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Study on durability properties of silica fume in concrete – A Review

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ABSTRACT

This review paper contains the assemblage of various data for improving the mechanical and durability properties of concrete by partial replacement of cement by Silica Fume. Silica Fume is a by-product obtained from silicon alloy factories which may improve the mechanical and durability properties of concrete. Studies show that Silica Fume is non-hazardous and non-metallic material having extreme fineness and high silica content which is a very effective pozzolanic material that suits for concrete mix. The durability properties of concrete play an important role in defining the life time of concrete structures subjected to various environments. The optimum replacement of Silica Fume in concrete is found by study on mechanical properties of concrete with various replacements. The study confirms the optimum replacement of Silica Fume in concrete as 10%. This paper also represents the durability tests on concrete such as acid resistance, sulphate attack, carbonation, water absorption, sorptivity and rapid chloride permeability test. These durability test results indicate the quality of concrete.

Keywords: By-product, durability properties, extreme fineness, mechanical properties, Silica Fume.

INTRODUCTION

Most commonly used building material is concrete which contains cement, fine aggregate, coarse aggregate and water. In recent days, many alternative materials are used in concrete instead of usual mixing materials. The alternate material found may be industrial waste or by-product from industries using minerals as their raw material. Cement is an artificial material used as a binder in concrete. The major components in cement are Lime, Silica, Alumina, Iron and Magnesium. The manufacturing process of cement emits large amount of CO₂ which is a green house gas causing various of environmental effects. To reduce these environmental effects, cement is totally or partially replaced by pozzolanic material. One of such pozzolanic material is Silica Fume.

Silica Fume is obtained as a by-product resulting from reduction of high purity quartz with coal in an electric arc furnace in the production of silicon alloys such as ferro-

chromium, calcium silicon, ferro-manganese, etc. Dumping of this in environment can cause environmental pollution and health hazard. One of the most beneficial use of Silica Fume is using it in concrete instead of cement. Due to its extreme fineness and high silica content it can be effectively replaced for cement. Silica Fume is also referred as micro silica, silica dust or condensed silica fume. The particle size of Silica Fume is 2 times finer, when compared to cement. Since Silica Fume has large surface area, it gets packed in a denser manner in the paste of cement and aggregate which reduces the wall effect in the transition zone between the paste and aggregate.

Silica Fume contains more than 90% of silicon dioxide (SiO₂) and the other composition of Silica Fume are sulphur, carbon and oxides of aluminium, calcium, magnesium, iron, potassium and sodium. The diameter of Silica Fume is between 0.1 micron and 0.2 micron. Its density varies from 150 to 700 kg/m³ and surface area

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ranges between 20,000-30,000 m²/kg. Use of Silica Fume does not influence on the weight of concrete. Addition of optimum percentage of Silica Fume increases the strength and durability properties of concrete.

LITERATURE REVIEW

Dilip Kumar Singha Roy and Amitava Sil [1] experimented on the effect of partial replacement of cement by Silica Fume on hardened concrete on various percentages from 0 to 10 percentage in M₂₀ grade of concrete. This experiment concluded that while Silica Fume is replaced in concrete for cement by 10%, the mechanical properties of Silica Fume concrete is increased when compared to normal concrete and also results show that the strength of M₂₅ grade of concrete is achieved by using the M₂₀ grade design mix proportion with cost reduction of 4%. Silica Fume concrete is more compact and durable in nature and hence with particular degree of quality control, the concrete may be used in places of construction where there are chances of chemical attack, frost action, etc.

Akshay Suryavanshi et. al. [2] investigated and experimented on partial replacement of cement in concrete by Silica Fume on various grades of concrete of M₂₀, M₂₅ and M₃₀ with addition of Silica Fume in different percentages ranges from 2.5% to 30% which varies within 2.5%. Various tests such as compression test, flexural test and split tensile test have been conducted at 7, 14 and 28 days of curing to determine the mechanical properties of the concrete. From the results they concluded that Silica Fume is a superior replacement of cement whereas the workability of concrete decreases as the proportion of Silica Fume increases and also the maximum compressive strength, split tensile strength and flexural strength were obtained at 10% replacement of Silica Fume in concrete.

