AN INVESTIGATION ON HIGH STRENGTH CONCRETE BLENDED WITH SILICA FUME AS A CEMENT REPLACEMENT

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ABSTRACT

This paper presents the result of mix design developed for high strength concrete and with replacement of cement by silica fume a comparison is drawn to find optimum percentage of silica fume .It involves the process of determining experimentally the most suitable concrete mixes in order to achieve the maximum compressive strength of concrete for various mix proportions. In this research work 53 grade Ordinary Portland Cement, the locally available river sand, 16 mm and 10 mm graded coarse aggregate with a combination of 60% and 40% were selected based on ASTM C 127 standard for determining the relative quantities and proportions for the grade of concrete M60. For this design Is 10262-2009 guidelines were followed by trial and error method fixed the mix design without any mineral admixtures.

Index Terms— *High Strength Concrete, silica fume, compressive strength, Water to cement Ratio.*

INTRODUCTION

High Strength Concrete (HSC) may be defined as concrete with characteristic cube strength between 60 and 100 N/mm^2. High-Strength Concrete is used more widely with each passing year The compressive strength of high strength concrete with cement-silica fume blend of 0 - 15% mass of silica fume and water to Cementitious ratio of 0.32 from 3 days to 28 days is investigated. The compressive strength of High Strength

Concrete after 28 days is found and keeping workability criteria in mind, the mechanical properties are found. The appropriate replacement of silica fume, low *w/c* ratio are beneficial to the compressive strength of the High Strength concrete by blending silica fume in various percentages. Silica fume or micro silica is very fine non-crystalline silica produced in electric arc furnaces as a by-product of the production of elemental silicon or alloys containing silicon.

Although high-strength concrete is often considered a relatively new material, its development has been gradual over many years. As the development has continued, the definition of high-strength concrete has changed. In the1950s, concrete with a compressive strength of 34 N/mm^{2}a was considered high strength. In the 1960s, concrete with and 41 and 52 N/mm^2 compressive strengths were used commercially. In the early 1970s, 62 N/mm^2 concrete was being produced. More recently, compressive strengths approaching 138 N/mm^2 have been used in cast-in-place buildings. For many years, concrete with compressive strength in excess of 41 N/mm^2 was available at only a few locations. However, in recent years, the applications of high-strength concrete have increased, and high-strength concrete has now been used in many parts of the world. The growth has been possible as a result of recent developments in material technology and a demand for higher-strength concrete.

The construction of Chicago"s Water Tower Place and 311 South Wacker Drive concrete buildings would not have been possible without the development of high-strength concrete.

The use of concrete superstructures in long span cable-stayed bridges such as East Huntington, W.V., and bridge over the Ohio River would not have taken place without the availability of high-strength concrete. The composition of HSC usually consists of cement, water, fine sand, superplastisizer. Sometimes components as well for HSC having ultra-strength and ultra-ductility respectively.

The key elements of high strength concrete can be summarized as follows:

- Low water-to-cement ratio,
- Large quantity of cement
- Mineral admixtures (Silica fume)
- Coarse Aggregates(16 mm &10 mm) and fine sand,
- High dosage of Super plasticizers (1.2%)

Silica Fume as a Admixture:

In many instances, silica fume may also be used in the mix. The type of silica fume used will make a difference. I have had direct experience which indicates that the silica fume which comes in the form of a slurry works more efficiently than does that which comes in a dry, densified form. Typically, this does not become a major concern until the water-cement ratio drops to 0.32.

For high-strength concrete, typical dosage rates for the slurry-type silica fume range between 0 to 15%, by weight of cement. Pozzolonic materials are siliceous or siliceous and aluminous materials, which in themselves possess little or no Cementitious value, but will , in finely divided form and in the presence of moisture, chemically react with calcium hydroxide liberated on hydration, at ordinary temperature, to form compounds, possessing Cementitious properties.

