EFFECT OF SILICA FUME ON STEEL SLAG CONCRETE

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***Abstract*: Concrete is the most versatile building material, since it can be designed to withstand the most hostile environments by adopting the most stimulating forms. Engineers are continually pushing the boundaries to improve their performance with the help of innovative chemical additives and complementary cement materials. Today, most of the concrete mix contains additional cementitious material that is part of the cement component. These materials are important by-products of other processes. The main advantages of SCMs are their ability to replace a certain amount of cement and yet they can have cement properties, thus reducing the cost of using Portland cement. The rapid growth of instrumentation has led to tons and tons of by-products or waste materials, which can be used as SCMs such as fly ash, silica fumes, blast furnace slag, steel slag, etc. The use of these by-products not only helps to use these waste materials, but also improves the properties of concrete in fresh and hydrated states. Slag cement and fly ash are the two most common SCMs used in concrete. Most of the concrete produced today includes one or both of these materials. For this reason, their properties are frequently compared with one another by the designers of mixtures seeking to optimize concrete mixtures. Perhaps the most successful SCM is silica fume because it improves both the strength and durability of concrete to such an extent that modern design rules require the addition of fume silica for the design of high-strength concrete.**

***Keywords*: Silica fume, fly ash, Flexural Test, Wet-dry Test, Porosity Test, Compressive Strength Test, Capillary absorption Test**

INTRODUCTION:

Concrete is a mixture of cement, sand, coarse aggregates and water. Its success lies in its versatility, since it can be designed to withstand the most difficult environments by adopting the most stimulating forms. Engineers and scientists are also trying to increase their limits with the help of innovative chemical additives and various additional SCM cementing materials.

The first SCM consisted of natural, readily available materials, such as volcanic ash or diatomaceous earth. The marvels of engineering, such as the Roman aqueducts, the Coliseum, are examples of this technique used by the Greeks and Romans. Nowadays, most concrete mixtures contain SCM which are mainly by-products or waste from other industrial processes.

1.1 SUPPLEMENTARY CEMENTITIOUS MATERIAL:

More recently, stringent environmental pollution controls and regulations have resulted in an increase in industrial waste and undervalued by-products that can be used as SCMs, such as fly ash, silica fumes, milled blast furnace slag, etc. The use of SCM in concrete constructions not only prevents these materials from controlling pollution, but also to improve the properties of concrete in fresh and hydrated states.
The SCM can be divided into two categories based on the type of reaction: hydraulic and pozzolanic. Hydraulic materials react directly with water to form a cementitious compound such as GGBS. Pozzolanic materials do not have cement properties, but when used with cement or lime they react with calcium hydroxide to form products that have cement prosperity.

1.1.1. Ground granulated blast furnace Slag: It is hydraulic type of SCM.

Ground granulated blast furnace slag (GGBS or GGBFS) is obtained by extinguishing the cast iron slag, a by-product of the manufacture of iron and steel from a blast furnace in water or steam, to produce a granular and vitreous product that is then dried and a fine powder is ground.
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.

1.1.2. Fly ash: It is pozzalanic SC material.

Fly ash is one of the waste generated in the combustion of coal. Fly ash is usually captured from the chimneys of coal-fired power plants, and is one of two types of ash that are collectively known as coal ash; the other, the bottom ash, is removed from the bottom of the coal furnaces. Depending on the source and composition of the burning coal, the constituents of the 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 into class F and class C types.

It is considered that the substitution of Portland cement for fly ash reduces the "footprint" of greenhouse gases in the concrete, since the production of one ton of Portland cement produces approximately one ton of CO2 compared to the production of zero CO2 using ashes existing flyers. The new production of fly ash, that is, the burning of coal, produces approximately twenty to thirty tons of CO2 per ton of fly ash. Given that global Portland cement production is expected to reach almost 2 billion tons by 2010, the replacement of any large portion of this cement with fly ash could significantly reduce the 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 the concrete. Several laboratory and field studies of concrete containing fly ash showed excellent mechanical and durability properties. However, the pozzolanic reaction of fly ash is a slow process, its contribution towards the development of force occurs only at later ages. Due to the spherical shape of the fly ash particles, the workability of the cement can also increase and reduce the demand for water.

