Effects and Usage of Silica Fume on Steel Slag Concrete

Himanshi Bhardwaj[1], Sumit Kumar[2]
[1]M. Tech. Scholar, Department of Structural Engineering, Gateway Institute of Engg. and Tech., Sonipat, India
[2]Assistant Professor, Dept. of Structural Engineering, Gateway Institute of Engg. and Tech., Sonipat, India

***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. 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. 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.**

***Keywords*: Silica Fume, Sieve Analysis XRD Analysis Porosity Test, Wet-Dry Test, Flexural Test, Porosity Test.**

1. 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. 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 cementations 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. 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.

2. Review of literature

M.D.A. Thomas, M.H.Shehata 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. 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. 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. 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.

3. Materials and methods

The chemical analysis of cement is done to know the amount of chemical composition present in cement. Its procedure is accordingly Vogel‟s Inorganic Quantitative Analysis. This experiment was done in our institute chemistry laboratory. Here our aim is to determine actual chemical composition of the specimen provided by the company. The chemical analysis of slag cement is listed in Table. 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

Table 1
Chemical compound and slag cement

Chemical Compound	Slag Cement in (%)
SiO_2	12
Cao	43
MgO	0.37
Fe_2O_3	12
Al_2O_3	26

A. Methodology

1) Test procedure

The Experimental programme was carried out in two stages

- *Stage 1:* Experimental work were conducted on mortar mixes by using different binder mix modified with different percentages of silica fume.
- *Stage2:* Experimental works were conducted on steel slag concrete mixes by using different binder mix modified with different percentages of silica fume.
- *Stage 3:* This experimental investigation was carried out for three different combinations of slag cement and fly ash 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%, 10 % and 20 % 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.
- *Stage 4:* Here concrete is prepared with three different types of binder mix with silica fume.

4. Laboratory test conducted

A. 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

B. 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].

C. 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.

D. 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.

$$\text{Flexural strength} = PL/BD^2$$

Where, P is load, L= Length of Prism = Breadth of Prism, D = Breadth of Prism

5. Results and discussion

Fig. 1. Compressive testing machine

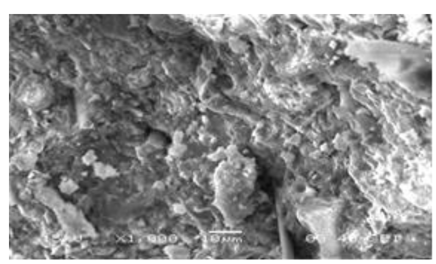

Fig. 2. Slag concrete with 0% silica fume replacement

The Fig. 2, shows that there is good bond formation between gel matrices and the aggregate. But some voids are visible. We conclude that uniform and dense gel matrices formation is visible in the fig. this is due to addition of silica fume. But figure shows interfacial bond failure between the aggregate and gel matrices. This is because of alkali-aggregate reaction.

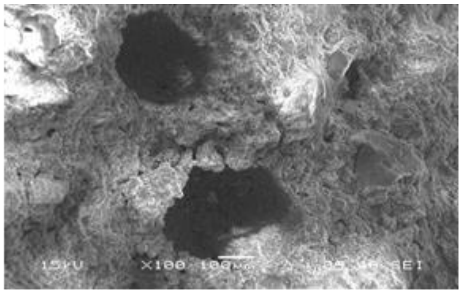

Fig. 3. Steel slag concrete with 10% silica fume replacement

This Fig. 3 shows voids, which are form due to increased cohesiveness of concrete matrix, because of addition of silica fume. Due to the presence of voids and failure of bond between gel matrices and steel slag. So strength of concrete is less.

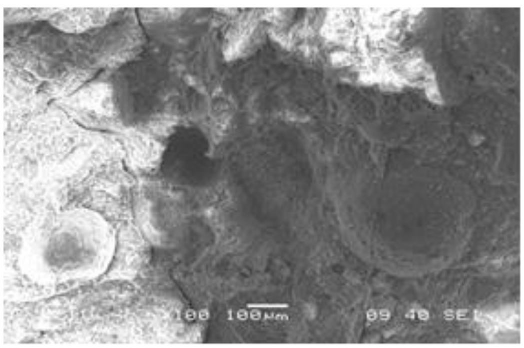

Fig. 4. Steel slag concrete with 20% silica fume replacement

This Fig. 4, shows voids, which are form due to increased cohesiveness of concrete matrix, because of addition of silica fume. Due to the presence of voids and failure of bond between gel matrices and steel slag. So strength of concrete is less.

6. Conclusion

Inclusion of silica fume improves the strength of different types of binder mix by making them denser. Addition of silica fume improves the early strength gain of fly ash cement whereas it increases the later age strength of slag cement. The equal blend of slag and fly ash cements improves overall strength development at any stage. 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. 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.

References

[1] Thomas M. D. A. and Shehata, M. H. " Use of ternary cementitious systems containing silica fume and fly ash in concrete "; cement and concrete research 29 (1999).
[2] Sandor P. "Portland Cement- Fly ash - Silica fume Systems in concrete "Department of civil and Architectural Engineering, Drexel University, Philadelphia, Pennsylvania.
[3] Bijen J. "Benefits of slag and fly ash," construction and building materials, vol. 10, no.5, pp. 309-314, 1996.
[4] Lam L, Wong Y. L., and Poon C. S. "Effect of fly ash and silica fume on compressive and fracture behaviors of concrete " Cement and Concrete research, vol. 28, no. 2, pp. 271-283, 1988.
[5] 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.
[6] 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.
[7] 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", a Centre for Built Environment Research, School of Planning, Architecture and Civil Engineering, Queen‟s University.
[8] Belfast, Northern Ireland BT7 1NN, United Kingdom, 15 July 2009.
[9] 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.
[10] Jigar P. Patel, "Broader use of steel slag aggregates in concrete", M. Tech. Thesis, Cleveland State University, December, 2008.
[11] 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.
[12] Tasdemir C," Combined effects of mineral admixtures and curing conditions on the sorptivity coefficient of concrete", cement and concrete research 33(2003), pp.1637-1642.