PROPERTIES OF SILICA FUME

PHYSICAL PROPERTIES	RESULTS
PHYSICAL STATE	Micronized Powder
ODOUR	Odourless
APPEARANCE	White Colour Powder
COLOUR	White
PACK DENSITY	0.76 gm/cc
pH of 5% SOLUTION	6.90
SPECIFIC GFRAVITY	2.63
MOISTURE	0.058%
OIL ABSORPTION	55 ml / 100 gm

CHEMICAL PROPERTIES	RESULTS
SILICA (SIO2)	99.886%
ALUMINA (Al2O3)	0.043%
FERRIC OXIDE (Fe2O3)	0.040%
TITANIUM OXIDE (TiO2)	0.001%
CALCIUM OXIDE (CaO)	0.001%
MAGNESIUM OXIDE (MgO)	0.000%
POTTASIUM OXIDE (K2O)	0.001%
SODIUM OXIDE (Na2O)	0.003%
LOSS ON IGNITION	0.015%
HEAVY METALS: LEAD (Pb) ARSENIC (As)	 0.000% 0.000%

Fig 1. Silica fume

Scope of the project:

According to the codal procedure, we have to perform the tests to know about the fresh and hardened properties of High strength concrete made with silica fume replacement. The experimental work was conducted on cubes and beams so that it leads to evaluate the compression and flexural strengths of concrete.

The details and properties of materials that were used in this study are discussed High strength Concrete (HSC) can be used in high-rise buildings, tall structures and both in super and substructure of bridges and many more. The mix design developed for high strength concrete with silica fume. Here four mixes proportions were designed with Silica fume quantities varied from 0 to 15 percent weight of Cementitious materials. Each mix 9 numbers of specimens cube, were cast then kept in curing tank after 24 hours of time period. For M60 grade of concrete, the Cementitious materials are replaced with silica fume in the proportion of 0%, 5%, 10%, 15% (by weight) in all mixes. Here an attempt made on concrete blended with silica fume of various proportion in concrete to evaluate the Compressive strength,workability, compaction factor, slump is calculated.

LITERATURE REVIEW

In recent years, the applications of high-strength concrete have increased, and high-strength concrete has now been used in many parts of the world.

Prasad. [1] has undertaken an investigation to study the effect of cement replacement with micro silica in the production of High-strength concrete.

Yogendran.[2] investigated on silica fume in High-strength concrete at a constant water-binder ratio (w/b) of 0.34 and replacement percentages of 0 to 25, with varying dosages of HRWRA.The maximum 28-day compressive strength was obtained at 15% replacement level.

Lewis [3] presented a broad overview on the production of micro silica, effects of standardization of micro silica concrete-both in the fresh and hardened state.

Bhanja., and Gupta [4] reported and directed towards developing a better understanding of the isolated contributions of silica fume concrete and determining its optimum content. Their study intended to determine the contribution of silica fume on concrete over a wide range of w/c ratio ranging from 0.26 to 0.42 and cement replacement percentages from 0 to 30.

MATERIAL AND EXPERIMENTAL INFORMATION

3.1. Properties of Cement

Ordinary Portland cement of grade 53 ACC was used in this experimental work. The properties of cement are as follows

i. Specific gravity :3.24
ii. Normal Consistency: 26.5%
iii. Fineness of cement (m^2/kg) :289
iv. Fineness :3%
v. Setting time (minutes)
   a. Initial setting :39
   b. Final setting :185
vi. Soundness of cement :1.0

Fig 2 cement

3.2. Fine aggregate:

Locally available river sand is used as fine aggregate which is passed through 4.75mm I.S. sieve. The specific gravity of the sand is found to be 2.343. The sand used for the experimental program was locally procured and conformed to Indian Standard Specifications IS: 383-1970.

i. Specific gravity : 2.343
ii. Fineness modulus : 3.015
iii. Bulk density :16.70 KN/m^3
iv. Bulking of Sand : 27.53%
v. Grading of Sand : Zone – II

Fig 3 fine aggregate (sand)

3.3 Coarse aggregate:

The local available natural granite aggregate is used in this study. The all in all size coarse aggregate which passes through IS 20mm sieve and retained on IS 10mm sieve has been used in this study. The all in all size aggregate is preferred for effective utilization and good placing of aggregates. The properties of granite aggregate are shown in the following tables. Locally available coarse aggregate having a maximum size of 16mm, 10mm were used for work. The aggregates were tested as per Indian Standards Specification IS: 383-1970.

i. Specific gravity
   a. 16 mm :2.62
   b. 10 mm : 2.74
ii. Fineness modulus : 2.08
iii. Flakiness Index : 18.96 %
iv. Elongation Index : 24.64%
v. Crushing Value: 20 %
vi. Impact Value : 20.36 %
vii. Water Absorption : 0.50 %

Fig 4 Coarse aggregate (kankar)

3.4. Properties of fresh concrete using silica fume

Workability:-

Water demand increases in proportion to the amt of silica fume added. The increase in water demand of concrete containing silica fume is about 1% for every1% cement substituted Workability is the ease with which a concrete mix can be handled. Water measures can be taken to avoid this increase by adjusting aggregate grading and use of super plasticizer. The addition of silica fume will lead to a cohesive mix due to more solid-to-solid contact and will have a lower slump. This reduces bleeding and segregation.

