An Experimental Study on Strength of Self Compacting Concrete Replacing Cement with Silica Fume

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Abstract:

Self compacting concrete (SCC) is a special type of concrete that can flow through intricate geometrical configurations under its own mass without external or internal vibration or segregation. Construction of durable concrete structures requires skilled labor for placing and compacting concrete.

Therefore, there is a need to render the durability of the concrete structures to be independent of the quality of the construction worker. For the above, Self Compacting Concrete is an obvious answer. The proposed experimental program is aimed to evaluate performance of SCC by varying the percentage of Silica fumes as replacement of cement. An attempt has been made to study fresh and harden properties of Self Compacting Concrete with Silica fume as a mineral admixture.

The trial mix which satisfies the fresh concrete properties as per enforce guidelines. In this project the strength characteristics of M30 grade of Self Compacting Concrete were tested by casting concrete specimens using 53 grade of OPC. Various workability tests and strength tests were conducted.

This research work presents an investigation of the cement has been replaced by silica fume accordingly in the range of 0%, 5%, 10%, 15% and 20% by weight of cement for M-30 mix. After iterative trial mixes the water/cement ratio (w/c) was selected as 0.40. Self compacting Concrete mixtures produced, tested and compared in terms of Cubes of size 150mmx150mmx150mm and cylinder size 150 mm in diameter and 300mm long to check the compressive strength and beams of size 500mmx100mmx100mm for checking flexural strength were casted. All the specimens were cured for the period of 7, 14 and 28 days before testing. .

Keywords **Self Compacting Concrete, Silica Fume, Fresh Concrete test etc**

1. Introduction

Self – consolidating concrete has recently been used in the pre – cast industry and in some commercial applications, however the relatively high material cost still hinders the wide spread use of such specialty concrete in various segments of the construction industry, including commercial and residential construction.

Self – compacting concrete (SCC) is a fluid mixture, which is suitable for placing difficult conditions and also in congested reinforcement, without vibration. In principle, a self – compacting or self – consolidating concrete must have a fluidity that allows self – compaction without external energy. Remain homogeneous in a form during and after the placing process. Flow easily through reinforcement. The

SCC essentially eliminates the need for vibration to consolidate the concrete.

This results in an increase in productivity, a reduction in noise exposure and a finished product with few if any external blemishes such as “bug holes”. However, after completion of proper proportioning,

This project presents the feasibility of the usage of Fly ash and silica fume partially substitutes for cement in self compacting concrete. Tests were conducted on cubes, beams and cylinder to study the compressive, tensile and flexural strengths of concrete for SCC with Fly ash and silica fume partially as cement. Silica fume As per ACI 116R, silica fume is defined as a by - product from electric arc furnaces used in the manufacture of silicon metal or silicon alloys. It exhibits excellent Pozzolanic characteristics. The use of Fly ash as a partially in cement in self compacting concrete is expected to affect some properties, such as the compressive strength, durability, strength development, and economy.

However the reduction in compressive strength of Fly ash in self compacting concrete was overcome when mineral admixtures such as silica fume are used. Silica fume is a highly reactive Pozzolanic and the micro filling abilities of its ultrafine particles results in concrete with a much denser matrix. Silica fume is 100 times finer than fly ash and has over 90% of silicon hydroxide. This will mean an increase rate of gain of strength and improved impermeability at a much earlier age than a fly ash mix. Silica fume was more effective than fly ash to overcome the loss of strength and produced the highest level of compressive strength at any age.

2.LITERATURE REVIEW

Junaid Mansoor , Syyed Adnan Raheel Shah , Mudasser Muneer Khan , Abdullah Naveed Sadiq , Muhammad Kashif Anwar[12] This study aims to enlighten the use and comparative analysis for the performance of concrete with added industrial byproducts such as Ground Granulated Blast Furnace Slag (GGBFS), Silica fumes (SF) and Marble Powder (MP) in the preparation of SCC. This paper deals with the prediction of mechanical properties (i.e., compressive, tensile and flexural Strength) of self-compacting concrete by considering four major factors such as type of additive, percentage additive replaced, curing days and temperature using Artificial Neural Networks (ANNs).

