EXPERIMENTAL STUDY OF CONCRETEUSING SILICA FUME AS PARTIAL REPLACEMENT WITH CEMENT

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ABSTRACT

Cement, sand, aggregate are basic needs for any construction industry. Cement is a primary material used for preparation of mortar and concrete and which plays a major role in mix design. The high rise in cost of conventional building material in developing countries has been a source of concern to government and private developers. Now a day's absence of power and lack of materials, there is scarcity of cement and also increasing the cost of cement. The high cost of the cement will affect the construction industries. Hence there is a need to find the new alternative material to replace the cement. In our project we are plan to replace cement by using silica fume. This project focuses on investigating characteristics of M20 concrete with partial replacement of cement with silica fume. The present study investigates the compression strength of silica fume in concrete compared with normal conventional concrete.The silica fume is replaced as 0%, 10%, 20%, 30%, 40% and 50%, cubes have been casted and tested for compression with an increases in increase in percentage in fine aggregate is been done and compared to the conventional concrete.
Keywords: Cement, silica and concrete.

INTRODUCTION

The production of Ordinary Portland Cement (OPC), the main ingredient in normal concrete unfortunately, emits vast amounts of carbon-dioxide gas into the atmosphere which has major contributions to green house effect and thereby causing global warming; hence it is obvious to use either alternate or other materials as part replacement. Some alternate or supplementary pozzolanic materials like Fly ash, silica fume, Rice husk ash, Ground Granulated Blast furnace Slag, and High Reactive Metakaolin can be used for cement as partial replacement in concrete and should lead to global sustainable development and lowest possible environmental impact and energy saving (Chen and Chung, 1993). The advantages like high strength, durability and reduction in cement production are obtained due to the incorporation of silica fume in concrete and the optimum percentage replacement of silica fume ranging from 10 to 20 % to obtain maximum 28-days strength of concrete. Durability and the other mechanical properties of concrete are improved when pozzolanic materials are incorporated in concrete because of the reaction between silica present in pozzolans and the free calcium hydroxide during the hydration of cementand consequently forms extra calcium silicate hydrate (C – S – H). Researchers showed that a part replacement of cement by silica fume at varyingpercentage has improved the performance of concrete in strength and durability aspect and reported that 10-15 % silica fume replacement level produce the optimum (7 and 28- days) compressive strength and flexural strength and it is seemed that silica fume have a more prominent effect on the flexural strength than the split tensile strength (Luther, 1988).

The incorporation of silica fume in concrete is useful to increase the compressive strength, decrease the drying shrinkage, and the permeability. Also the incorporation of silica fume in concrete is effective to increase the bond strength with the steel reinforcement and abrasion resistance. Consequently, the use of silica fume concrete in civil structures is wide spreading. Nevertheless, the loss of workability due to the use of silica fume creates the difficulty to utilize silica fume concrete accurately (Bhanja Santanu, and Sengupta Bratish, 2003). The smaller sizes (10 mm and 5mm) and rounded shape aggregates should be used for high strength of concrete than other sizes and shape respectively. Incorporation of silica fume inconcrete has an adverse effect on workability and higher percentage of super plasticizer isneeded for higher percentage of cement replacement by silica fume. In this paper our attempt have been made to investigate the different mechanical properties like compressive strength, compacting factor, slump of concrete incorporating silica fume considering a single water-cementitious material ratio of 0.40.

SILICA FUME:

Silica fume is a byproduct if producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume in concrete. because of its chemical and physical properties, it is a very reactive pozzolano. Concrete containing silica fume can have very high strength and can be very durable. Silica fume is available from suppliers of concrete admixtures and, when specified, is simply added during concrete production. Placing, finishing, and curing silica fume concrete require special attentionon the part of the concrete contractor (Bubshait *et al.,* 1996).

Silica fume consists primarily of amorphous (non-crystalline) silicon dioxide (SiO2). The individual particles are extremely small, approximately 1/100th the size of an average cement particle Because of its fine particles, large surface area, and the highSiO2 content. Silica fume is a very reactive pozzolan when used in concrete. the quality of silica fume is specified By ASTMC C 1240 and AASHTO M 307.