1.1.3. 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 absorption techniques, with particles approximately one-hundredth the size of the average cement. its extreme fineness and high content of silica Content, silica fume is a particle of pozzolanic material very effective.
Silica fume is added to Portland cement concrete to improve its properties, in particular its compressive strength, adhesion strength and abrasion resistance. These improvements are due both to the mechanical improvements resulting from the addition of a very fine powder to the cement paste mixture and to the pozzolanic reactions between the silica fume and the free calcium hydroxide in the paste. The addition of silica fume also reduces the permeability of the concrete to the chloride ions, which protects the reinforcing steel of the concrete from corrosion, especially in chloride-rich environments such as coastal regions. Hours due to the release of OH ions and alkalis in the fluid of the pores. The increase in hydration rate can be attributed to the ability of silica fume to provide nucleation sites to precipitate hydration products such as 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, you have paid much attention to the use of silica fume as a partial replacement of cement to produce high strength concrete.

1.3. STEEL SLAG:
Steel slag, a byproduct of steel production, is produced during the separation of molten steel from impurities in steel production furnaces. This can be used as a particular aggregate. The aggregate of steel slag generally shows a propensity to expand due to the presence of free calcium and magnesium oxides that have not reacted with the silicate structure and that can be hydrated and expanded in humid environments. This potentially expansive nature (volume varies up to 10% or more attributable to the hydration of calcium and magnesium oxides) could cause difficulties with products containing steel slag, and is one of the reasons why the addition of Steel slag is not used in concrete construction. Steel slag is currently used as an aggregate in mixed hot bituminous surface applications, but more work is needed to determine the viability of using this industrial by-product more intelligently as a substitute for fine and coarse aggregates in a conventional concrete mix. Most of the volume of concrete is added. Replacing all or part of the natural aggregates with steel slag would lead to important environmental benefits. The steel slag has a high specific weight, a high abrasion value compared to the naturally available aggregate, as well as drawbacks such as water absorption and high alkalis. Therefore, with the right treatments it can be used as a coarse aggregate in the concrete.

The production of an HSC can be hindered if the aggregates are weak. Weak and marginal aggregates are widespread in many parts of the world and there is a concern about the production of HSC in those regions. The incorporation of fume silica is one of the methods to improve the strength of the concrete, in particular when the aggregates are of low quality.

2. LITERATURE SURVEY:

Much work has been done to explore the benefits of using pozzolanic materials to fabricate and improve concrete properties. M.D.A. Thomas, M.H.Shehata[1] et al. They have studied the ternary cementitious mixtures of Portland cement, silica fume and fly ash that offer significant advantages over binary mixtures and even greater improvements over smooth Portland cement. Sandor Popovics[2] has studied Portland fly ash ash smoke systems in concrete and concluded several beneficial effects of the addition of silica fume to fly ash cement mortar in terms of strength, workability and ultrasonic speed test results. . Jan Bijen[3] has studied the benefits of slag and fly ash added to concrete made with OPC in terms of silica reaction with alkali, sulfate attack. L. Lam, Y.L. Wong, and C.S. Poon[4] in their study entitled Effect of fly ash and silica fume on concrete compression and fracture behaviors, concluded the improvement in concrete strength properties by adding a different percentage of fly ash and silica fume. Tahir Gonen and Salih Yazicioglu[5] studied the influence of the binary and ternary mixture of mineral additives on the short and long term performance 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 the composition of the mixture and the initial curing conditions on the peeling

