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The Analysis of Impact of Silica Fume on Fresh Properties of Concrete

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Abstract

This paper reveals The effect of using silica fume as partial replacement of cement. The ordinary Portland cement is one of the main ingredients used for the production of cement involves emissions of large amounts of carbon dioxide gas into the atmosphere a major contributor for green house effect and global warming hence it is inevitable either to search for another material or partly replace it by some other material. The search for any such material which can be used as an alternative or as a supplementary for cement should lead to sustainable development. Silica fume is the materials which take place the cement replacing material .silica fume is waste material which is obtained from the manufacturing process of silicon or ferrosilicon alloy. the compressive tensile and flexural strength of concrete can be determined by using silica as cement replacement material in different proportions .the use of silica fume in combination with a super plasticizer is most commonly used to obtain high strength of concrete in these days.

Keywords: Silica Fume, Split Tensile Strength, Compressive Strength, Flexural Strength

Introduction

A number of studies are going on in India as well as abroad to study the impact of use of these pozzolanic materials as cement replacements and the results are encouraging. Addition of silica fume to concrete has many advantages like high strength, durability and reduction in cement production. The optimum silica fumes replacement percentage for obtaining maximum 28- day's strength of concrete ranged from 10% to 20%. When pozzolanic materials are incorporated to concrete, the Silica present in these materials reacts 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 .

Concrete is a widely used construction material for various types of structures due to its structural stability and strength. The usage, behavior as well as the durability of concrete structures, built during the last first half of the century with ordinary Portland cement (opc) and plain round bars of mild steel, the ease of procuring the constituent materials (whatever may be their qualities) of concrete and the knowledge that almost any combination of the constituents leads to a mass of concrete have bred contempt. Strength was stressed without a thought on the durability of structures. As a consequence of the liberties taken, the durability of concrete and concrete structures is on a southward journey; a journey that seems to have gained momentum on its path to self–destruction. The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact. Substantial energy and cost savings can result when industrial by products are used as a partial replacement of cement. Fly ash, ground granulated blast furnace slag, rice husk ash, high reactive met kaolin, silica fume are some of the pozzolanic materials which can be used in concrete as partial replacement of cement.

Aims & Objectives

The use of silica fume in combination with a super plasticizer is most commonly used to obtain high strength of concrete in these days. The uses of silica fume in the concrete have attracted the attention of researchers throughout the world. According to the guidelines of the previous work and need for further research to explore the ever expanding field of silica fume concrete, the following are the objectives of using silica fume in concrete:

1. To study the effect of silica fume in concrete when mix design almost fix.
2. To determine the maximum range of water cement ratio used when cement is replaced by silica fume.
3. To determine the maximum percentage of cement replaced with silica fume.
4. To study the concrete properties which occur due to the replacement of cement with silica fume as the mix design remain almost constant.
5. To determine the effect of micro silica on the compressive, tensile, and flexural strength of concrete.
6. To study the rate of evolution of strength and percentage gains with respect to control concrete.

Literature Review

N. K. Amudhavalli, Jeena Mathew (2012)

The main parameter investigated in this study is M35 Grade concrete with partial replacement of cement by silica fume by 0, 5, 10, 15 and by 20% [14]. This paper presents a detailed experimental study on Compressive strength, split tensile strength, flexural strength at age of 7 and 28 day. Durability study on acid attack was also studied and percentage of weight loss is compared with normal concrete. Test results indicate that use of Silica fume in concrete has improved the performance of concrete in strength as well as in durability aspect.

Faseyemi Victor Ajileye (2012)

Now a day, we need to look at a way to reduce the cost of building materials, particularly cement is currently so high that only rich people and governments can afford meaningful construction. Studies have been carried out to investigate the possibility of utilizing a broad range of materials as partial replacement materials for cement in the production of concrete [15].

