ABSTRACT
The paper presents a review on the role of silica fumes in concrete based mainly on the experience of the author and that of his colleagues. A significant amount of work has been carried out on silica fume and its uses in concrete, both from a research and field perspective. Recently there has been a great demand for high quality concrete and concrete structures with high performance. In this context, silica fume is one of the most remarkable mineral admixtures that can give high workability, strength and durability. However, it is unclear as to type of form silica fume take in concrete, mortar and cement paste. Some researchers point out that silica fume may be in high agglomeration. Therefore, it is very important to disperse silica fume in concrete effectively to get high performance concrete. Consequently, this paper deals with the effect of physical and chemical treatment of silica fumes on properties of cement mortar.

Key words: Silica fume, concrete, agglomeration, workability, strength, durability.

Introduction
The first testing of silica fume in Portland cement-based concrete was carried out in 1952. The American Concrete Institute defines silica fume as “Very fine non crystalline silica produced in electric arc furnaces of the production of elemental silicon or alloys containing silicon”. It is usually a gray colored powder, somewhat similar to portland cement or some fly ashes. Silica fume is a byproduct of smelting process in the silicon and ferrosilicon industry [2]. In recent years significant attention has been given in research application to the use of condensed silica fume as concrete property-enhancing material partial replacement for portland cement. The initial interest in the use of condensed silica fume was mainly caused by the strict enforcement of air pollution control measures in various countries to stop release of material into the atmosphere. It is also known as micro silica, condensed silica fume, volatilzed silica or silica dust. These metals are used in many industrial application to include aluminium and steel production, computer chip fabrication and production of silicones, which used in lubricants and sealants. Silica fume consists of very fine vitreous particle with a minimum surface area is 15000 m^2/kg. The mean particle size of silica fume is between 0.1 and 0.2 micron. Its particle are approximately 100 times smaller than the average cement particles. Because of its extreme fineness and high silica content, silica fume is a highly effective pozzolanic material. Silica fume is used in cement to improve its properties.
Applications of Silica fume

- High performance concrete containing silica fume for high way bridges, parking decks, marine structures.
- It is used to construct a New TJ ORN bridge in Sweeden which having the high strength, workability, durability and free form any deformation and cracks.
- Grinders using Silica fume concrete
- It is mostly used in high rise structures to increase the life time of the strcture without any effects.
- It is most widely used in important structure which had a high strength when compared with another [4].

Properties of Silica Fume

Silica fume particles are extremely small, with more than 80% of the particles finer than 1 micron. Silica fume is composed primarily of pure silica in non crystalline form. Silica fume has a very high content of amorphous primarily of pure silica in non-crystalline form. Silica fume has a very high content of amorphous silico dioxide and consists of very fine spherical particles

Chemical Properties

Amorphous: This term simply means that silica fume is not crystalline material. A crystalline material will not dissolve in concrete, which must occur before the material can react. Don’t forget that there is a crystalline material in concrete that is chemically similar to silica fume. That material is sand.

- Silicon Dioxide: This is the reactive material in silica fume.
- Trace elements: there may be additional materials in silica fume based upon the material being produced in the smelter from which the fume was recovered. Usually these materials have no impact on the performance of silica fume in concrete.[5]

Physical Properties

Colour: Most silica fumes range from light to dark grey in colour. Because SiO2 is colourless, the colour is determined by the nonsilica components, which typically include carbon and iron oxide. In general, the higher the carbon content of silica fume is affected by many factors relating to the manufacturing process. The degree of compaction may also affect the colour.

Density: The specific gravity of silica fume is approximately 2.2 as compared to about 3100 kg/m³ for normal portland cement. However, the density of silica fume may exceed 2200kg/m³. Variation in density are attributed to the non silica components of the various silica fumes.

