Comparative Study of Effect of Silica Fume and Quarry Dust on Strength of Self Compacting Concrete

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Abstract

Self compacting concrete is category of high performance concrete that has excellent deformability in the fresh state and high resistance to segregation and can be placed and compacted under its self weight without applying vibration. Over the last ten years, significant amount of work has been carried out on self-compacting concrete all over the world.

The objective of this study is to compare the strength characteristics between self compacting concrete using silica fume and quarry dust. A simple mix design for SCC proposed by Nan-Su et al has been used for fixing the trial mix. The trial mixes which satisfy the fresh concrete properties as per EFNARC guidelines and the one which gives the maximum strength has been used in the present work. The harden properties such as compressive strength, split tensile strength of SCC using silica fume and quarry dust were determined, silica fume shows the better result in strength properties than those of quarry dust.

Keywords – Self compacting concrete; Silica Fume; Quarry Dust; Compressive Strength; Split Tensile Strength.

I. Introduction

The development of self compacting concrete (SCC) has been one of the most important development in the building industry. The purpose of this concrete concept is to decrease the risk due to human factor. The use of SCC is spreading world wide because of its very attractive properties. Self compacting concrete has properties that differ considerably from conventional slump concrete. SCC is highly workable concrete that can flow through densely reinforced and complex structural element under its own weight and adequately fill all voids without segregation, excessive bleeding, excessive air migration or other separation and materials and without the need of vibration or other mechanical consolidation. The use of SCC is considered to have a number of advantages as:

- Faster placement
- Better consolidation around reinforcement.
- Easily placed in the walled element.
- Improves the quality, durability and reliability of the concrete structures.
- Reduces the total time of construction and the cost.

It will replace manual compaction of fresh concrete with a modern semi-automatic placing technology and in that way improve health and safety on and around the construction site. However, this type of concrete needs a more advanced mix design than traditional vibrated concrete and a more careful assurance with more testing and checking, at least in the beginning when using SCC. It is possible to improve the mechanical properties of concrete by using chemical, mineral additives. For instance, producing SCCs with the use of chemical additives, decreasing shrinkage and permeability and using mineral additives increased compressive strength. As it is well known, there are a wide range of cementitious mortars based on cement and components similar to those of concrete. The use of industrial by-products, such as SF, QD offers a low-priced solution to the environmental problem of depositing industrial waste.

Silica Fume

Silica fume as very fine non crystalline silica produced in electric arc furnace as a by product of the production of elemental silicon or alloys containing silicon. It is usually a gray coloured powder, somewhat similar to Portland cement.

Silica fume is usually categorized as a supplementary cementitious material. It has excellent pozzolanic properties. This term refers to materials that are used in concrete in addition to Portland cement.

Quarry Dust

Basalt fines, often called quarry or rock dust are by products of the production of concrete aggregates by crushing of rocks.

The addition of quarry dust to normal concrete mixes is limited because of its high fineness. The addition of quarry dust to fresh concrete increases the water demand and consequently the cement content for given workability and strength requirement however potential benefits to using quarry dust is the cost having, because the material cost varies depending on the source.

II. Experimental Investigation

2.1 Materials

2.1.1 Cement

In this experimental study, Ordinary Portland Cement 53 grade, conforming to IS: 8112-1989 was used. The different laboratory tests were conducted on cement to determine the physical and mechanical properties of the cement used are shown in Table 1.

Table 1: Properties of Cement

Physical Property	Result
Fineness (retained on 90-□m sieve)	5%
Normal Consistency	29%
Vicat initial setting time (minutes)	75 min.
Vicat final setting time (minutes)	482 min.
Specific gravity	3.12
Compressive strength at 7-days	37.33 Mpa
Compressive strength at 28-days	53.64 Mpa

2.1.2 Aggregates

Locally available natural sand with 4.75 mm maximum size confirming to class II- IS 383 was used as fine aggregate, having specific gravity, fineness modulus and unit weight as given in Table 3 and crushed stone with 16mm maximum size having specific gravity, fineness modulus and unit weight as given in Table 3 was used as coarse aggregate. Table 2 gives the physical properties of the coarse and fine aggregates.

Table 2: Physical Properties of Coarse and Fine Aggregates

Property	Fine Aggregate	Coarse Aggregate
Specific Gravity	2.5	2.85
Fineness Modulus	2.8	7.44
Surface Texture	Smooth	---
Particle shape	Rounded	Angular

2.1.3 Water

Ordinary potable water available in the laboratory has been used.

2.1.4 Chemical Admixtures

Super plasticizers or high range water reducing admixtures are an essential component of SCC. It is used to provide necessary workability. Glanium B233 (modified P.C. based) was obtained from BASF India Limited, Mumbai.

2.1.5 Quarry Dust

Quarry dust is used as an inert powder. It has been obtained from stone crusher; Quarry dust of specific gravity 2.5 passing through 90µ sieve is used. Chemical composition of Quarry dust is given in table 3.

Table 3: Chemical Composition of Quarry Dust

Sr. No.	Constituents	Quantity (%)
1.	SiO_2	70.74
2.	Al_2O_3	20.67
3.	Fe_2O_3	2.88
4.	TiO_2	0.33
5.	Na_2O	0.11
6.	K_2O	0.19
7.	MgO	1.57
8.	M_2O_2	0.01
9.	CaO	0.2
10.	ZnO	0.01
11.	Pb	625 ppm
12.	Cr	125 ppm
13.	LOI	0.72

2.1.6 Silica Fume

Silica fume imparts very good improvement to rheological, mechanical and chemical properties. It improves the durability of the concrete by reinforcing the microstructure through filler effect and reduces segregation and bleeding. It also helps in achieving high early strength. Silica fume of specific gravity 2.2 is used in this study. Chemical composition of silica fume is given in table 4. Silica fume was obtained form ELKEM materials, Mumbai.