Silica Based Concrete

Considerable progress has been achieved in the design and use of structural light weight concretes, which have the dual advantage of reduced density coupled with increased thermal insulation. With the present state of knowledge in the field of concrete mix design, it is possible to select and design concrete capable of resisting heat, sea water, frost and chemical attack arising out of industrial effluents. When the concrete was first adopted as a structural material during the nineteenth century, compressive strength was perhaps the only criterion in the proportioning of a concrete mix. High strength concrete refers to concrete that has a uniaxial compressive strength greater than the normal strength concrete obtained in a particular region. High strength and high performance concrete are being widely used throughout the globe and in the production of these concretes it is necessary to reduce the water/binder ratio with the subsequent increase in the binder content. High strength concrete refers to good abrasion, impact and cavitation resistance. The deterioration and premature failure of concrete structures such as marine structures, concrete bridge deck etc. Has lead to the development of high performance concrete. The high performance concrete is defined as the high-tech concrete whose properties have been altered to satisfy specific engineering properties such as high workability, very high strength, high toughness and high durability to severe exposure condition. Nowadays silica fume is almost invariably used in the production of High Performance Concretes. Silica fume (SF) is a byproduct of the smelting process in the silicon and ferrosilicon industry. The reduction of high-purity quartz to silicon at temperatures up to 2000 °c produces Sio_2 vapors, which oxidizes and condense in the low temperature zone to tiny particles consisting of non-crystalline silica. By-products of the production of silicon metal and the ferrosilicon alloys having silicon contents of 75% or more contain 85–95% non-crystalline silica. The by-product of the production of ferrosilicon alloy having 50% silicon has much lower silica content and is less pozzolanic. Therefore, Sio_2 content of the silica fume is related to the type of alloy being produced.

FigureNo.-4: Testing for cylinder

Silica fume is also known as micro silica, condensed silica fume, volatilized silica or silica dust. The American concrete institute (ACI) defines silica fume as a ''very fine non crystalline silica produced in electric arc furnaces as a byproduct of production of elemental silicon or alloys containing silicon''. It is usually a grey colored powder, somewhat similar to Portland cement or some fly ashes. It can exhibit both pozzolanic and cementations properties. Silica fume has been recognized as a pozzolanic admixture that is effective in enhancing the mechanical properties to a great extent. By using silica fume along with super plasticizers, it is relatively easier to obtain compressive strengths of order of 100–150 mpa in laboratory. Addition of silica fume to concrete improves the durability of concrete through reduction in the permeability, refined pore structure, leading to a reduction in the diffusion of harmful ions, reduces calcium hydroxide content which results in a higher resistance to sulphate attack. Improvement in durability will also improve the ability of silica fume concrete in protecting the embedded steel from corrosion.

Fig. No.-1: Corresponding Author – Dr. Arvind Dewangan, During Performing of Sample Test in the Concrete Lab in Haryana College of Technology & Management, Kaithal (2014)

Effect of Silica Fume on Fresh Properties of Concrete

Fresh concrete containing silica fume is more cohesive and less prone to segregation than concrete without silica fume. Concrete containing silica fume shows substantial reduced bleeding. Additionally silica fume reduces bleeding by physically blocking the pores in the fresh concrete. Use of silica fume does not significantly change the unit weight of concrete.

Consistency

Rao (2003) determined the influence of silica fume on the consistency of cement pastes and mortars. Specific gravity and specific surface of the silica fume were 2.05 and 16,000 m^2/kg, respectively. Silica fume was varied from 0 to 30% at a constant increment of 2.5/5% by weight of cement. Since the SF is finer than the cement, the specific surface increased with increase in SF content. The standard consistency of pure cement paste was found out to be 31.50%; while at 30% SF, it was 44.25%. It was observed that the consistency of cement increased with the increase in SF content. As much as 40% of additional water requirement was observed for cement pastes containing 20–30% SF. Fig. 2, shows the variation of consistency of cement at different silica fume contents which is following as:

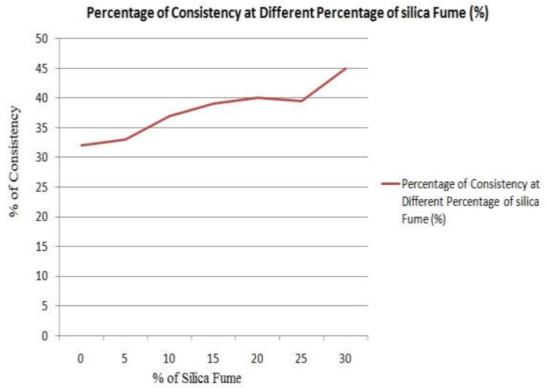

Figure No.-2 Variation of Consistency of Cement PasteC Different % of Silica Fume