Bulk Density: This is just another term for unit weight. The bulk density of the as produced fume depends upon the metal being made in the furnace and upon how the furnace is operated. Because the bulk density of the as-produced silica fume is usually very low, it is not very economical to transport it for long distances.[6]

Fineness: Silica fume consists primarily of very fine smooth spherical glassy particles with a surface of approximately 20000m²/kg when measured by the nitrogen-adsorption method. The extreme fineness of silica fume is best illustrated by the following comparison with other fine materials.

<table>
<thead>
<tr>
<th>Material</th>
<th>Surface Area (m²/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica Fume</td>
<td>13-30 km²/kg</td>
</tr>
<tr>
<td>Fly ash</td>
<td>400 to 700 m²/kg</td>
</tr>
<tr>
<td>Portland Cement</td>
<td>300 to 400 m²/kg</td>
</tr>
</tbody>
</table>

Particle Shape and size: The particle Size distribution of a typical silica fume shows most particle to be smaller than one micrometer with an average diameter of about 0.1μm. This is approximately 1/100 of an average cement particle. The particle size distribution of silica fume may vary depending upon the fume type and furnace gas exhaust temperature. The particle shape of silica fume is spherical in shape.[7]

Reaction of silica fume

Because of its extreme fineness and very high amorphous silicon dioxide content, silica fume is a very reactive pozzolan material. Mechanism of silica fume in concrete can be studied basically under three roles: pore-size refinement and matrix densification. Reaction with free-lime. Characteristics of the transition zone between the aggregate particles and cement paste plays a significant role in the cement-aggregate bond. Silica fume addition influences the thickness phase in mortars and the degree of the orientation of the CH crystals in it. The thickness compared with mortar containing only Ordinary Portland Cement decreases and reduction in degree of orientation of CH crystals in transition phase with the addition of silica fume. Hence mechanical properties and durability is improved because of the enhancement in interfacial or bond strength. Mechanism behind is not only connected to chemical formation of C-S-H at interface, but also to the microstructure modification as well. [8]

Effects of silica fumes on properties of fresh concrete

Water Cement Ratio: The water demand of concrete containing silica fume increases with increasing amount of silica fume. This increase caused primarily by the high surface area of the silica fume. To achieve a maximum improvement in strength and durability.
Workability: Fresh concrete containing silica fume is more cohesive and less prone to segregation than concrete without silica fume. As the silica fume content is increased, the concrete becomes sticky.

Slump loss: The presence of silica fume by itself will not significantly change the rate of slump loss of a given concrete mixture. However, since silica fume is typically used in conjunction with water reducing admixtures, different chemical admixtures produce differing rates of slump loss.

Time of setting: Silica fume concrete usually includes chemical admixtures that may affect the time of setting of the concrete. Experience indicates that the time of setting is not significantly affected by the use of silica fume by itself.

segregation: Concrete containing silica fume normally does not segregate appreciably because of the fineness of the silica fume and the use of HRWRA. Segregation may occur in many types of concrete with excessive slump, improper proportioning, improper handling. The use of silica fume will not overcome poor handling or consolidation practices.

Bleeding: Concrete containing silica fume shows significantly reduced bleeding. This effect is caused primarily by the high surface area of the silica fume to be wetted; there is very little free water left in the mixture for bleeding.

Plastic shrinkage: Plastic shrinkage cracks generally occur when the water evaporation rate from the concrete surface exceeds the rate at which water appears at the surface due to bleeding or when water is lost into the subgrade. Since silica fume concrete exhibits significantly reduced bleeding.

Air entrainment: The dosage of air entraining admixture to produce a required volume of air in concrete usually increases with increasing amounts of silica fume due to the very high surface of silica fume and to the effect of carbon when the latter is present.

Unit weight of fresh concrete: The use of silica fume will not significantly change the unit weight of concrete. Any changes in unit weight are the result of other changes in concrete proportions made to accommodate the use of the silica fume. [9]

Properties of hardened concrete

Compressive strength: Mortar with 30% of silica fume gives maximum strength than the cement paste for the same water cement ratio. The addition of silica fume to mortar results in improved bond between the hydrated cement matrix and sand in the mix.

