Journal of Advances and Scholarly Researches in Allied Education
Vol. 16, Issue No. 9, June-2019, ISSN 2230-7540

Study on the Silica Fume and Its Effects on Concrete Properties

Manik Deshmukh[1]* Ram Pant[2] Suresh Patil[3]

[1] Assistant Professor, SVERI's College of Engineering, Pandharpur

[2] Concrete Research Lab, UltraTech Cement, Kalburgi

[3] Professor, PDA College of Engineering, Kalburgi

Abstract – The job of silica fume as a cementitious result is accounted for, as far as its recorded and test perspectives. Silica fume is discovered to be ≈100nm in size and hence is the best segment at any point to be utilized to make concretes or concrete up until now. Its normal molecule size when contrasted with that of Portland concrete (≈10–15µm) is very nearly multiple times more modest as far as the measurement size of the molecule. Obviously, upgraded compressive strength from the utilization of silica fume was found. This is believed to be because of further developed densification of the concrete network. Appropriate presentation of silica fume in concrete works on both the mechanical and sturdiness qualities of the concrete. The drawn out compressive strength of silica-fume concrete has been as of late addressed by certain analysts. This paper reports the aftereffects of compressive strength information on 4-to 6-year-old centers acquired from all around archived field tests where both silica-fume and non-silica fume concrete blends were utilized. The viability of silica-fume concrete in opposing harm brought about by consumption of implanted steel has been explored utilizing a sped up intrigued voltage-testing arrangement. The checked expansion in the strength of the silica fume concrete over the two reference concretes, which was noticed even at one day, was not joined by freedom of exorbitant warmth. Besides, the compressive strength results acquired on concrete centers required following a 4-year time frame from an exploratory section developed with an exceptionally high-fortitude concrete additionally affirmed that there was no inclination for strength misfortune in silica-fume concretes. The trial program involved six degrees of silica-fume substance (as incomplete substitution of concrete by weight) at 0% (control blend), 5%, 10%, 15%, 20%, and 25%, with and without superplasticizer. It additionally included two blends with15% silica fume added to solidify in typical concrete. Toughness of silica-fume mortar was tried in substance conditions of sulfate compounds, ammonium nitrate, calcium chloride, and different sorts of acids. It was discovered that there was an ideal worth of silica-fume content at which concrete strength improved essentially.

Keywords – Silica Fume, Effects, Properties

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INTRODUCTION

Concrete is the main component of framework advancement across the globe and an all-around planned concrete can be a strong development material. Nonetheless, there is a developing worry about the natural part of Portland concrete, as the concrete assembling industry is liable for about 2.5% of complete overall emanation from mechanical sources (Aldea et al, 2000). Especially, carbon dioxide emanation has been a significant issue on the planet because of the nursery impact. After the Rio-de Janeiro Earth Summit in 1992 and following the Kyoto Protocol in 1997, numerous nations have consented to diminish the discharge of carbon dioxide (Ozer and Ozkul 2004). These natural concerns require a decrease of clinker creation in the concrete business that is conceivable exclusively by utilizing the cementitious materials, called the mineral admixtures or pozzolans (otherwise called advantageous solidifying materials). As per ASTM C 595, a pozzolana is characterized as 'a siliceous or siliceous and aluminous material, which in itself groups practically zero cementation esteem however will, in finely separated structure and within the sight of dampness, artificially respond with calcium hydroxide to shape compounds having cementitious properties' (Papadakis and Tsimas 2002). In this way, a pozzolanic material requires calcium hydroxide to shape strength items. Portland concrete contains calcium hydroxide as a hydration item.