Bhanja and Sengupta, 2002 represents a mathematical model developed using statistical methods to predict the 28-day compressive strength of silica fume concrete with water-to cement (w/cm) ratios ranging from 0.3 to 0.42 and silica fume replacement percentages from 5 to 30. Strength results of 26 concrete mixes, on more than 300 test specimens, have been analyzed for statistical modeling. The ratios of compressive strengths between silica fume and control concrete have been related to silica fume replacement percentage. The expression, being derived with strength ratios and not with absolute values of strength, is independent of the specimen parameters and is applicable to all types of specimens. On examining the validity of the model with the results of previous researchers, it was observed that for results on both cubes and cylinders, predictions were obtained within 7.5% of the experimentally obtained values.

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A. In 2001, Nan-Su e al conducted experimental studies and tests on concrete for achieving self-compacting property and finally given a simplest procedure called Nan-Su method of mix design for self-compacting concrete.

B. In 2011, B Mahalingam et al carried out an experimental work on SCC using fly ash as partial replacement material for cement, at replacement levels of 30%, 40% and 50% respectively and also using suitable super plasticizer. Finally SC with 30% replacement of fly ash gives better results for fresh and hardened properties of concrete.

C. In 2012, Navaneetha Krishnan et al did an investigation study on SCC using Nan-Su method of mix design with silica fume as
a partial replacement material, at various replacement levels of 0%, 10%, 15% and 20% for cement. Finally SCC with 15% replacement of silica fume gives maximum compressive strength values compared to other replacements

A. Ravichandran, K. Suguna and P. N. Ragunath (2009)(15) In this study high strength concrete (HSC) of 60 MPa containing hybrid fibers, combination of steel and polyolefin fibers, at different volume fraction of 0.5, 1.0, and 2.0% were compared in terms of compressive strength, splitting tensile and flexural properties with HSC containing no fibers. Based on the results they have concluded that fibers when used in hybrid form could result in enhanced flexural toughness compared to high strength steel fiber reinforced concrete .The compressive strength of the fiber-reinforced concrete reached maximum at 1.5% volume fractions and the splitting tensile strength and modules of rupture improved with increasing volume fraction. Strength models were established to predict the compressive and splitting tensile strength and modules of rupture of the fiber-reinforced concrete.

3. MATERIALS AND THEIR PROPERTIES

Raw materials required for the concrete mix used in the present work are

- Cement OPC 53 Grade (Ultra tech super Shakti)
- Fine aggregate: Natural river sand
- Coarse Aggregates: 20mm(Locally Quarried and Crushed)
- Water: Potable drinking water
- Admixtures-Nil
- Silica fume powder

3.1 CEMENT: Ordinary Portland cement is very common and easily available everywhere. Ordinary Portland cement of grade 53 was used in this project to prepare the control specimen.

S. no	Property	Test value	Requirements as per Is: 12269 – 19879(11)
1	Specific gravity	3.01	3.15
2	Setting time Initial setting time	35 minutes	30 minutes (should not be less than)
3	Normal consistency	37%	-
4	Fineness of cement (by sieving test)	3.60	10% (should not be more than)

Table 1 Physical Properties of OPC 53 Grade Ultratech Brand Cement

3.2 FINE AGGREGATE: Fine aggregate which is free from debris, obtained from nearby river having 2.46 of specific gravity and passing through 4.75 mm sieve were used and Water absorption as 1.62%.and grading have zone-IV.

3.3COURSE AGGREGATE: Course aggregate is commonly known as crushed aggregates. The nominal maximum size of 20mm and 10mm aggregate were used in this study. Obtained from having of specific gravity came 2.67 and passing through max.25 mm sieve were used. Water Absorption as 0.21%.

3.4SILICA FUME: Silica fume is a waste by-product of the production of silicon and silicon alloys. Silica fume is available in different forms, of which the most commonly used in a densified form. In developed

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countries it is already available readily blended with cement. The details of silica fume used in this experiment.

I. Physical properties of the silica fume

1	Color	White
2	Specific Gravity	2.3
3	Fineness Modulus	520 Kg/M2
4	Specific Surface Area	520m2/Kg

3.5WATER

Available Water in lab was used for mixing and curing.

Figure 3.4: Silica powder

3.6 SLUMP TEST:

Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work. It is not a suitable method for very wet or very dry concrete. It does not measure all factors contributing to workability, nor is it always representative of the pliability of the concrete.