The strength of plain cement paste is greater than the strength the mortar. Thses are two reasons:
1) Work interfacial zone between cement paste and aggregates
2) Heterogeneous micro-structure of mortar.

When we add small amount of silica fume in concrete no significant change in strength is observed. When the quantity reaches 10% significant changes is observed.

Effects to the compressive strength of concrete

Spilt Tensile Strength: No significant change in spilt tensile strength can be observed with minor silica fume is added but when large amount is added then it reduces.

Bond strength: 15% replacement of cement with silica fume result in significant improvement in bond strength.

Durability: When we add small amount of silica fume in concrete decreases in durability. Specific resistance: Increases in the volume of cement paste in the concrete due to chemical reaction but produce by hydration of cement and solution sulphate. Reason of Silica fume presents Sulphate attack:
- Fineness make concrete impermiable and hepls resisting sulphate attack.
- Modification of the chemistry of the system result in formation of mono-sulphate resulting in significant expansion.

Permeability: When we add small amount of silica fume in concrete resulting less Permeability: Less permeability causes:
- No bleeding
- No plastic Shrinkage
- Increases in the requirment of air entraining admixtures
- High corrosion resistance
- Reduction in segregation

Modulus of Elasticity: The modulus of elasticity of silica fume concrete up to the age of 365 days. It can be seen that elastic modulus of the portland Cemeny Concrete was approximately equal to silica fume concrete at 28 days but continued to increse at later ages. [10]

Creep and Shrinkage: According to sellevold the inclusion of silica fume at high replacement levels
silica fume admixture products. The use of silica fume in blended cement has also attracted interest. Aitcin reported that one Canadian cement manufacturer has been making a blended cement since 1982. At present, several Canadian cement companies are selling blended cement containing 7 to 8 percent silica fume. The properties of cement containing silica fume as a blending material may be expected to be the same as if the silica fume were added separately. As with any blended cement, there will be loss in flexibility in mixture proportioning with respect to the exact amount of silica fume in a given concrete mixture.[13]

Working with silica fume in field concrete

Transporting and handling silica fume and silica fume admixture products
Handling procedures for silica-fume materials depend on the form of the product being used either dry or slurry. Within these two general product forms, silica fume can be provided with or without chemical admixtures. Because silica fume products are available in dry bulk, dry super sack, dry paper sack, liquid bulk, and liquid drums, the material handling systems and the equipment used in transportation, discharge, storage, batching, and mixing of the silica fume depend on the specific product form. Transportation of silica fume depends on the product form and, consequently, the economics of transportation and material handling are determined by the product’s weight (mass), density, available handling equipment, and applicable regulations.

Producing concrete
Dry silica fume
Producing silica-fume concrete with bulk dry densified material is very similar to producing ordinary concrete with other bulk mineral admixtures such as fly ash or slag. The bulk densified material is handled by normal cement storage and internal conveying and weighing equipment along with ordinary admixture dispensing, concrete batching, and mixing equipment. Dry silica fume weigh batching is usually accomplished by discharging silica fume into the cement weigh hopper on top of the cement after the cement weighing is completed. Silica-fume concrete using dry densified silica fume has been successfully prepared in both dry-batch and central-mixing concrete plants.

Slurred silica fume
At the concrete production plant, the slurry products are typically stored in steel or fiberglass 2000 to 6000 gal. (7500 to 23,000 L) tanks. These tanks usually have recirculation, mechanical agitation capability, or both, that are used intermittently as required to liquefy the material for dispensing. Typically, the slurry is pumped from the storage tank through a flow meter and a hose into the mixer or into the water weigh hopper. Some systems dispense the slurry by mass, but volumetric dispensers are more commonly used. Slurry silica fume products have been mixed successfully in various kinds of mixers, including truck mixers, central mixers (both drum and pan mixers), mortar mixers. [14]

Mixing silica fume concrete
To produce consistent silica-fume concrete, it is important that the mixing equipment be in good condition. Mixing time may need to be increased, and the volume of concrete mixed in truck mixers in particular may need to be decreased somewhat to achieve good concrete uniformity when using high dosages of silica fume with low-water-content concrete. The amount of increased mixing is generally higher for densified silica fume to achieve proper dispersion.

