the usability of steel slag as construction material under laboratory and practical conditions. For this application, the required properties are high compression strength, wear strength and resistance to climatic conditions.

The most important criterion is volume stability, in which free CaO and MgO contents of the slag play an important role. Both oxides can go into reaction with water.

C. Fly ash cement

Fly ash, which is largely made up of silicon dioxide and calcium oxide, can be used as a substitute for Portland cement, or as a supplement to it. The materials which make up fly ash are pozzolanic, meaning that they can be used to bind cement materials together.

Pozzolanicmaterials, including fly ash cement, add durability and strength to concrete. Fly ash cement is also known as green concrete. It binds the toxic chemicals that are present in the fly ash in a way that should prevent them from contaminating natural resources. Using fly ash cement in place of or in addition to Portland cement uses less energy, requires less invasive mining, and reduces both resource consumption and CO2 emissions.

D. Slag Cement

Slag cement has been used in concrete projects in the United States for over a century. Earlier usage of slag cement in Europe and elsewhere demonstrates that long-term concrete performance is enhanced in many ways.

Based on these early experiences, modern designers have found that these improved durability characteristics help further reduce life-cycle costs, lower maintenance costs and makes concrete more sustainable. For more information on how slag cement is manufactured and it enhances the durability and sustainability of concrete

IV. METHODOLOGY

The Experimental programmed was carried out in two stages Stage 1: Experimental work was conducted on mortar mixes by using different binder mix modified with different percentages of silica fume.

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Stage2: Experimental works were conducted on steel slag concrete mixes by using different binder mix modified with different percentages of silica fume.

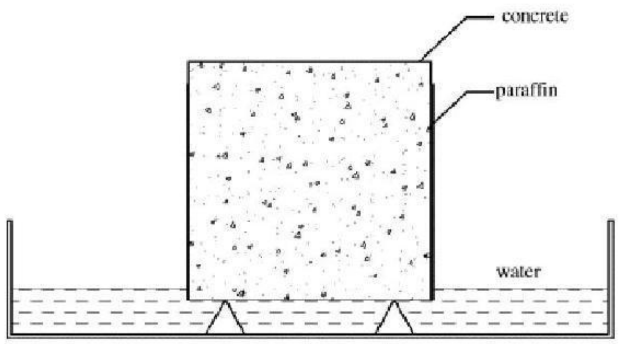

Fig1. Capillary Absorption Test in Process.

LABORATORY TEST

Compressive Strength Test

For each set six standard cubes were cast to determine 7-days,28 day and 56 days compressive strength after curing. Also nine no. of cube was casted to know the compressive strength of concrete. The size of the cube is as per the IS 10086 - 1982.

Capillary absorption Test

Two cube specimens were cast for both (Mortar and concrete cube) to determine capillary absorption coefficients after 7days, 28 days and 56 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].

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.

Wet-dry Test

Concrete cube were dipped inside a sea water for 4 hours and then exposed to dry for 20 hours.Sea water is prepared by dissolved 35 g of salt (Nacl) in one liter water. Here cubes were dipped inside the Sea water for 56 days and its compressive strength were determined by compressive testing machine.

Flexural Test

It is the ability of a beam or slab to resist failure in bending. The flexural strength of concrete is 12 to 20 percent of compressive strength. Flexural strength is useful for field control and acceptance for pavement .but now a day's flexural strength is not used to determine field control, only compressive strength is easy to judge the quality of concrete. To determine the flexural strength of concrete four numbers of prism were casting. Then it was cured properly.

Flexural Test

The flexural strength of steel slag concrete at 28 days and 56 days is given below.

Type of cement	% of SF replaced	28 days (N/mm^2)	56 days (N/mm^2)
Fly ash cement	0	6.875	4
(FC)	10	7	4.25
	20	6.875	4.5
Slag cement	0	7	5
(SC)	10	6.5	3.55
	20	6.125	3.975
Slag and fly ash	0	7	4.5
cement blend (1:1)	10	6.725	3.23
(SFC)	20	4.75	2.975

VI. RESULTS

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 are given in graphical presentation as below.

VII. 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 theconcrete 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.

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