International Journal of Innovative Technologies
WWW.IJITECH.ORG
ISSN 2321-8665
Volume.07, Issue.02,
July-December, 2019,
Pages: 100-103

Effect of Silica Fume on Steel Slag Concrete

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Abstract: Nano silica is an amorphous type of silica dust mostly collected in bag house filters as by-product of the silicon and Ferro-silicon production. The project summarizes important physical and chemical properties of Nano silica and its applications. Nano silica consists of spherical particles with an average particle size of 150 nm and a specific surface area of typically 20m3/g.The chemical and physical properties of this inorganic product are different as compared to other amorphous and crystalline silica poly morphs. More than 500.000 MT of Nano silica are sold to the building industry world-wide and are used in fibre cement, concrete, oil-well drilling, refractories, and even in polymers. Nano silica contains trace amounts of heavy metal oxides and organic deposits, which originate from natural raw materials. The main field of application is as pozzolanic material for high performance concrete. It is sometimes confused with fumed silica. However, the production process, particle characteristics and fields of application of fumed silica are all different from those of silica fume. Concrete occupies unique position among the modern construction materials. Concrete is a material used in building construction, consisting of a hard, chemically inert particulate substance, known as aggregate (usually made for different types of sand and gravel), that is bond by cement and water. These improvements stem from both the mechanical improvements resulting from addition of a very fine powder to the cement paste mix as well as from the pozzolonic reactions between the silica fume and free calcium hydroxide in the paste. This project summarises about the comparison between the M60 concrete with Nano silica concrete of same grade. The Mix Design for concrete M60 grade is being done as per the Indian Standard Code IS: 10262-1982. In this project Nano silica is used as an artificial pozzolon and 6%, 12%, 18% is added to the weight of cement in concrete.

Keywords: NanoSilica,Amorphous, Ferro-Silicon, Inorganic, Concrete.

I. INTRODUCTION

Nano silica is a mineral admixture composes of very fine solid glassy spheres of silicon dioxide (SiO2). Most Nano silica particles are less than 1 Nano (0.00004 inch) in diameter, generally 50 to 100 times finer than average cement or fly ash particles. Frequently called condensed silica fume, Nano silica is a by-product of the industrial manufacture of ferrosilicon and metallic silicon in high-temperature electric arc furnaces. The ferrosilicon or silicon product is drawn off as a liquid from the bottom of the furnace. Vapour rising from the 2000-degree-Cfurnace bed is oxidized, and as it cools condenses into particles which are trapped in huge cloth bags. Processing the condensed fume to remove impurities and control particle size yields Nano silica. Nano silica, also known as Silica fume is fine amorphous silica. Added to concrete at around 30kg/m^3 it changes the rheology and reacts with the cement hydration products to dramatically improve concrete strengths, durability and impermeability, allowing concrete to be used in ways never before possible. When pozzolonic materials are incorporated to concrete, the silica present in these materials react with the calcium hydroxide released during the hydration of cement and forms additional calcium silicate hydrate (C– S –H), which improve durability and the mechanical properties of concrete. High strength concrete refers to concrete that has a uniaxial compressive strength greater than the normal strength concrete obtained in a particular region.

Fig1. Nano Silica Powder.

High strength and high performance concrete are being widely used throughout the world and to produce them, it is necessary to reduce the water binder ratio and increase the binder content. High strength concrete means good abrasion, impact and cavitation's resistance. Using high strength concrete in structures today would result in economic advantages. In future, high range water reducing admixtures (Super plasticizer) will open up new possibilities for use of these materials as a part of cementing materials in concrete to produce very high strengths, as some of them are make finer than cement. Apart from its use in construction concrete for tunnels, bridges, parking structures and skyscrapers, the use of Nano silica in non-asbestos fibre cement enhances bending strength and density, while it reduces porosity and water absorption. This has a positive effect on the freeze-thaw properties. Furthermore, Nano silica is a key ingredient in refractories and special grades are even used as impact modifier and process aid in polymers.

II. LITERATURE REVIEW

H.Li et.al. (2004) experimentally investigated the mechanical properties o f nano-Fe2O3 and nano-SiO2 cement mortars and found that the 7 and 28 day strength was much higher than for plain concrete. The microstructure analysis shows that the nano particles filled up the pores and the reduced amount of Ca(OH)2 due to the pozzolonic reaction.

Tao Ji (2005) experimentally studied the effect of Nano SiO2 on the water permeability and microstructure of concrete. The findings show that incorporation of Nano SiO2 can improve the resistance to water of concrete and the microstructure becomes more uniform and compact compared to normal concrete.