The pattern of slump is shown in Fig. It indicates the characteristic of concrete in addition to the slump value. If the concrete slumps evenly it is called true slump. If one half of the cone slides down, it is called shear slump. In case of a shear slump, the slump value is measured as the difference in height between the height of the mold and the average value of the subsidence.

The vertical difference between top of the mold and the displaces original center of the top surface of the specimen 100 mm

The pattern of slump is shown True Slump/Shear Slump/ Collapse Slump.

3.7 SLUMP FLOW TEST

The slump flow is used to assess the horizontal free flow of SCC in the absence of obstructions.

V Funnel Test and at T5 minutes

The test was developed in Japan and used Ozawa et al. The equipment consists of a V-shaped tunnel.

L box test method

This test, based on a Japanese design for underwater concrete, has been described by Peterson. The test assesses the flow of the concrete, and also the extent to which it is subjected to blocking by reinforcement.

Table 2 : Acceptance criteria for SCC as per EFNARC guide lines[22]

Method	Unit	Typical range of values	
		Minimum	Maximum
Slump flow by Abram's cone	Mm	650	800
T_{50} slump-flow	Sec	2	5
V-funnel	Sec	6	12
V-funnel at T5 minutes	Sec	0	3
L-Box	H_2/H_1	0.8	1.0

Table3 : workability test SCC

S no	Test	result
1	Slump flow (mm)	724
2	V funnel(sec)	10
3	L box	0.93

MIXING AND CASTING

Weighing:

Estimated quantities in 1 m3 of concrete

Cement = 492.5 Kg/M3

Fine Aggregates = 610.86 Kg/M3

Coarse Aggregates = 1045.78 Kg/M3

Water = 197 kg/m3

Water-cement ratio = 0.40

The ratio comes to be 1: 1.24: 2.12 @ 0.40 for M30 grade concrete.

The mix proportions used in the present study on various percentages cubes is given in table 4

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Sno	% of silica fume add	Cement	Fine aggregate	Course Aggregate	Water	Silica fume grm
1	0%	1.65	2.32	3.94	0.4	0
2	5%	1.56	2.32	3.94	0.4	82.5
3	10%	1.48	2.32	3.94	0.4	165
4	15%	1.40	2.32	3.94	0.4	247.5
5	20%	1.32	2.32	3.94	0.4	330

4.TESTING OF SPECIMENS

Different tests were conducted on the specimens to determine and compare the strength properties silica fume.

Compressive Strength

4.1Compressive Strength for cubes
4.2compressive strength for cylinders

Tests were made at the ages of 7, 14 and 28 days. The ages were calculated from the time of the addition of water to the dry ingredients. For each trial mixes, three specimens were tested at each selected age. Specimens stored in water were tested immediately on removal from the water and while they were in the wet condition. Surface water and grit were wiped off the specimens and the projecting fins were removed if found.

4.1. Compressive Strength for cubes

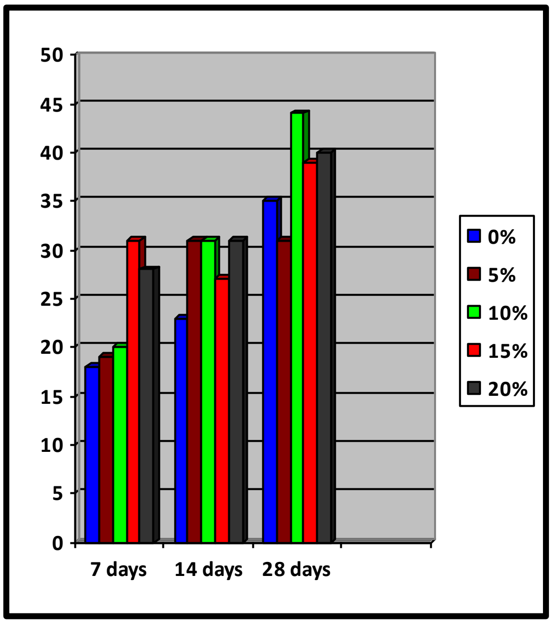
Compressive strength = P/A×1000

Where, P= failure Load in KN

A=Area of cube surface=150×150mm2

Table 5 Compressive Strength Results for cubes

S. NO	MATERIAL (silica fume)	CUBES UNDER COMPRESSIVE STRENGTH AGE IN(DAYS)		
		7	14	28
1	0%	18	23	35
2	5%	19	31	31
3	10%	20	31	44
4	15%	31	27	39
5	20%	28	31	40