Prof. Vishal S. Ghutke and Prof. Pranita S. Bhandari [3] studied the influence of Silica Fume on concrete of grade M₂₀ with replacement of Silica Fume in various percentages ranges from 0% to 25% and with varying water cement ratio. The results obtained from the various tests to determine mechanical strength of the concrete shows that increase in water cement ratio will decrease the strength of concrete and also the workability of concrete decreases as increase in percentage of Silica Fume content. The tests on

compressive strength of the concrete gives the optimum value of Silica Fume replacement as 10% - 15% as the strength of concrete decreases when the percentage is more than 15%.

Md Athar Kazmi et. al. [4] investigated on Micro Silica as partial replacement of cement in concrete of grade M₅₀ with water cement ratio of 0.38. The casted cubes were tested for their compressive strength for 7, 14 and 28 days with replacement of cement by Silica Fume in different percentage from 0% to 10% which varies in the range of 2.5%. The tests for mechanical properties of concrete show that the optimum replacement of Silica Fume is about 10% and the usage of Silica Fume decreases the voids in concrete. Results concluded that 5% - 10% replacement of Silica Fume in concrete will develop strength sufficient for construction purposes. The addition of optimum amount of Silica Fume in concrete has a marginal influence on the density of concrete.

Lakshbir Singh et. al. [5] studied on partial replacement of cement by Silica Fume with design mix for grade M₃₀. Silica Fume is replaced from 0% to 10% of cement by weight at the increment of 5% for both cube and cylinder. After casting the specimens, the specimens are subjected to curing upto 28 days. Tests are conducted to determine the compressive strength and split tensile strength of concrete. By adding 10% of Silica Fume, there is large amount of increase in mechanical strength in concrete after 7, 14 and 28 days respectively. Therefore, the compressive strength and split tensile strength of concrete tends to increase with increase in percentage of Silica Fume in the mix and decreases after 10% replacement.

N. K. Amudhavalli and Jeena Mathew [6] analyzed on the effect of Silica Fume on strength and durability parameters of concrete. The mix design was done based on I.S 10262-1982 for M₃₅ grade of concrete. The results concluded that the normal consistency increases about 40% when Silica Fume percentage increases from 0% to 20%. The optimum 7 and 28 days compressive strength and flexural strength have obtained in the range of 10% to 15% of Silica Fume replacement. The optimum value for split tensile strength is 10% whereas the flexural tensile strength increases up to 15% replacement of Silica Fume. To find the durability parameter acid resistance is conducted in which the loss in

weight and compressive strength percentages were found to be reduced by 2.23 and 7.69 when the cement was replaced by 10% of Silica Fume when compared to other mix.

Hiren Patel et. al. [7] performed the characteristics strength test on M₃₀ grade of concrete and on micro concrete. The cubes are taken for curing in water for 28 days and after that cubes are immersed in 5% H₂SO₄ and 5% HCl of the total volume of water for separate 28 days and 56 days to evaluate the decrement in the strength as compared to normal condition. After 28 days curing in chemical, the compressive strength of M₃₀ grade of concrete and micro concrete are 32.7 N/mm² and 45.26 N/mm² in HCl respectively and 30.98 N/mm² and 41.94 N/mm² in H₂SO₄ respectively. After 56 days curing in chemical, the compressive strength of M₃₀ grade of concrete and micro concrete seems to be reduced in certain percentage. It is noted that the compressive strength is reduced slightly more at immersing in H₂SO₄ as compared to HCl which shows that the action of H₂SO₄ is more on concrete when compared to HCl.

Dhyaneshwaran. S et. al. [8] investigated on durability characteristics of self compacting concrete with Fly Ash. The mix design was prepared with the addition of super plasticizer, Glenium B233 and the viscosity modifying agent, Glenium Stream 2. Studies shows that workability increases with increase in super plasticizer dosage. A small change in viscosity modifying agent may result in substantial change in properties of concrete. So, the dosage of viscosity modifying agent must be designed properly. The increase in replacement level of Fly Ash has resulted in strength of the concrete. So, the optimum replacement of Fly Ash is found to be 30% for flowability, mechanical properties and durability study. The acid resistance at the age of 28, 56, 90 days for concrete is higher in Fly Ash replaced concrete when compared with normal concrete. When the specimen is immersed in sodium sulphate solution, the average reduction in weight is decreased with increase in Fly Ash content in concrete. Water absorption test results that the water absorption level is low for 30% replacement of Fly Ash which is a good indicator of limited open porosity which could inhibit high flow of water into the concrete.