Setting Times

Alshamsi et al. (1993) reported that addition of micro-silica lengthened the setting time of Pastes. This was expected since micro-silica replaces part of the OPC, reducing the early Stiffening potential. While the addition of micro-silica (10%) had little effect on setting times, higher percentages produced significant influences. There was 6–20% increase in setting Times when OPC was replaced with 20% micro-silica. Lohtia and Joshi (1996) concluded that the addition of silica fume to concrete in the absence Of water-reducer or super plasticizer causes delay in setting time, compared to non-silica Fume concrete of equal strength, especially when the silica fume content was high. The Additions of 5 - 10% silica fume to either super plasticized or non-super plasticized concrete With W/C (SF) ratio of 0.40 did not exhibit any significant increase in setting time. However, When 15% silica fume was added with super plasticizer, both the initial and final setting times were delayed by approximately 1 and 2 h, respectively. The observed delay was attributed to the relatively high dose of super plasticizers needed for the high amount of silica fume added to concrete.

Work Ability

Sellevold et al. (1983) reported that there is net decrease in water requirements in concretes containing high concentration of silica fume and water-reducer or super plasticizers. The addition of water-reducer or a super plasticizer causes the dispersion of cement and silica fume particles and reduces the concentration of contact points between the different grains; resulting in less water requirement to achieve a given consistency.

Khayat and Aitcin (1993) reported that addition of 10% silica fume in a lean concrete (100 kg/m^3) of cement reduced the water demand. However, it exhibited poor durability against freeze–thaw attack. In normal structure concrete, even with 5% silica fume addition, the water demand is increased to maintain constant slump. For producing very high strength and durable concrete, silica fume up to 10% is added as an admixture and use of super-plasticizer to maintain specified slump is found necessary. When no plasticizers are used an additional l/m^3 of water should be used for every 1 kg/m^3 of silica fume addition to maintain constant level of fluidity.Wong and Razak (2005) studied the cementing efficiency factor (k) of silica fume. Specific gravity of silica fume was 2.22.

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Three water-to-cementitious material ratios (w/cm) of 0.27, 0.30 and 0.33 were used in concrete mixtures. At each w/c ratio, cement was replaced with 0, 5, 10, and 15% silica fume. Slump and Vebe time results are shown in Table1. It could be seen from this table that mixtures achieved slump values ranging from 30 to 260 mm, while Vebe time was in the range of 1–15 s. The large variation of workability across mixtures was due to the constant super plasticizer dosage used for mixtures with the same w/c ratio.

Table 1, Workability Characteristics

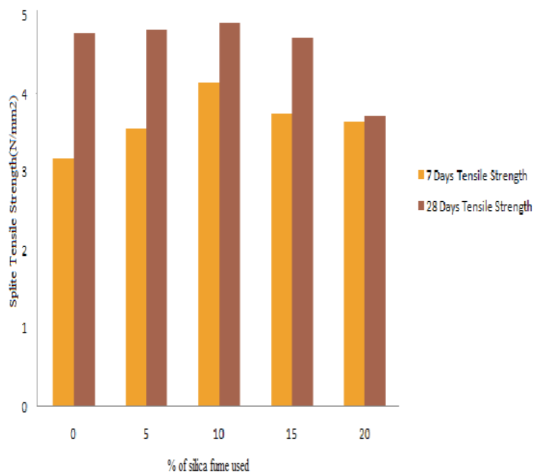
Mixture	C	SF5	SF10	SF15
w/c	0.27	0.27	0.27	0.27
Slump(mm)	165	1000	50	35
Vebe(s)	8	8	12	15
w/c	0.30	0.30	0.30	0.30
Slump(mm)	225	215	117	30
Vebe(s)	3	3	5	16
w/c	0.33	0.33	0.33	0.33
Slump(mm)	240	180	100	35
Vebe(s)	1	3	6	16