Hydrated concrete glue contains roughly 70% C-S-H, 20% calcium hydroxide, 7% of sulpho-aluminate and 3% of auxiliary stages. The calcium hydroxide, which shows up as a consequences of the hydration, impact the nature of the concrete contrarily by framing holes due to its solvency in water and its low strength (Oner et al 2005). The utilization of mineral admixtures positively affects nature of concrete by restricting the calcium hydroxide (Memon et al 2002; Papadakis and Tsimas 2002). The concrete hydration response and pozzolanic responses are as portrayed underneath:

Cement Hydration Reaction:

$$\text{Cement } (C_3S, C_2S) + H_2O \rightarrow \text{C-S-H gel} + Ca(OH)_2$$

Pozzolanic Reaction:

$$Ca(OH)_2 + SiO_2 \rightarrow \text{C-S-H gel}$$

In this manner, when presented in Portland concrete glue, as an incomplete substitution of concrete, pozzolanic material responds with calcium hydroxide to frame calcium-silicatehydrate gel. A portion of the normal instances of pozzolans or mineral admixtures are grain granulated impact heater slag (GGBS), fly debris (FA), silica fume (SF) and so on The concise correlation of these mineral admixtures with Portland concrete in made in Table 1.1 (Lewis et al 2003) and their ordinary molecule size conveyance.

As can be seen from the Table, every one of these mineral admixtures forces various properties. In this way, when utilized with concrete, they adjust the creation of concrete glue, impact the hydration and microstructure of the glues and mortars and the strength and porousness attributes of concrete.

There is a twofold natural profit with utilizing mineral admixtures. Right off the bat, lower concrete necessities prompts decrease in carbon dioxide created by the creation of concrete. Thusly, the concrete made by utilizing advantageous cementitious materials is more manageable (Harrison 2006). Besides, the utilization of mineral admixtures uses an item that would customary be utilized for a landfill. The utilization of mineral admixtures is considered as the best way to manage climate contemplations and carbon dioxide discharge and to utilize modern results judicially (Bentur 2002). In conventional concrete, fly debris is utilized basically for affordable reasons, as it is less expensive than Portland concrete that they supplant, yet silica fime, being more far reaching isn't utilized. Notwithstanding, for extremely high strength concrete and low porousness, the utilization of silica fume becomes fundamental (Mindess 2006).

Role of silica fume in concrete

Silica fume is the result during the production of silicon or of different silicon composites. Silica fume, which contains over 80% to 85% of SiO2 in indistinct structure, is reasonable to be utilized in concrete and concrete enterprises. The common molecule size of silica fume is around 0.1-0.5 µm and the nitrogen BET surface is 20,000 m3/kg. It is being utilized progressively on the planet as a mineral admixture to create superior concrete. Silica fume is light and has a low mass thickness of 200 to 300 kg/m3. It was first used in 1970's as an added substance in concrete in Norway (Sabir 1997).

The activity of silica fume in concrete is physiochemical. The actual period of this activity is in the refinement of void arrangement of concrete glue; especially the progress zone because of its tiny size. This actual activity gives a denser, more homogenous and uniform glue. A substitution of 15% of concrete mass by silica fume will add roughly 20,00,000 particles to each concrete grain, so that the fine particles encompass each concrete grain, consequently densifying the framework, working on the bond with total and supporting materials, for example, glass filaments (Isaia et al 2003). The substance stage comprises of the pozzolanic response that changes the feeble calcium hydroxide gems into the solid C-S-H gel.

REVIEW OF LITERATURE

Concrete is the most normally utilized development material and its utilization in structures is in excess of three quarter of extremely old. Most recent twenty years of twentieth century saw a significant blast in the improvement in innovation of concrete as a material. The compressive strength of common concrete has expanded from 15 MPa in 1910 to 60 MPa in 2001. Also, this improvement prompted presentation of various new materials into concrete. The gainful effects of consolidating these materials in concrete are broadly talked about in writing (Guneyisi et al 2005; Hussain and Rasheeduzzafar 1994). The expansion of a wide scope of building materials of various synthetic structure has additionally brought huge variety into the concrete framework. The wide variety in the presentation of building materials might be represented to the variety in their physical, synthetic and mineralogical arrangement coming about because of the modern cycles that are additionally identified with the crude materials utilized in the creation of these materials. Besides, due to the pozzolanic response of these materials, which is frequently lethargic, mixed concrete is accounted for to have longer restoring period when contrasted with plain concrete (Manmohan and Mehta 1981).