High strength concrete is a very economical material for carrying vertical loads in high rice structures. Until a few years ago 6000psi concrete was considered to be high strength today, using silica fume, concrete compressive strength in excess of 15000psi can be readily produced. The greatest cause of concrete deterioration in the US today is corrosion induced by deicing or marine salts. Silica fume concrete with a low water content is highly resistant to penetration by chloride ions. More and more transportation agencies are using silica fume in their concrete for construction of new bridges or rehabilitation of existing structures (Amudhavalli *et al.,* 1993).

Silica fume concrete does not just happen. A specifier must make a conscious decision to include it in concrete to achieve desired concrete properties. Assistance in specifying silica fume concrete for high strength or increased durability can be obtained from the SFA or from major admixture suppliers.

Silica fume for use in concrete is available in wet and dry forms. It is usually added during concrete plants. Silica fume concrete has been successfully produced in both central-mix and dry-batch plants. Assistance is readily available on all aspects of handling silica fume and using it to produce consistent, high quality concrete.

PRODUCTION OF SILICA FUME

The raw materials for the production of silica fume are by-products from the production of silicon metal, and these by-products are further processed to produce cementitious materials for use inconcrete. Silica fume is a by-product of the manufacture of silicon metal and ferro-silicon alloys. The process involves the reduction of high purity quartz (SiO2) in electric arc furnaces at temperatures in excess of 2,000°C. Silica fume is a very fine powder consisting mainly of spherical particles or microspheres of mean diameter about 0.15 microns, with a very high specific surface area (15,000–25,000 m2/kg). Each microsphere is on average 100 times smaller than an average cement grain. At a typical dosage of 10% by mass of cement, there will be 50,000–100,000 silica fume particles per cement grain (Shi Zeng and Chung, 1997.

PROPERTIES OF SILICA FUME CEMENTANIOUS PROPERTIES:

The materials differ in their chemical reactivity. GGBS is a latent hydraulic binder, i.e. when mixed with water, it slowly sets and hardens. With GGBS alone, the rate ofhardening is relatively slow and for normal concrete applications, GGBS needs to be activated by combining it with CEM I. Fly ashand silica fume are pozzolanas, i.e. they do not react with water alone but do react chemically with the calcium hydroxide produced by the hydration of CEM I to form calcium silicate hydrates (C-S-H) whichbind the concrete together. Limestone is chemically, relatively inert but limestone fines, because of their fine particle size, can contribute towards strength by a physical, void-filling mechanism. There is evidence that fine calcium carbonates act as nucleation sites, accelerating the hydration of CEM I, improving early strength development. Silica fume is a highly reactive pozzolana that converts all or most of the liberated calcium hydroxide to C-S-H As a result of their chemical reactivity and also fineness, the materials differ in the proportion of the cementitious content at which they can be used,with indicative proportions being:

GGBS typically 50% but can be up to 70% or moreFly
ash typically 30% but can be up to 50% or more
Limestone fines typically 15% but can be up to 20% or more
Silica fume typically <8% but can be up to 12.5% or more

Permeability

Silica fume can produce very large reductions in water permeability of up to one order magnitude or more, depending on the mix design and dosage of silica fume. The reduction in the size of capillary pores increases the probability of transforming continuous pores into discontinuous ones, see Philleo. Because capillary porosity isrelated to permeability, see Powers et al [Ref. 85], the permeability to liquids and vapours is thus reduced by silica fume addition. Silica fume can produce very large reductions in water permeability, up to an order of magnitude or more, see Hooton. Data for mortar and concrete show a similar trend in that silica fume reduces permeability, see for example Scheetz, Grutzek and Strickler, Mehta and Gjørv and Delage andAitcin. Maage and Maage and Sellevold reported a reduction in permeability of about one order of magnitude for silica fume dosages of 5% to 12%; the most improvement was with the lowest dose that was used with the lowest w/c ratio (Khedr and Abou Zaid, 1994). Measurement of the water permeability for quality concrete (40N/mm2) is often impossible because of the measuring equipment limitations and leakage around the permeability cells, see for example Hustad and Loland and Hooton. El-Dieb and Hooton were able to measure a water permeability of 1.9 × 10-16 m/s for a 0.29 w/c concrete with 7% silica fume plus 25% GGBS. The mechanism involved is due primarily to the high pozzolanic reaction linked with improvement in the interfacial transition zone.