Er. Magudeaswaran. P and Dr. Eswaramoethi. P [9] experimented on durability characteristics of high performance concrete where cement is partially replaced by Fly Ash (FA) and Silica Fume (SF) in different percentages such as 25% FA & 12.5% SF, 30% FA & 15% SF and 35% FA & 17.5% SF with the addition of super plasticizer named CONPLAST SP 430. The result conclude that the strength and durability characteristics of the concrete is increased by using admixtures. Compression strength is increased by 31.6% for 35% & 17.5% of Fly Ash and Silica Fume. Flexural strength of concrete is increased by 24.46% when Fly ash and Silica Fume is replaced by 35% & 17.5% respectively. The pH value of the concrete decreases by 5.47% and the water absorption rate is reduced by 0.24% with the addition of admixtures.

RM. Senthamarai et. al. [10] performed a study on durability properties of concrete made from ceramic industry waste with different water cement ratio. The recycled aggregate concrete possess higher permeation characteristics values when compared with conventional concrete. The permeation characteristics like water absorption, volume of voids, rapid chloride permeability test and sorptivity values decreases with decrease in water-cement ratio for both coarse aggregate concrete and ceramic electrical insulator replaced concrete. The factors controlling permeation characteristics of concrete materials are relative volume of paste, the pore structure of the concrete and the interfacial transition zone around the aggregate particle. Number of studies show that the rougher the aggregate surface the better the bonding in the concrete. From the results it is concluded that the permeation characteristic values increase as water cement ratio increases both for ceramic electrical insulator waste concrete and conventional concrete.

Pazhani. K and Jeyaraj. R [11] experimented on durability of high performance concrete with industrial wastes where the durability properties include water absorption and chloride penetration. The experiment is done by replacing cement by ground granulated blast furnace slag (GGBS) and fine aggregate is replaced by copper slag in various proportions. The value of slump increases by 60mm to 85mm when fine aggregate is replaced by copper slag

for 100% which shows that copper slag consumes less water when compared to river sand. When GGBS is replaced for cement by 30% water absorption is decreased by 4.58% and when copper slag is replaced by 100% the water absorption decreases by 33.59%. The chloride iron penetrability decreases by 29.90% when GGBS is replaced by 30% for cement and the chloride penetrability decreases by 77.32% when copper slag is replaced by 100% for fine aggregate. The pH value for 30% replacement of cement by GGBS decreases by 0.39% and the pH value for 100% replacement of fine aggregate with copper slag decreases by 3.04%. The results show that the optimum value for GGBS replacement is 30% and for copper slag replacement is 100%.

Roshni. K. G and Vineeth. P. C [12] studied on strength and durability properties of concrete containing foundry sand and ground granulated blast furnace slag (GGBS) where quarry sand was replaced by 0, 15, 25, 35 and 45% and cement was replaced by 0, 30 and 50%. Strength tests such as compressive strength, split tensile strength and durability properties such as sulphate attack and water absorption tests were to be performed on the concrete specimens. As comparing with other mixes the mix with 30% replaced GGBS gives a good result due to good packing of materials which indicates the pozzolanic properties of GGBS which provide strength to the mix. The mix is safe against water absorption and was good resistance to sulphate attack than control mix. So these material mixes can be used effectively in highly sulphate regions. Addition of increases in percentage of GGBS increases the value of carbonation, this may happen due to chemical properties of

GGBS. So, addition of GGBS is only upto a limit. From the results it is concluded that replacing of fine aggregate with foundry sand is possible upto 35% when GGBS is replaced for cement upto 30% and without GGBS fine aggregate is replaced only upto 25%.

CONCLUSION

The review paper regarding partial replacement of cement by Silica Fume in concrete concludes that the optimum value of Silica Fume to be replaced in concrete as 10%. During this replacement significant change is observed in the strength properties of concrete such as compressive strength, flexural strength and split tensile strength. The study shows that replacement of cement by Silica Fume in concrete increases mechanical properties as well as durability parameters of concrete structures. It is also observed that increase in workability decreases the compressive strength of the concrete. Variation of water cement ratio also has an impact on the compressive strength of concrete. Addition of Silica Fume in correct proportion results in improvement of durability attack by acidic waters and improves the condition of concrete. Extreme fineness of Silica Fume leads to high normal consistency. With the results obtained from the study on durability properties of concrete shows that life time of concrete can be increased with the addition of admixtures in the concrete. The different durability tests conducted on concrete gives the quality of concrete structures to withstand weathering action, chemical attack, abrasion or any other process of deterioration while maintaining its desired engineering properties.

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