Effect of Silica Fume on the Hardened Properties of the Concrete

Compressive Strength

The 7 day compressive strength on 150x150x150 mm cube specimens has been taken in this study. The strength values at different water/binder ratios have been taken at each silica fume replacement level. The result shows that there is an increasing trend in the compressive strength as the silica fume content increases. This is clearly depicted in all the result for all the water/binder ratios and for all types of specimens. But at higher percentages of silica fume the trend takes a decreasing trend. For all the water cement ratios, compressive strength increased continuously from 0% to 10% silica fume replacement levels. For the minimum water/binder ratio of 0.30, maximum strength is obtained at 10% replacement level [8]. Beyond that percentage the strength decreases at 15% replacement levels. Maximum 7 day compressive strength at 10% silica fume content was obtained at 54 mpa, which was reduced to 45 mpa at 15% replacement level for the minimum water binder ratio of 0.30. This effect is noted for all the specimens. At such a low value of water binder ratio and high percentage replacement of silica fume, the mix becomes very hard to compact. Hence the mixes might have suffered from improper compaction resulting in strength reduction. For water cementations material ratio of 0.34 and above the compressive strength of concrete increased up to 10% silica fume content. Even at high silica fume content, concrete mixes with water binder ratios of 0.34 and above had good workability (as indicated by the slump and compaction factor values) and as such achieving proper compaction was not difficult. At higher water/binder ratios, cement replacement by 10% silica fume has a beneficial effect on the 7 day compressive strength of concrete. At 15% replacement level the compressive strength fell below that at 10% but remained higher than control. A large proportion of the pozzolanic action of the silica fume takes place as early as 3 days. At a high water/binder ratio, a high percentage of silica.

7 and 28 days tensile strength are graphically represented as a below



Strengths were measured at 7, 28 and 90 days on samples of 150x150x150 mm cube specimens. The values of the compressive loads at failure at age levels of 7, 28 and 90 days have been presented in table. The corresponding compressive strengths (mpa) with silica fume results in a better pore structure by filling the voids and greater degree of hydration than the same percentage at a lower water/binder ratio. Therefore from the present results it can be concluded that the 7 day compressive strength of concrete can be improved by the replacement of cement by silica fume up to 10% replacement level. This significant gain in the compressive strength at the 7 day stage can be primarily attributed to the filler effect, as at the early stages it is the filler effect which enhances the concrete strength and not the pozzolanic effect.

The relationship between compressive strength and silica fume replacement percentage at the different water/binder ratio exhibit a common trend as expected. At the lowest value of the water/binder ratio i.e. 0.30, the compressive strength increased continuously with respect to control up to 10% replacement level where the maximum value was reached. Thereafter the strength decreased at higher percentage i.e. 15% replacement level. But even at 15% replacement level, the strength was higher than that of control. At the intermediate water/binder ratio i.e. 0.34 and 0.38, compressive strengths exhibit a continuously increasing trend up to 10% silica fume replacement. But after attaining the maximum value at 10%, the strengths fell at 15% replacement level. The strengths of concrete at higher values of water/binder ratio i.e. 0.42, had a similar increasing trend like the lower water/binder ratio concretes. Even at 15% replacement level, the strength of silica fume concrete is higher than the corresponding control concrete. The concept of durability, workability and other factors influencing the mix proportions, as they are understood now, are of comparatively recent origin. The strength of concrete was supposed to improve with the increase in the quantity of cement and with better compaction. High strength concrete refers to concrete that has a uniaxial compressive strength greater than the normal strength concrete obtained in a particular region. High strength and high performance

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concrete are being widely used throughout the globe and in the production of these concretes it is necessary to reduce the water/binder ratio with the subsequent increase in the binder content. High strength concrete refers to good abrasion, impact and cavitations resistance. The deterioration and premature failure of concrete structures such as marine structures, concrete bridge deck etc. Has lead to the development of high performance concrete. The high performance concrete is defined as the high-tech concrete whose properties have been altered to satisfy specific engineering properties such as high workability, very high strength, high toughness and high durability to severe exposure condition [10]. Nowadays silica fume is almost invariably used in the production of High Performance Concretes. In future, high range water reducing admixtures (Super plasticizers) will open up new possibilities for the use of such material as partial replacement of cement to produce and develop high strength concrete, as some of them are much finer than cement.

Flexural Strength after 7 Days

Table 5.5 7 Days Flexural Strength Test Result

Mix Designation	Percentage of Silica fume	Split Tensile Strength (KN)	Split Tensile Strength (N/mm^2)	Average strength (N/mm^2)
M0	0	285 275 250	5.07 4.90 4.46	4.81
M1	5	325 395 390	5.76 7.05 6.99	6.6
M2	10	435 400 375	7.70 7.10 6.65	7.15
M3	15	445 455 365	7.89 8.10 6.51	7.5
M4	20	390 360 265	6.90 6.40 4.75	6.01

The 90 days compressive strengths results obtained are similar to those at 28 day level for all the specimens at all water cemtitious material ratios. At the entire water/binder ratio i.e. 0.30, 0.34, 0.38 and 0.42, maximum strength occurs at 10% replacement level. The 90 days strength (moist cured up to 28 days and then air cured) have been found to be always higher than the corresponding 28 days strengths (moist cured). Goldman and Bentur (1989) have reported that though air curing results in a somewhat lower strength as compared to continuous moist curing, air curing is not detrimental to the strength of silica fume concrete [8]. This was attributed to the fact that the influence of silica fume takes place quite early, during the period of 1 to 28 days. Iravani (1996) reported that silica fume ultra high strength concrete is less sensitive to drying than high strength concrete without silica fume.