BLEEDING AND SEGREGATION:-

The effect of silica fume on the rheology of fresh concrete is considered a stabilizing affect in the sense that addition of fine particle to a concrete mix tends to reduce segregation and bleeding. When very fine particles of silica fume are added to concrete the size of flow channel is greatly reduced because these particle are able to find their way into empty spaces between the two cement grains causing drastic segmentation of bleed water flow and reduce bleeding. Due to increase in the number of solid-to-solid contact, the cohesiveness of the concrete mix is greatly improved when silica fume is added. This makes the concrete highly attractive for pumping, shot-creting as it reduces segregation.

3.4.1 TIME OF SET:

Silica fume in small amounts (10% by weight of cement) to ordinary concrete mixtures (250 to 300 kg/ m^3 cement) either has no significant effect or alters the time of set of reference concrete only slightly.

3.5..CEMENTITIOUS APPLICATION OF SILICA FUME

1. It is a very reactive and effective Pozzolonic material due to its fine particle size and high purity of sio2 (99.5%) content.
2. It enhances the mechanical properties, durability and constructability in concrete.
3. It is used in the production of high strength & high performance concrete.
4. It is used in the production of high performance concrete structures like bridge's where the strength and durability properties of the concrete are required.

5. It can be used to build marine structures as it reduces the damage caused due to the reaction of chloride and various chemicals, it helps in protection of steel from rust and corrosion and increases the life of the structure.
6. The recommended dosage is 7 – 10 % of the cement weight added to the concrete.

3.5.1HIGH STRENGTH CONCRETE:

High Performance Concrete (HPC) enhanced with silica fume is so strong it becomes an economical alternative to steel. Besides providing architects and engineers with greater design flexibility, there is more usable space, since smaller columns and beams can be used in high rise buildings and long span structural designs.

3.6 WATER:

The locally available potable fresh water was used for mixing and curing of specimens. Clean portable water was used for mixing motor, concrete and curing. Water must be free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. Portable water is generally considered satisfactory for mixing concrete.

Water content: 148.8 kg/m^3

3.7 SUPERPLASTICIZER:

SP430 is a chloride free, superplasticising admixture based on selected sulphonated napthalene polymers. It is supplied as a brown solution which instantly disperses in water. It has been specially formulated to give high water reductions up to 25% without loss of workability or to produce high quality concrete of reduced permeability.

Specific gravity : 1.26

IV . Results and Discussion

4.1 preliminary results on concrete:

NO	TEST	RESULT	INFERENCE
1	Slump cone	4-13 mm	Low workability
2	Compaction factor	0.84-0.91	Low workability
3	Vee –Bee	T=13-8 sec	Low workability

4.2 MIX DESIGN PROPORTIONS:

Specimen	Mix proportions		
	Cement	Fine aggregate	Coarse aggregate
S_1 (nominal mix)	1	1.29	2.57
S_2	1	1.205	2.398
S_3	1	1.269	2.525
S_4	1	1.344	2.674

S_1: Sample one of mix design of proportion (nominal mix M_{60}) Here silica fume content is 0% and cement content is 100% and SP 430 of 1.2% of cement content and here coarse aggregate of 16 mm and 10 mm in combination is used in 60 and 40%.

S_2: Sample two, the mix design of proportion the replacement of silica fume is done, here silica fume content is 5 % and cement content is 95 % and SP 430 of 1.2% of cement content and here coarse aggregate of 16 mm and 10 mm in combination is used in 60 and 40%.

S_3: Sample three, the mix design of proportion the replacement of silica fume is done, here silica fume content is 10 % and cement content is 90 % and SP 430 of 1.2% of cement content and here coarse aggregate of 16 mm and 10 mm in combination is used in 60 and 40%.

S_4: Sample four, the mix design of proportion the replacement of silica fume is done, here silica fume content is 15 % and cement content is 85 % and SP 430 of 1.2% of cement content and here coarse aggregate of 16 mm and 10 mm in combination is used in 60 and 40%.