Durekovic and Popovics (1990) in their study on interest for super plasticizer and air entraining specialist on account of mixes of customary Portland concrete with various substitution of silica fume utilized in mortar found that substitution of normal Portland concrete by dense silica fume cause the adjustment of molecule size dissemination of anhydrous mixes expanding the more modest particles, that outcome more sought after for super plasticizer and air entraining specialist. Khatri et al (1995) additionally saw that the option of silica fume diminishes the setting time yet increment the super plasticizer interest for comparable functionality. They ascribed the more popularity of super plasticizer in silica fume concrete to the fine molecule size of silica fume. The decline in setting time by the expansion of silica fume was clarified by producing into account the results of fine molecule size on the hydration interaction. The little silica fume particles fill the interface of the concrete particles and goes about as nucleation locales for the hydration and subsequently speed up the pace of concrete hydration. Comparable perceptions was made by **Mazloom et al (2004)** while leading the tests on concrete example at water-to-cover proportion of 0.35 and changing level of silica fume from 0% to 15%. They further saw that blends consolidating silica fume were more strong then the comparing blends without silica fume.

Nehdi et al (1998) examined the impact of ultrafine particles like limestone fillers, finely ground silica and silica fume when utilized exclusively as incomplete substitution of concrete on rheology of high strength concrete. Likewise, triple mixed composite concretes containing various extents of limestone filler and silica fume were additionally contemplated. A rheometer and the droop cone were utilized to quantify the rheological properties. It was tracked down that within the sight of super plasticizer, the better the miniature filler, the lower was the stream obstruction of the blend. Among the different fillers, up to 20% ground silica or limestone didn't expand the super plasticizer necessity to accomplish a consistent functionality. Silica fume, notwithstanding, expanded the super plasticizer interest at a steady usefulness. They proposed that high surface region isn't the sole boundary affecting the super plasticizer interest of silica fume blends and construed that silica fume may have a solid liking for multi-facet adsorption of super plasticizer particles. It was additionally inferred that it is feasible to configuration triple mixed composite concretes including various fillers to accomplish worked on rheological qualities.

Langan et al (1987) examined different properties of high strength concrete fusing silica fume as substitution of concrete. They saw that up to 5% substitution level, there is no increment in water interest to keep up with consistent drop of 50 mm. The water prerequisite anyway increments directly as the level of silica fume substitution increments from 10% to 30%. Also, the dose of super plasticizer needed to keep up with consistent droop increments straightly with the level of silica fume substitution level.

Duval and Kadri (1998) examined the functionality of silica fume concrete at low water-cementitious materials proportion with napthelene sulfonate super plasticizer. They saw that 10% silica fume by mass of concrete doesn't diminish concrete usefulness. Accordingly, 10% of concrete might be supplanted by silica fume without hurting the concrete usefulness. The super plasticizer measurement relies on the concrete qualities, I. e. C3A content and antacid sulfate content of concrete. It was seen that the super plasticizer dose copies when the level of C3A increment from 2% to 10%.

Ferraris et al (2001) considered the impact of six mineral admixtures on the rheology of concrete glue and found that combinations with ultra-fine fly debris addressed the best rheological improvement while silica fume addressed the most noticeably awful. It was seen that the substitution of concrete by silica fume bring about expansion in water interest and expansion in high reach water reducer dose to keep up with the rheological properties of the control. Conversely, the substitution of concrete by ultra-fine fly debris brings about decrease of the water interest and in high reach water reducer dose to keep up with similar rheological properties of the control. They presumed that if the objective is to lessen high reach water reducer dose and water-concrete proportion in a blend containing mineral admixture, the best choice is utilize ultra-fine fly debris and not silica fume. The other mineral admixtures like metakaolin, coarse fly debris, fly debris and fine fly debris gave results in the middle of silica fume and ultra-fine fly debris. They further saw that the scaled down droop and the bog cone test results couldn't be depended upon to foresee concrete rheological boundaries from concrete glue rheological boundaries. It was tracked down that small droop test results connect in specific cases with the yield pressure, however there is a wide dissipate of information. Be that as it may, no relationship was seen between the hour of stream in swamp cone and plastic consistency results.