strength of the ternary concrete have discovered the effect of different proportions of the ingredients of the ternary mixture of the mixture of binders on the resistance to scale of concrete in low temperatures SA 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 and concluded that the addition of lime and silica smoke improves the compressive strength of the first days and the development of long-term strength and durability of the concrete. Susan Bernal, Ruby De Gutiérrez, Silvio Delvasto[8], Erich Rodriguez carried out a research project on the performance of an alkali activated slag ore reinforced with steel fibers. His conclusion is that the AASC developed has greater resistance to compression than the concrete reference OPC. The tensile strengths per division increase in both OPCC and AASC concretes with the incorporation of fibers after 28 days of curing. Hisham Qasrawi, Faisal Shalabi, Ibrahim Asi [9] carried out a research work The use of unprocessed steel slag with low CaO content in the concrete as fine aggregate. O. Boukendakdji, S. Kenai, E.H. Kadri, F. Rouis [10] carried out a research work on the effect of slag on the rheology of fresh self-compacted concrete. His conclusion is that the slag can produce a good self-compacting concrete. Shaopeng Wu, Yongjie Xue, Qunshan Ye, Yongchun Chen[11] carried out research work on the use of steel slag as aggregates for mixtures of mastic asphalt (SMA). His conclusion is that the test paths show excellent performance after 2 years of service, with a friction and abrasion coefficient of 55BPN and a surface texture depth of 0.8mm.

3.2 METHODOLY TEST PROCEDURE:

The Experimental programme was conducted in two stages as

Stage 1: Experimental work was carried out on mortar mixes by using different binder mix modified with different percentages of silica fume.

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

Stage 1: This experimental investigation was done for three different combinations of slag cement and fly ash cement. In each of the combination, three different proportions of silica fume have been added along with the controlled mixture without silica fume.

The binders that were used were different combinations of slag cement, fly ash cement in the proportions 1: 0, 0: 1 and 1: 1, therefore, total three combinations. In addition, in each type of binder mixture combination, 0%, 10% and 20% silica fume were added. Therefore, a total of 12 sets of 1: 3 ratio mortar were prepared by mixing one part of the binder mixture and three parts of available natural sand.

Stage2: In this experimental concrete is prepared with three different kinds of binder mix with silica fume.

A: DETERMINATION OF STRENGTH OF CONCRETE OF 1:1.5:3 MIX PROPORTION BY USING FLY ASH CEMENT + SILICA FUME AS BINDER MIX, SAND AS FINE AGGREGATE AND STEEL SLAG AS COARSE AGGREGATE.

In this phase concrete having mix proportion 1 : 1.5 : 3 will be prepared using fly ash cement and silica fume as binder mix with different proportion of silica fume, sand as fine and steel slag as coarse aggregate. The various proportions of silica fume in the concrete mix will vary from 0%, 10%, and 20%. The concrete mixtures will be tested for following parameters.

- Compressive strength after 7 days, 28 days, 56 days
- Porosity test after 28 days and 56 days
- Flexural strength after 28 days, 56 days
- Capillary absorption test after 28 days and 56 days
- Compressive strength by Rebound hammer method
- Wet - dry test after 26 days and 56 days

B: DETERMINATION OF STRENGTH OF CONCRETE OF 1:1.5:3 MIX PROPORTION BY USING SLAG CEMENT+SILICA FUME AS BINDER,SAND AS FINE AGGREGATE AND STEEL SLAG AS COARSE AGGREGATE

In this phase concrete having mix proportion 1 : 1.5 : 3 will be prepared using slag cement and silica fume as binder mix with different proportion of silica fume ,sand as fine and steel slag as coarse aggregate. The proportion of silica fume used in the concrete mix will vary from 0% , 10% and 20 % of the blend. The concrete mixes will be tested for following parameters.

- Compressive strength after 7 days,28 days, 56 days
- Compressive strength by Rebound hammer method.
- Flexural strength after 28 days, 56 days
- Porosity test after 28 days and 56 days
- Wet - dry test after 28 days and 56 days
- Capillary absorption test after 28 days and 56 days

C: DETERMINATION OF STRENGTH OF CONCRETE OF 1:1.5:3 MIX PROPORTION BY USING FLY ASH CEMENT+SLAG CEMENT + SILICA FUME AS BINDER MIX ,SAND AS FINE AGGREGATE AND STEEL SLAG AS COARSE AGGREGATE.