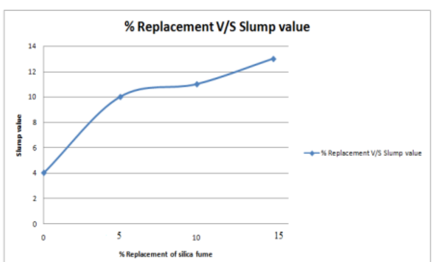

Fig 5 Percentage replacement v/s slump

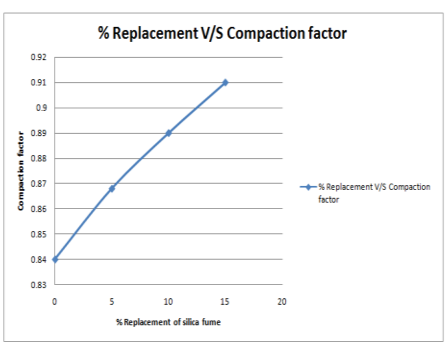

Fig 6.Percentage replacement v/s compaction factor

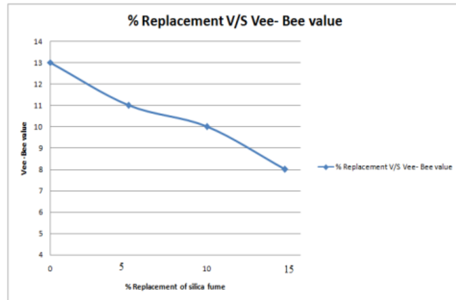

Fig 7 Percentage replacement v/s VEE-BEE value

4.3 Cube compressive strength test

Fig 8 Apparatus of Compressive strength test

Replacement of Silica fume (%)	Compressive Strength in N/mm^2		
	3 days	7 days	28 days
S_1 (0%)	34.47	46.25	64.93
S_2 (5%)	34.52	50.12	72.58
S_3 (10%)	34.61	55.20	75.48
S_4 (15%)	41.18	51.39	69.23

Table: Compressive Strength values for High strength Concrete Mix M60

The tables shows the average compressive strength values recorded at the time of testing for 3, 7 and 28 days of curing and the percentage difference of compressive strength for all batch mixes. The variation of compressive strength at 3, 7 and 28 days to the percentage replacement of Silica fume is shown in the figure . The figure shows that the compressive strength value increased when we replace the Silica fume up to 10% after that it gradually declined up to 15%. At the same time, As a result the percentage difference for 0% and 10% silica fume replacement is 16.25. Surprisingly in this analysis the replaced Silica fume in High-Strength concrete got more compressive strength value and satisfied the nominal mix i.e. 0% replacement of silica fume with 100% cement content.

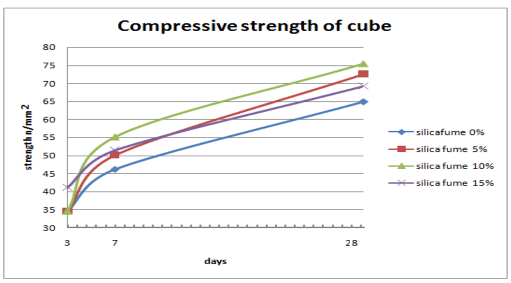

Fig. 9 Curing periods v/s Compressive Strength

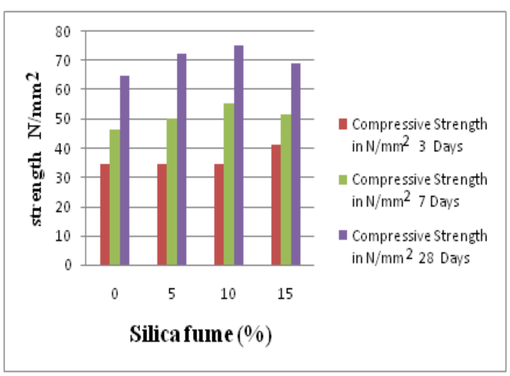

Fig 10 Percentage replacement v/s Compressive Strength

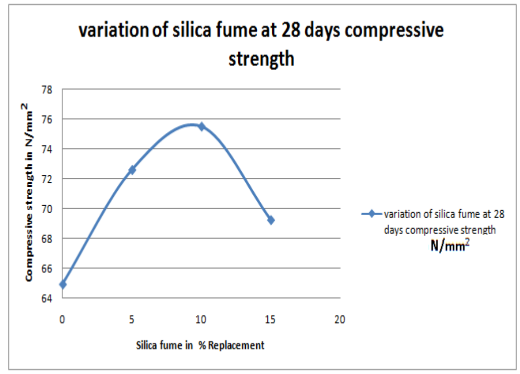

Fig 11 Percentage replacement v/s Compressive Strength (28 days)

The above figures shows the various percentages of replacement of silica fume like 0%,5%,10%,15% and their curing periods v/s compressive strength and replacement percentages represented in line diagrams an bar charts. In this compressive strength are increased from 0% replacement of silica fume to 10% replacement later it is slightly declined to 15%.