METHODOLOGY

Materials proposed to be used in the present study are:

1. Coarse aggregate size 20mm, 12.5mm and below 4.75mm.
2. Fine aggregate
3. Binder PPC 53 grade

CEMENT

Ordinary Pozzolana Cement was used in casting the specimens. The Specific Gravity, Fineness, Initial setting time and Consistency of the cement weretested.

COARSE AGGREGATE

Hard granite broken stones of less than 20mm size were used as coarse aggregate. The Specific Gravity, Fineness modulus, Water absorption and Bulk density of the coarseaggregate were tested (Table 1).

Table 1. Properties of coarse aggregate

S.No	Description	Values
1	Specific gravity	2.75
2	Bulk density	1648.73 Kg/m^3
3	Water absorption	1%
4	Fineness modulus	4.67
5	Average Impact Value	15.79%
6	Average Crushing value	20.8%

River sand of size less than 4.75 mm size were used as fine aggregate. The Specific Gravity, Fineness modulus, Water absorption and Bulk density of the fine aggregate were tested. Potable water available in laboratory with pH value of of not less than 6 and conforming to the requirement of IS 456-2000 was used for mixing concrete and curing the specimen as well (Table 2).

Table 2. Properties of fine aggregate

S.No	Description	Values
1	Specific gravity	2.69
2	Bulk density	1632.19 Kg/m^3
3	Water absorption	1%
4	Fineness modulus	2.72

TESTS ON CEMENT

Testing of cement can be brought under two categories,

- Field testing
- Laboratory testing

FIELD TESTING

It is sufficient to subject the cement to field tests when it is used for minor works. The following are field tests, stiff paste. A stiff paste is obtained with sharpedge, place it on a glass plate and slowly take it under bucket filled with water. See that the shape of the cake is not disturbed while taking down to the bottom of the bucket. After 24 hours, the cake should retain the original shape and at the same time it should attain some strength.

LABORATORY TESTING

If a sample satisfies the above field tests it may be concluded that the cement is not bad. The above tests do not really indicate that the cement is really good for important works. For using cement in important and major works it is incumbent on the part of the user to test the cement in laboratory to confirm the requirements of the IS specification with respect to its physical and chemical properties. No doubt, such confirmations will have been done at the factory. But the cement may be bad during transportation and storage prior to its use in works.

RESULTS

Take the reading by noting the depth of penetration of the plunger. Conducta second trial (say with 25 percent of water) and find out the depth of penetration of the plunger. Conduct trials with higher and higher water/cement ratios till such time the plunger penetrates for a depth of 5 to 7mm from bottom is known as percentage of water required to produce a cement paste of standard consistency. This percentage is usually denoted as “P” (Table 3).

Table 3. Standard Constant Test Values

Percentage of water by weight (%)	Penetration depth from bottom (mm)
30	22.5
32	12.5
33	7

The percentage of water required to produce a cement paste of standardconsistency is 33%.

Initial setting time of cement = 150 minutes > 60 minutes (OK) Final setting time of cement = 230 minutes<600 minutes (OK).

The specific gravity of cement = 3.15g/cc (Table 4).

Table 4. Properties of Ordinary Portland Cement

S.No.	PARTICULARS OF TEST	RESULT	SPECIFICATION AS PER IS:8112-1976
1	Normal Consistency	33%	-
2	Setting time in minutes		
	Initial	150	>60 minimum
	Final	240	<600 maximum
3	Specific gravity	3.15	

The results of this experiment are provided graphical form to identify the type of gradation of the aggregate. Typical sieve analyses involve a nested columnof sieves with wire mesh cloth. A representative weight sample is poured into the top sieve which has the largest openings. Each lower sieve in the column has smaller openings than the one above. At the base is a round pan, called the receiver. Normal river sand was used for the preparation of concrete mixture. The tests were carried out to find out the properties of normal sand (Table 5-6).

Table 5. Sieve Analysis of Fine Aggregate

S.No.	IS Sieve size	Quantity retained (gms)	Percentage retained	Cumulative percentage retained	Cumulative percentage passing
1.	4.75mm	95.0	9.5	9.5	90.5
2.	2.36mm	42.5	4.25	13.75	86.25
3.	1.18mm	110.5	11.05	24.8	75.2
4.	600µ	128.5	12.85	37.65	62.35
5.	300µ	308.0	30.8	68.45	31.55
6.	150µ	281.0	28.1	96.55	3.45
7.	Pan	34.5	3.45	0.00	0.00

Hence the fineness modulus of fine aggregate is found to be 2.5

Sample of coarse aggregate size 20mm were used.