Graph 4.1.1 Comparison of Compressive Strength of cubes

Discussion: Compressive Strength of cubes For 7 days curing period, the strength of the concrete is increased about 94%, 58.01% and 64.26 % increased for 15% of silica fume respectively when compared with that of conventional concrete. For 14 days curing period, the strength of the concrete increased about 79.54%, 89.7% and 87.5% for 10%,15% and 20%and decreases about 65% for 5% of silica fume respectively when compared with that of conventional concrete. At 28 days of the compressive strength of silica fume self-compacting concrete was found to be more. From the results the optimum percent of silica fume was found to be 80% is highest at 10% of silica fume used in concrete.

4.2 Compressive Strength for cylinders

Compressive strength = P/A×1000

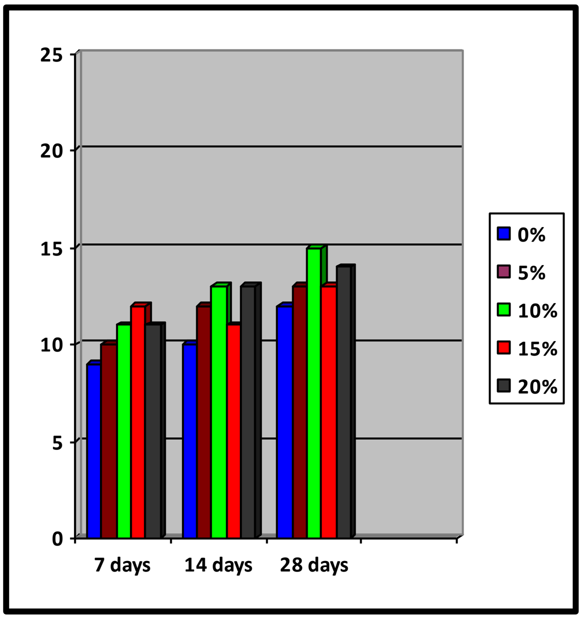
Where,

P= failure Load in KN

A=Area of cylinder surface=150×300mm2

Table 6 Compressive Strength Results for cylinders

S.NO	MATERIAL (silica fume)	CYLINDERS UNDER COMPRESSIVE STRENGTH AGE IN(DAYS)		
		7	14	28
	0%	9	10	12
1	5%	10	12	13
2	10%	11	13	15
3	15%	12	11	13
4	20%	11	13	14



Graph 4.1.2 Comparison of Compressive Strength of cylinders

Discussion: Compressive Strength of cylinders For 7 days curing period, the strength of the concrete is increased about 75% increased for 15% of silica fume respectively when compared with that of nominal mix concrete. For 14 days curing period, the strength of the concrete increased about 76.92% for 10%, 20%. At 28 days of the compressive strength of silica fume self-compacting concrete was found to be more. From the results the optimum percent of Silica fume was found to be 80% is highest at 10% of Silica fume used in concrete.

5. Conclusions

Based on the study, following conclusions can draw.

i. There is a no change in slump flow and l-box and v-funnel has maximum values when compared with normal mix in self compacting concrete.

ii. The compressive strengths of cubes and cylinders mix at the age of 7 days was gradually increases its strength when compared with normal mix.

iii. It was observed that the compressive strength of Silica fume 5% and 10% at the age of 28 days has reached its target mean strength; however the compressive strength of cubes and cylinders was increased at 10% in 28 days when compared with total replacement of all mixes.

iv. It was observed that the compressive strength of 15% and 20% cubes and cylinders at the age of 28 days has decreases its compressive strength when compared with the 10%.

v. Cement can be replaced with silica fume is higher strength at 10% without much loss in compressive strength of cubes and cylinders.

vi. It has been shown in this study that 10% silica fume can be used as a partial cement replacement material with technical and environmental benefits. Concerned stakeholder, such as silica fume industries, cement industries and relevant government institutions, should be made aware about this potential cement replacement material and promote its standardized production and usage.

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