Park et al (2005) completed work to study the rheological properties of cementitious materials containing impact heater slag, fly debris and silica fume. They saw that the yield pressure and plastic consistency increments steeply with expansion in silica fume content. They found that silica fume has exceptionally high explicit surface region and extremely fine particles which are artificially profoundly responsive and effectively adsorb super-plasticizer atoms with multi-facets. Thus, as the supplanting of common Portland concrete with silica fume builds, the amount of super plasticizer expected to keep up with required usefulness in the framework diminishes and the yield pressure and plastic thickness increments. Then again, expansion of fly debris works on the flowability of

the framework in light of the circular state of fly debris particles that diminishes the frictional powers among the precise molecule of customary Portland concrete. They likewise saw that unburnt carbon in the fly debris ingests super-plasticizer, accordingly bringing about lessening the impact of superplasticizer on better flowability of cementitious materials. Hassan et al (1997) revealed that for each 10% substitution of standard Portland concrete by fly debris in a concrete blend, the water necessity diminishes by 3% to 4%.

Roncero et al (2002) directed bog cone test and typical consistency test on glue to study the impact of silica fume on smoothness, loss of ease, immersion dose of super plasticizer and water interest at a temperature of 5ºC to 45ºC. They saw that the ease of concrete silica fume glue diminishes and immersion measurements of superplasticizer increments. Expansion of 5% silica fume (by weight of concrete) prompts critical expansion in super-plasticizer interest because of higher explicit surface space of silica fume. Expansion in temperature over the reach prompts decline in ease of concrete silica fume glue yet this is in opposition to solidify glue alone. Regardless, the immersion measurement stays unaffected by the adjustment of temperature. Gallias et al (2002) completed standard consistency test to study the impact of fine mineral admixture on water prerequisite of concrete glues for steady functionality without water diminishing admixtures. They saw that water necessity increment with explicit surface region. They additionally discovered higher water necessity for mixed blends containing mineral admixtures like silica fume.

Chatterjee et al (1982) presumed that the purposes behind the improvement of properties of the concrete examples because of expansion of silica fume are of actual nature and not due to the pozzolanic movement. Cohen et al (1994) explored various properties of mortar combinations made with either Portland concrete alone or with Portland concrete and silica fume with differing total size. They revealed that the pozzolanic activity of silica fume mortars was not as critical as the microfiller impact. Detwiler and Mehta (1989) gathered that albeit the actual making up for of shortcomings with fine silica fume particles may prompt beginning pore refinement, the resulting substance response is additionally huge. As indicated by Cohen (1990), it isn't sure with respect to whether pozzolanic or filler activity offers more to the improvement in strength and toughness of concrete.

Goldman and Bentur (1993) considered the impact of expansion of idle carbon dark as microfiller and contrasted it with the impact of expansion of silica fume on the presentation of high strength concrete in glues at water-to-fastener proportion of 0.46. The creators inferred that silica fume concrete has biggest expansion in strength. They gathered that silica fume alters the microstructure of the change zone, making it denser and more grounded, bringing about a genuine composites material where the total strength likewise adds to the concrete strength. It was likewise derived that silica fume changes the customary concrete conduct by further developing the total glue bond instead of expanding the glue strength and the microfiller impact is as significant (maybe more huge than) as the pozzolanic impact.

OBJECTIVE OF THE STUDY

1. To study the impact of silica fume and fly debris on the concrete framework as far as new properties of concrete at variable water-to-fastener proportions and mineral admixture content.

2. To set up the numerical connections between different qualities that are appropriate to a wide strength range and to the variable relieving rehearses received.