Transporting
Silica-fume concrete has been successfully transported and placed using the most commonly available concrete equipment and methods. Typically, there is no requirement to modify
transportation and placing equipment or procedures. [15]

Placing

It is absolutely essential to adhere to good concrete placement practices as outlined to achieve a high level of concrete performance. Before placing silica-fume concrete, the contractor should be prepared. Adequate manpower, backup equipment (vibrators, vibratory screeds, and power sprayers), and the proper curing materials should all be on hand. Generally, with silica-fume concrete, the placing, finishing, and curing procedures should all be performed in a continuous operation. Silica-fume concrete should be placed at the highest practical slump that is suitable for the placing conditions. Because silica-fume concrete is much more cohesive, it should be specified with a slump that is 1 to 2 in. (25 to 50 mm) higher than normally allowed (Holland 1989). Silica-fume concrete is very cohesive and resists segregation at high slumps. Although silica-fume concrete flows well, vibration is needed for good consolidation, even at high slumps. The use of a vibratory screed is recommended when placing slabs and concrete overlays. Proper vibration will also help finishing by bringing fines to the surface of the slab. The use of a vibratory screed on slabs and concrete overlays are recommended.

Finishing

The addition of silica fume to concrete will increase cohesiveness and reduce bleeding, thereby altering the finish ability and the finishing operations required. As the amount of silica fume in the concrete increases, so will the effect of the silica fume on finishing. The absence of bleed water and the stickiness of concrete with high silica fume dosages (10 to 20%) makes screening and trowelling slab surfaces more difficult than for ordinary concrete.

The best way to establish exact finishing methods for any particular project (especially for large-scale flatwork) is to stage small, trial placements before the start of the actual work. These trials can be repeated until the best methods for a given project and its specified mixture proportions are identified. [16]

Conclusion

Results indicated general superior performance of silica-fume concrete and mortar with 1:1 cement replacement, compared to respective control concrete and mortar that incorporates type I cement and the same mix proportions. The silica fume presented herein as a mineral admixture is employed to produce concrete of special characteristics or to produce less expensive concrete of comparable characteristics, as silica fume is less expensive than cement. On the basis of the experimental results of this research, the following main conclusions are inferred. Test results have clearly shown significantly better performance of concrete containing silica fume as 1:1 replacement of cement. It is important to note that the graphs are plotted to different scales. The effect of silica fume is more noticeable for the 28-day curing period than for the 7-day period. On the other hand, the effect of curing period was not as significant for the control mix. Longer curing allows the Pozzolanic activity to develop, leading to the significant performance improvement. The variation in electric current was not consistent. Therefore, maximum or high values of current, or electric resistivity, alone will not be a sufficient qualitative indicator of the concrete performance. The time to crack, has given a better indication. It increased for concrete with higher resistance to corrosion damages when comparison was done within each test group.

- Due to its fineness and high amorphous silicon dioxide content, silica fume is a very reactive pozzolanic material. Silica fume influences the thickness of transition phase in mortars and the degree of the orientation of the CH crystals.
- Addition of silica fume accelerates the hydration of cement at all stages of hydration. The pozzolanic action of silica fume seems to be very active at early hours of hydration.
- Addition of silica fume results in significant reduction in the chloride-ion diffusion. This could be attributed to have been caused by addition of silica fume cause considerable pore refinement i.e. transformation of bigger pores into smaller one due to their pozzolanic reaction concurrent with cement hydration.
- Silica fume improves the long-term corrosion resistance, alkali silica expansion, but increases the carbonation depth.

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