H. Li et.al. (2006) studied the abrasion resistance of concrete blended with nano particles of TiO2 and SiO2 nano particles along with polypropylene (PP) fibers. It was observed that abrasion resistance can be improved considerably by addition of nano particles and PP fibers. Also the combined effect of PP fiber + Nano particles shows much higher abrasion resistance than with nano particles only. It was found that abrasion resistance of nano TiO2 particles is better than nano SiO2 particles. Also relationship between abrasion resistance and compressive strength is found to be linear.

B.-W Jo et. al. (2007) studied the characteristics of cement mortar with Nano SiO2 particles experimentally and observed higher strength of these blended mortars for 7 and 28 days. The microstructure analysis showed that SiO2 not only behaves as a filler to improve microstructure, but also as an activator to the pozzolanic reaction.

III. CONCRETE MIX DESIGN METHODS

The basic objective of concrete mix design is to find the most economical properties to achieve the desire end results (strength, cohesion, workability, durability) the proportioning of concrete is based on certain material properties of cement, sand, and aggregates. Concrete mix design is basically a process of taking trials with certain proportions. Methods have been developed to arrive at these proportions that will most economically achieve end results. These methods only serve as a base to star and achieve the end result on the fewest possible trials. The basic assumptions made in mix design is that the compressive strength of workable concrete, by and large, governed by the water/cement ratio. Another most convenient relationship applicable to normal concrete is that for a given type, size and grading of aggregates, the amount of water determines its workability. However, there are various other factors which affect the properties of concrete, for example the quantity and quality of cement, water and aggregates; batching; transportation; placing; compaction; curing; etc. therefore, the specific relationships that are used in proportioning concrete mixes should be considered only as the basis for trial, subject to modifications in the light of experiences as well as for the particulars materials used at the site in each case. Different mix designs methods helps us to arrive the mix that will give us required strength, workability, cohesion etc. these mix design methods have same common threads in arriving at proportion but their method of calculations is different.

A. Mix Design Methods

IS method: The BIS recommends designing mixes based on locally available cement and other materials. These guidelines are applicable for normal concrete (less than about 45 MPa) mix design. Use of gap graded aggregates, various admixtures, and pozzolonas was beyond the scope of this specification. The design steps for mix proportioning were as under: The target average compressive strength (f'ck) at 28days was determined by using equation 1:

$$f'_{ck} = f'_{ck} + k_s$$

Where, fck = characteristic compressive strength at 28 days,
s = standard deviation of compressive strength,
t = a statistic, depending upon the accepted proportion of low results and the number of tests.

The water cement (w/c) ratio was chosen from an empirical relationship (generalized graph or graphs based on the strength of cement or accelerated strength of concrete) for the given 28-day target mean strength. The w/c ratio was checked against the limiting w/c ratio to satisfy the durability requirements.Air content, amount of entrapped air in fresh concrete, as percentage of volume of concrete, was estimated based on the nominal maximum size of aggregate(NMSA). Initially, water content, as mass (kg) per unit volume (m3) of concrete, was selected based on the target strength. Then, the initially determined water content was adjusted for workability conditions depending upon the compacting factor and types of aggregates. Sand content, as percentage of total aggregate volume, was selected based on the NMSA and the target strength. Then, the initially determined sand content was adjusted for workability conditions depending upon the sand grading zone, w/c ratio, and type of aggregates. The cement content was calculated from the w/c ratio and the water content. The cement content, thus calculated, was then checked against the minimum cement content to satisfy the durability requirement. With the quantities of water and cement per unit volume of concrete and the percentage of sand in the total aggregate already determined, the coarse and fine aggregate contents per unit volume of concrete was calculated from the following equations, respectively:

Calculation for C.A. & F.A

$$V = [W + (C/Sc) + (1/p) . (fa /Sfa)] x (1/1000)$$

$$V = [W + (C/Sc) + \{1/(1-p)\} . (ca/Sca)] x (1/1000)$$

where,

V = absolute volume of fresh concrete, which is equal to gross volume (m3) minus the volume of entrapped air,

W = mass of water (kg) per m^3 of concrete

C = mass of cement (kg) per m^3 of concrete

Sc = specific gravity of cement,

(p) = Ratio of fine aggregate to total aggregate by absolute volume,

(fa), (ca) = total mass of fine aggregate and coarse aggregate (kg) per m^3 of concrete respectively,

Sfa, Sca = specific gravities of saturated surface dry fine aggregate and coarse aggregate respectively.

IV. CONCLUSION

From the present study the following conclusions are drawn: 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.

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