RESEARCH METHODOLOGY

Experimental section

Ongoing advancements in concrete innovation have made it conceivable to deliver concrete combinations of solidarity more prominent than the qualities indicated in the codes of training. Notwithstanding, all the time it isn't the further developed strength which is the essential target. Maybe the further developed toughness – the capacity of concrete to perform agreeably with negligible support over the expected assistance life of the construction – and generally execution is the significant objective of any turn of events. This unrest in concrete innovation has happened with the utilization of beneficial cementitious materials like fly debris, silica fume, impact heater slag and so on These property-upgrading admixtures are accepted to work on both strength and solidness of the subsequent concrete. With the coming of high reach water reducers, the opportunities for the utilization of mineral admixtures has additionally expanded.

Keeping in see the expanding utilization of these admixtures in concrete industry, the significant destinations of the study is to tentatively research the impact of silica fume and fly debris, as an incomplete substitution of concrete, on the resultant lattice as far as strength and sturdiness of coming about concrete. The examination is completed for wide scope of water-to-cover proportions and under factor relieving conditions.

Experimental parameters and their levels

The different boundaries that are taken as factors for exploring the strength and sturdiness parts of

concrete incorporate water-to-fastener proportion, presence of mineral admixtures, concrete age and restoring conditions received and forceful conditions. The premise of decision of these boundaries is examined here under.

Water-to-Binder Ratio

It was in 1918 that a defining moment occurred throughout the entire existence of concrete innovation with the 'Abrams water – concrete proportion' law (Yeh 2006). According to this law, it was recommended that the strength of a completely compacted concrete handled with explicit kind of totals at a given time of restoring and at an endorsed temperature, is reliant basically on water – concrete proportion.

Mineral Admixtures

Hydrated concrete glue contains around 70% C-S-H gel, 20% calcium hydroxide, 7% sulphoaluminate and 3 percent of auxiliary stages (Oner et al 2005). The calcium hydroxide, which is framed because of the hydration interaction, influences the nature of concrete by shaping depressions because of its high dissolvability in water and low strength. Then again, the mineral admixtures positively affect the nature of concrete as they tie with calcium hydroxide, changing it into auxiliary C-S-H gel, consequently causing the change of bigger pores into better pores because of pozzolanic response.

Curing Conditions

It is notable that the hydration of concrete and cementitious materials isn't prompt and happens throughout some stretch of time. Along these lines, age is another factor that controls both strength and sturdiness of concrete. The period of concrete is chosen as a boundary in the examination. The strength improvement examines are done at the seven relieving ages of 1 day, 3, 7, 14, 28, 56 and 90 days. The restoring age is reached out past 28 days (just like the ordinary practice) since it is realized that in mineral admixture concrete, there can be critical strength acquire over the long haul (Yogendran and Langan 1991)

DATA ANALYSIS

Strength aspects of tested concrete

Strength of concrete is considered as its most significant property since it as a rule gives a general image of nature of concrete. Besides, strength of concrete is constantly a crucial component of foundational layout and is determined for consistence purposes. The target of the initial segment of the study is to look at the impact of different boundaries on the strength advancement of mineral admixture concrete. The boundaries that are changed for the examination incorporate water-to-fastener proportion, rate substitution of mineral admixtures, restoring age, relieving systems and so forth The point is to choose the most reasonable blend as far as strength improvement, impermeability qualities and prudent angles. Alongside this, the choice of the most helpful relieving system is completed.

Effect of Water-to-Binder Ratio

It is seen from Figures 4.1 to 4.3 that with the diminishing in water-to-fastener proportion, the compressive strength increments for all blends. It is an undeniable perception according to Abrams law. To additionally assess the overall significance of pozzolanic admixtures and water-to-cover proportion, a compressive strength advancement chart of the parallel blends containing just silica fume as the pozzolanic material is attracted at all water-to-folio proportions as displayed in Fig. 4.4. It is seen from the figure that the impact of water-tobinder proportion is more articulated than the impact of expansion in the level of pozzolanic material.

