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Effect Of Silica Fume On Steel Slag Concrete

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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 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.**

I. Introduction

Concrete at present is the most widely used construction 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.

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 into 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 (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.

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.Shehata1 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 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 have 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. Claisse13 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. Houssam A. Toutanji and Tahar El-Korchi14 carried out experimental work on Oxygen and water vapour transport in cement pastes, hence concluded that the increase in compressive strength of mortar containing silica fume as a partial replacement for cement, greatly contributes to strengthening the bond between the cement paste and aggregate. It was also demonstrated that super plasticizer in combination with silica fume plays a more effective role in mortar mixes than in paste mixes.

This can be attributed to a more efficient utilization of super plasticizer in the mortar mixes due to the better dispersion of the silica fume. Jigar p. patel carried out experimental work on broader use of steel slag aggregate in concrete, hence concluded that durability of steel slag aggregates concrete under freeze-thaw environment was the main goal in this research, as there was a belief that the steel slag aggregates have expansive characteristics and would causecracking in concrete. The results proved that if up to 50 to 75 % of steel slag aggregates are incorporated in the traditional concrete, there would not be much change in the durability of concrete. Micheline Moranville-Regourd16 carried out experimental work on the Cements Made from Blastfurnace Slag, hence concluded that Slag has found a considerable use in the road and building industries, in the production of cementing materials, as an aggregate in concrete and tarmacdam, in the production of light weight aggregate, and in the manufacture of slag wool for thermal insulation. M. J. Shannag carried out experimental work on the high strength concrete containing natural pozzolana and silica fume, hence concluded that use of natural pozzolana in combination with silica fume in the production of high strength concrete, and for providing technical and economical advantages in specific local uses in the concrete industry. Houssam A. Toutanji and Ziad Bayasi carried out experimental work on the Effect of curing procedures on properties of silica fume concrete hence concluded that Steam curing was found to enhance the properties of silica fume whereas air curing exhibited adverse effects as compared to moist curing. Enhancement in the mechanical properties of silica fume concrete caused by steam curing was manifested by strength increase and permeability and permeable void volume decrease. A. M. Boddy, R. D. Hooton and M. D. A. Thomas carried out experimental work on the effect of product form of silica fume on its ability to control alkali-silica reaction, hence concluded that slurried Silica fumes are significantly better at controlling the expansion of a reactive siliceous limestone aggregate than are densified or pelletized silica fume. Ha-Won Song,Seung-Woo Pack, Sang-Hyeok Nam, Jong-Chul Jang and Velu Saraswathy carried out experimental work on the Estimation of the permeability of silica fume cement concrete, hence concluded that higher permeability reductions with silica fume are due to pore size refinement and matrix densification, reduction in content of $Ca(OH)_2$ and cement paste-aggregate interfacial refinement. Finally, optimum silica fume replacement ratios that reduce the permeability of concrete reasonably are proposed for durable concrete.

II. MATERIALS

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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 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.

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.

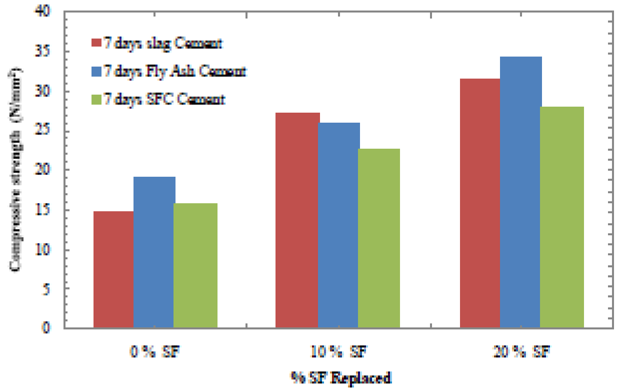
Fly ash, which is largely made up of silicon dioxide and calcium oxide, can be used as a substitute for Portland cement, or as a supplement to it. The materials which make up fly ash are pozzolanic, meaning that they can be used to bind cement materials together. Pozzolanic materials, including fly ash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

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. The most common constituent of sand, in inland continental settings and non-tropical coastal settings, is silica(silicon dioxide, or SiO_2), usually in the form of quartz which, because of its chemical inertness and considerable hardness, is the most common mineral resistant to weathering.It is used as fine aggregate in concrete.

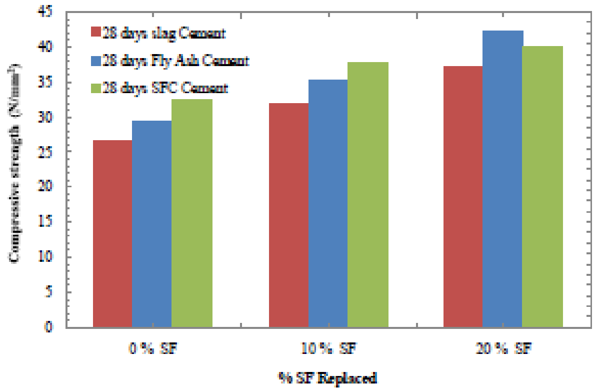
III. EXPERIMENTAL RESULTS

Compressive Strength of Mortar.

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



Compressive strength of mortar for 7 days



Capillary Absorption for mortar for 28 days

CONCLUSIONS

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.

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