In this one concrete having mix proportion 1 : 1.5 : 3 will be prepared using fly ash cement, slag cement and silica fume as binder mix with different proportion of silica fume, and using sand as fine and steel slag as coarse aggregate. The proportions of silica fume in the concrete mix vary from 0%, 10%, and 20%. The concrete mixes will be then tested for following:

- Compressive strength after 7 days, 28 days, 56 days
- Porosity test after 28 days and 56 days
- Flexural strength after 28 days, 56 days
- Capillary absorption test after 28 days and 56 days
- Compressive strength by Rebound hammer method
- Wet - dry test after 26 days and 56 days

3.3 LABORATORY TEST CONDUCTED:

3.3.1 Compressive Strength Test

For each set six standard cubes were molded to determine the compressive strength of 7 days, 28 days and 56 days after curing. Also nine number of the cube was casted to know concretes compressive strength. The size of the cube is according to IS 10086 - 1982.

3.3.2 Capillary absorption Test

Two samples of cubes were molded for both (mortar and concrete cube) to determine the capillary absorption coefficients after 7 days, 28 days and 56 days of curing. This test is carried out to verify the capillary absorption of different mortar mixture matrices that indirectly measure the durability of the different mortar matrices [8].

3.3.3 Porosity Test

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

3.3.4 Wet-dry Test:

The concrete cubes were submerged in sea water (salt water) for 4 hours and then exposed to dryness for 20 hours. Seawater (salt water) is prepared by dissolving 35 g of salt (Nacl) in one liter of water. Here, the cubes were submerged in the sea water for 56 days and their compressive strength was determined by a compression test machine.

3.3.5 Compressive test by pulse velocity.

Concrete's strength is generally governed by cement paste strength. If the strength of the paste can be measured, we can find a reasonable indication of the concrete's strength. This force can be measured on site by the rebound hammer method. The rebound hammer is an instrument that provides fast and simple non-destructive tests to obtain an immediate indication of the strength of the concrete in each part of the structure.

3.3.6 Flexural Test:

It is the ability of a beam or slab to withstand bending failures. The bending strength of concrete is 12 to 20 percent of the compressive strength. Flexural strength is useful for field control and paving acceptance. But nowadays flexural strength is not used to determine field control, only the compressive strength is easy to judge on the quality of the concrete. To determine the bending strength of the concrete, four numbers of prisms were cast. Then it was cured properly.

CONCLUSION:

From the present work we can draw the following conclusions:

1. Silica fume inclusion improves strength of different binder mixes by making them denser.
2. Silica fume addition improves early strength gain of the fly ash cement whereas it increases the later age strength of the slag cement.
3. The equal blend of fly ash and slag cements improves the overall strength development at any stage.
4. Silica fume addition to any of the binder mixes reduces porosity and capillary absorption because silica fume fine react with lime present in cement and form hydrates denser and crystalline in composition.
5. The porosity and capillary absorption decreases with increasing the dose upto 20% replacement of the silica fume for mortar.
6. Silica fume addition to concrete containing steel slag as coarse aggregate reduces strength of the concrete at any age.
7. This is due to the formation of empty spaces during mixing and compaction of the concrete mix in the vibration table

because the silica fumes make the mixture sticky or more cohesive, which does not allow trapped air to escape. Using the needle vibrator can help minimize this problem.

8. The most important reason for the reduction in strength is due to the reaction of the alkaline aggregate between the binding matrix and the slag of steel used as a coarse aggregate. By nature the cement paste is alkaline. The presence of Na_2O, K_2O alkalis in steel slag makes the cement more alkaline. When silica fume is added to the concrete, the silica present in the silica fume reacts with the alkalis and the lime and forms a gel that damages the bond between the aggregate and binder matrix. This decrease is more evident with a greater dose of silica.

9. The combination of fly ash cement and silica fumes makes the cement more cohesive or sticky than the cement which contains cement of slag and silica fumes which causes the formation of more spaces with the fly ash cement. Therefore, concrete mixtures containing silica fume and fly ash show more porosity and capillary absorption than concrete mixtures containing slag cement and silica.

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