CONCLUSIONS

Based on the Investigation conducted on the Mix design of high strength concrete by using silica fume, the following conclusions were made. Increase in the percentage of Silica fume requires more demand of water because of the Greater fineness.

To maintain the workability of the concrete use of super plasticizer is necessary. Increase in Percentage of Silica fume the slump of the concrete was reduced, to maintain the require slump addition of super plasticizer is necessary. In this study Silica fume added from 0 to15%, the observation was Increase in Silica fume compressive strength also increased up to 10% but the slump value was reduced. Replacement of cement with Silica fume 10%, gave the maximum compressive strength, so 10% replacement of Silica fume is optimum.The following are the key points that are concluded from the present experimental work.

1. The compressive strengths for HSC has increased for 5% and 10% replacement of Silica fume and decreased in 15% replacements. So, optimum percentage of replacement of silica fume is 10%.
2. Success of HSC requires more attention on proper mix design, production, placing and curing of concrete. For each of these operations controlling parameters should be achieved by concrete producer for an environment that a structure has to face.
3. Even though the initial cost of HSC is comparatively higher than conventional concrete, considering the long service life of the structures and the minimum maintenance required, the benefit cost ratio is very much in favor.
4. The higher strength concrete permits use of reduced sizes of structural members and increases available usable space in building, which is an important factor in congested urban locations.
5. HSC can be advantageously used for the production of precast products which can be mass produced and which utilize effectively the high durability and strength characteristics such as electric poles in coastal areas, pipes for transportation of corrosive liquids such as sewage, effluents etc.
6. The workability for HSC with replacing of silica fume decreases.

RECOMMENDATIONS FOR FUTURE INVESTIGATIONS:

1. The study on high strength concrete with replacing of silica fume in various percentages can be further extended for research purpose.
2. We can increase the strength of concrete by replacing mineral admixtures and also have wide scope in tall structures.
3. Studies can be conducted by incorporation of variation of other percentages of silica fume replacement.
4. Studies can be conducted on HSC with percentages of silica fume replacement such as sulphate attack, acid resistance , performance under impact, torsion etc.,
5. In metro projects HSC can be useful and also piers and abutments and to build high rise buildings by reducing column sizes and increasing available space.

5.2 REFERENCES:

1) Prasad AS, Santanam D, Krishna Rao SV. Effect of micro silica on high strength concrete, National conference-emerging trends in concrete construction, 22-24 Jan 2003, CBIT, Hyderabad, India.
2) Yogendran V, Langan BW, Haque MN, Ward MA. Silica fume in High- strength concrete, ACI Material Journal, No. 2, 84(1987) 124-9.
3) Lewis RC. Ensuring long term durability with high performance micro silica concrete, The Indian Concrete Journal, October 2001, pp. 621-26.
4) Bhanja S, Sengupta B. Optimum silica fume content and its mode of action on concrete,ACI Materials Journal, September- October 2003, pp. 407-712.
5) Indian Standard Recommended guidelines for Concrete Mix Design, IS 10262: 1982, Bureau of Indian Standard, New Delhi.

6) Krishna Raju, N. (2006), ―Design of concrete Mixes‖, CBS Publishers & Distributors, New Delhi, pp.283-295.
7) Indian standard code of practice for plain and reinforced concrete, IS 456: 2000. Bureau of Indian Standards, New Delhi.
8) Indian Standard Methods of Sampling and Analysis of Concrete, IS 1199-1959, Bureau of Indian Standards, New Delhi.
9) Krishnan, B., Singh, A. and Singhal, D. (2006), ―Mix Design Method for HPC and Effect of different types of cement on HPC‖, National Conference on HRB.
10) Indian Standard Methods of Tests for Strength of Concrete. IS: 516–1959. Bureau of Indian Standards, New Delhi.
11) Indian Standard Specification for Coarse and fine aggregates from natural sources for concrete, IS 383-1970, Bureau of Indian Standards, New Delhi.
12) "High strength concrete containing natural pozzolan and silica fume "by M.J Shannag.
13) High-strength concrete (Practical guide) by MichealA.Caldarone.
14) Safwan, A.K. and Mohamed, N.A. (1995), ―Characteristics of Silica Fume Concrete‖, Journal of Materials in Civil Engineering, Vol.6, No.3, pp. 357-375.