Table 6. Sieve Analysis of Coarse Aggregate

S.No.	IS Sieve size (mm)	Quantity retained (gms)	Percentage retained	Cumulative percentage retained	Cumulative percentage passing
1.	80	0	0	0	100
2.	40	370	12.33	12.33	27.62
3.	20	1.818	60.00	72.93	27.07

4.	10	570	19.00	91.93	2.07
5.	4.75	242	8.02	100	0
6.	2.36	-	-	100	0
7.	1.18	-	-	100	0

Hence the fineness modulus of coarse aggregate is found to be 4.8

CALCULATING CEMENTIOUS MATERIAL CONTENT

From the water cement ratio and the quantity of water per unit volume of cement, the amount of cementious material is calculated.

C = 186/0.46 = 404.35 kg/m^3.

MIX CALCULATIONS

A	Volume of concrete	1m^3	1m^3
B	Volume of cement	(Mass of cement/specific gravity of cement)*(1/1000)	= (404.35/3.15)*(1/1000) = 0.128
C	Volume of water	(Mass of water/specific gravity of water)*(1/1000)	= (186/1)*(1/1000) = 0.186
D	Volume of air	2% of 1m3.	= (2)*(1/100) = 0.02
E	Volume of total aggregate (C.A+F.A)	[a-(b+c+d)]	= 1 – (0.128+0.186+0.02) = 0.665m^3
F	Mass of coarse aggregate	e*Volume of coarse aggregate*specific gravity of coarse aggregate*1000	=(65/100)*0.665*2.80*1000 = 1209.6 kg/m^3

G	Mass of fine aggregate	e*Volume of fine aggregate*specific gravity of fine aggregate*1000	= (35/100)*0.665*2.69*1000 = 626.77 kg/m^3

The mix calculations per unit volume of concrete shall be done as follows

MIX PROPORTION

The mix proportion required for the grade M_{20},

Mass of Cement in kg/m^3	404.35
Mass of Water in kg/m^3	186
Mass of Fine Aggregate in kg/m^3	626.77
Mass of Coarse Aggregate in kg/m^3	1209.6
Water Cement Ratio	0.46

The required mix ratio is **1: 1.55: 2.99.**

The result of the investigations carried out for finding out compressive strength, split tensile strength, flexural strength using silica fume as partial replacement of cement (Table 7-9).

Table 7. Compressive strength of concrete

% of silica fume	**Compressive strength of concrete N/mm^2**		
	7 Days	**14 Days**	**28 Days**
0	14.83	19.74	26.78
10	16.24	23.49	29.37
20	17.53	25.37	33.92
30	15.17	22.18	27.14
50	13.47	17.86	22.58

Table 8. Tensile strength of concrete

% of silica fume	**Tensile strength of concrete N/mm^2**		
	7 Days	**14 Days**	**28 Days**
0	13.88	17.74	21.79
10	15.94	20.43	25.56
20	18.41	22.98	27.41
30	14.28	18.56	23.18
50	11.91	15.87	19.23

Table 9. Flexural strength of concrete

S.no	**% of silica fume**	**Flextural strength of concrete N/mm^2**
1	0	3.46
2	10	4.12
3	20	5.05
4	30	3.92
5	50	3.08

CONCLUSION

- From the results obtained in compression testing, tensile testing and flexural testing it is found that the compression strength, tensile strength and flexural strength was found to be increasing up to and 20% replacement of cement by silica fume and full coarse aggregate.
- Silica fume can be used to replace cement and fully fine aggregate in concrete. Addition of silica material helps to reducing the utilization of cement in concrete.
- The compressive strength of concrete with the replacement of silica fume and fully fine aggregate at a rate of 20% shows a higher result than the control concrete and also it increase the split tensile strength of the concrete with the addition of these silica material.
- The flexural strength of concrete with the replacement of silica fume at a rate of 20% shows a higher result than the normal concrete at only 28days.
- Water absorption of the specimens are constantly reducing with increase in addition of these silica materials.
- In feature further study can be done by using different type of admixtures.
- The quality of concrete was found to be good compared to control concrete. Hence this replacement technique will turn in a fruitful concrete in future.

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