Hence the amount of silica fume required for maximizing the concrete strength will depend on the water/binder ratio and the age at which the strength is measured [8]. Similar observations were obtained by Yogendral et al.(1991) and Khedr and Abou-Zeid (1994). However, optimum dosage of silica fume depends on a host of parameters like type of cement, cement content, mix proportions, temperature of curing etc.

Split Tensile Strength

It is observed that silica fume incorporation increases the split tensile strength of concrete. A close observation of exhibits that very high percentages of silica fume do not significantly increase the split tensile strengths and the increase is almost insignificant beyond 15%. For all the w/cm ratios, 5–10% replacements considerably improve the split tensile strength with respect to control. The initial filling of the voids by silica fume significantly improves the tensile strengths, but at higher levels, the improvements decrease [8]. On computing the percentage gains in split tensile strengths of silica fume concrete with respect to control at the different water–binder ratios, the values of the average gains at 5%, 10%, 15%, 20% and 25% replacement levels are obtained as16.7%, 22%, 25%, 25.7% and 19.3%, respectively. Although the trend in strength gain is almost similar with that of compressive strength, the optimum 28-day split tensile strength lies in the range of 5–10%.

Flexural Tensile Strength

Silica fume seems to have a more pronounced effect on the flexural strength than the split tensile strength. For flexural strengths, even very high percentages of silica fume significantly improve the strengths. The average percentage gains in the flexural tensile strengths of silica fume concrete with respect to control at the different water– binder ratios are computed as 10.2%, 14.5%, 27%, 31% and 26.6% at 5, 10, 15, 20 and 25 percentage replacement levels, respectively . The gains in split tensile strengths are higher than the flexural strengths at lower replacement levels. But a steady increase in the flexural strength is observed with increase in the silica fume replacement percentage, and the gains are higher than those of split tension at higher replacement levels. The flexural strengths almost follow the same trend as the 28-day compressive strength does. The results of the present investigation indicate that the optimum silica fume replacement percentage for 28-day flexural tensile strength is not a constant one but a function of the water cementitious material ratio of the mix and has been found to range from 15% to 25%.

Conclusion

There is a significant improvement in the compressive strength of concrete because pozzolanic natures of the silica fume and its void filling ability. The results obtained in the present study indicates that it is feasible to replace the cement by silica fume for improving the strength characteristics of concrete, thus the silica fume can be used as an alternative material for the production of concrete to address the waste disposal problems and to minimize the cost of construction with usages of silica fume which is most freely available. Consistency of cement depends upon its fineness .silica fume is having greater fineness then cement and greater surface area so the consistency increases greatly when silica fume percentage increases. The normal consistency increases about 40% when silica fume percentage from 0% to 20%. There is a significant improvement in the compressive strength of concrete because pozzolanic natures of the silica fume and its void filling ability. Silica fume seems to have a pronounced effect on the flexural strength than the split tensile strength.

References

1. T.Shanmugapriya , Dr.R.N.Uma, "*Experimental Investigation on Silica Fume as partial Replacement of Cement in High Performance Concrete*"**,** The International Journal Of Engineering And Science (IJES) ,Volume 2, Issue 5 , Pages 40-45, 2013, ISSN(e): 2319 – 1813 ISSN(p): 2319 – 1805.
2. N. K. Amudhavalli1, Jeena Mathew, "*Effect of Silica Fume on Strength And Durability parameters Of Concrete*", International Journal of Engineering Sciences & Emerging Technologies, August 2012. ISSN: 2231 – 6604 Volume 3, Issue 1, pp: 28-35.
3. Faseyemi Victor Ajileye, "*Investigations on Micro silica (Silica Fume) As Partial Cement Replacement in Concrete*", Global Journal of researches in engineering Civil And Structural engineering, Volume 12, Issue 1, Version 1.0, January 2012.
4. Dilip Kumar Singha Roy, Amitava Sil, "*Effect of Partial Replacement of Cement by Silica Fume on Hardened Concrete*", International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, Volume 2, Issue 8, August 2012.