Durability aspects of tested concrete

A critical designing property of concrete is its strength and protection from substance assaults. The weakening of concrete because of forceful climate is an issue of significant worry all through the world. In the event that the concrete that is affordable while considering strength viewpoints doesn't have great synthetic opposition against forceful arrangements, it causes gigantic harm in the long haul, along these lines expanding the maintenance cost of the construction. In this manner, compound opposition of concrete chooses the general economy of the framework. It decides the help life of concrete constructions altogether. Hence, the current study gives an equivalent significance to strength and solidness parts of concrete. In the initial segment, the accentuation has been laid on choosing the blend of silica fume and fly debris that gives best execution in strength advancement and furthermore on the quantity of relieving days that are vital and adequate to reach at a specific strength level. In the second piece of the study, the accentuation is on the quantity of relieving days needed for the blends to arrive at an ideal water impermeability level and the conduct of the chose blends in forceful ecological conditions. For studying the toughness of concrete, the blends that are discovered to be best in strength and water impermeability contemplates are picked and are exposed to forceful synthetic of various focuses, as portrayed.

WATER IMPERMEABILITY TEST

The profundity of water infiltration of all blends when exposed to variable restoring systems is displayed in Figs. 5.1 to 5.3 for water-to-folio

proportions of 0.45, 0.35 and 0.25 separately. The impact of different boundaries on water infiltration, and consequently porousness, is examined in the accompanying areas.

Effect of Mineral Admixtures

From Figs. 5.1 to 5.3, it tends to be seen that at all water-to-cover proportions, expansion of silica fume in the double framework constantly prompts decrease in water infiltration profundity and porousness. Among the ternary blends, water infiltration profundity is least on account of TC1 blend. Penetrability of TC1 blend (having a mix of 5% silica fume and 15% fly debris) is considerably lesser that BS1 and BS2 blend, in which silica fume is utilized as a parallel framework. It demonstrates that the better pore refinement can be accomplished by utilizing a legitimate mix of silica fume and fly debris as mineral admixtures, rather than utilizing just silica fume. The impermeability test interfaces straightforwardly with the sturdiness of concrete. It is because of the way that the division of the slender pores administers the toughness part of concrete. This perception further accentuation the significance of reasonable ternary blends, containing both silica fume and fly debris, to improve concrete as far as both strength and toughness.

Effect of Curing Regimes

The impact of relieving systems on water entrance profundity of different blends pursues the direction like the impact on strength advancement. The water infiltration profundity is most extreme noticeable all around relieved system (R2) for all the blends, affirming that air restoring is the most exceedingly terrible relieving system and ought not be followed as a development practice. Occasionally of beginning water restoring is fundamental to get solid and tough blend.

CONCLUSION

The utilization of silica fume in concrete blend has essentially expanded and upgraded the properties of the concrete whether it is in wet stage or in solidify condition. The strength and sturdiness attributes of concrete having a blend of concrete, silica fume and fly debris as solidifying material, are researched in the current study. Based on the different tests directed for assessing the presentation of blends and the numerical models created, the accompanying ends are drawn. In ternary blends, consideration of fly debris in the silica fume concrete framework helps in repaying the expanded interest of super-plasticizer, delivered because of the presence of silica fume alone, along these lines lessening the ideal level of super plasticizer needed for wanted usefulness. The increment in ideal measurement of super-plasticizers increments with decline in water-to-folio proportion. This expansion is extremely sharp when the water-to-fastener proportion is diminished from 0.35 to 0.25 when contrasted with the increment when the shift is from 0.45 to 0.35. This is credited to the way that at extremely low water fastener proportions, concrete particles are firmly stuffed, and thus to beat bury molecule contact and entomb molecule powers of fascination, higher ideal portion of super-plasticizer is required.

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Corresponding Author

Manik Deshmukh*

Assistant Professor, SVERI's College of Engineering, Pandharpur