Table 4: Chemical Composition of Silica Fume

Sr. No.	Constituents	Quantity (%)
1.	Sio_2	91.03
2.	Al_2O_3	0.39
3.	Fe_2O_3	2.11
4.	CaO	1.5
5.	LOI	4.05

2.2 Mix Proportion

The mix proportion was done based on the method proposed by Nan-Su et al. [4]. The mix designs were carried out for concrete grades 25, 35, 45. This method was preferred as it has the advantage of considering the strengths of the SCC mix.

The details of mixes are given in table 5. All the ingredients were first mixed in dry condition. Then 70% of calculated amount of water was added to the dry mix and mixed thoroughly. Then 30% of water was mixed with the super plasticizer and added in the mix.

Then the mix was checked for self compacting ability by slump flow test, v-funnel test and L-box test.

Table 5: Mixture proportion for 1m^3 of SCC

Grade of concrete	Cement (kg/m^3)	Fine Agg. (kg/m^3)	Coarse Agg. (kg/m^3)	Silica Fume (kg/m^3)	Water (kg/m^3)	Water/Binder	Super Plasticizer (kg/m^3)
αS1	315	960	813	215	239	0.45	6.2
αS2	357	960	813	196	223	0.40	6.3
αS3	411	960	813	135	196	0.35	7.29

Grade of concrete	Cement (kg/m^3)	Fine Agg. (kg/m^3)	Coarse Agg. (kg/m^3)	Crusher dust (kg/m^3)	Water (kg/m^3)	Water/Binder	Super Plasticizer (kg/m^3)
αD1	315	960	813	215	239	0.45	2.558
αD2	357	960	813	196	223	0.40	3.0
αD3	411	960	813	135	196	0.35	3.5

Self Compact ability Tests on SCC Mixes

Various tests were conducted on the trial mixes to check for their acceptance and self compact ability properties. The tests included flow test and V-funnel tests for checking the filling ability and L-box test for passing ability. The mixes were checked for the SCC acceptance criteria given in table no. 6.

Table No. 6 SCC Acceptance Criteria

Method	Properties	Range of values
Slump flow	Filling ability	650-800mm
V-funnel	Viscosity	6-12 sec.
L-box	Passing ability	0.8-1.0

Table 7: SCC Test Results of SCC Mixes

Mix Code	Flow (mm)	V-funnel time (s)	L-box (h2/h1)	Segregation	Remark
□S1	660	8.6	0.90	No	SCC
□S2	680	8.9	0.88	No	SCC
□S3	710	9.4	0.97	No	SCC
□D1	720	8.8	0.95	No	SCC
□D2	705	9.3	0.93	No	SCC
□D3	690	9.5	0.90	No	SCC

The result of the self compact ability tests are tabulated in table 7. All the mixes satisfied the acceptance criteria for self compacting concrete. Hence these mixes were chosen as the successful mixes. The cube specimens of size 150 x 150 x 150 mm were cast for the successful mixes and were tested for the 7-day 28-day compressive strengths. Also cylindrical specimens of size 300mm height and 150mm diameter were cast and tested for 28-days split tensile strength.

3. RESULT AND DISCUSSION

3.1 HARDENED PROPERTIES OF SCC MIXES

Compressive Strength of SCC Mixes

Table 9 and fig. no. 8 gives the cube compressive strength of the mixes. It can be seen that strength increases with decreasing Silica Fume and Quarry Dust content. Four standard cubes each for various mixes were tested to determine 7 days and 28 days compressive strength, compressive strength increased with decrease in W/C ratio.

The strength of SCC with silica fume and SCC with quarry dust ranges from **45 MPa** to **62 MPa** and **31 MPa** to **52 MPa** respectively, average compressive strength of SCC having silica fume at 28-days compared to SCC having quarry dust was increased by **25.51%.** Depending upon the mineral admixture, curing condition, the result indicates that the Mineral admixture addition helps in gain of compressive strength than that of Quarry dust. The compressive strength of SCC containing silica fume was greater than that of SCC containing Quarry dust.

Split Tensile Strength

The split tensile strength result shown in table 9 and fig. no. 9. Two standard cylinder specimens each for various mixes were tested to determine 7-days and 28-days split tensile strength. Split tensile strength shows the same trend as compressive strength, increased with decrease in W/C ratio.

Split tensile strength of SCC containing Silica Fume & SCC having quarry dust ranges from **4.3 MPa** to **6.72 MPa** and **3.5 MPa** to **5.29 MPa** respectively. Average split tensile strength of SCC having silica fume at 28-days compared to SCC having quarry dust was increased by **18.06%.**

Silica fume shows the better result in strength properties than quarry dust.

Table 9: Harden Properties

Mix Code	W/C	Compressive Strength (MPa)		Split Tensile Strength (MPa)	
		7 Days	28 Days	7 Days	28 Days
αS1	0.45	27.33	45.11	3.07	4.3
αS2	0.40	32.29	57.11	4.87	5.58
αS3	0.35	44.66	61.12	5.86	6.72
αD1	0.45	22.52	31.5	2.1	3.5
αD2	0.40	29.4	39.9	3.4	4.78
αD3	0.35	37	51.2	4.2	5.29

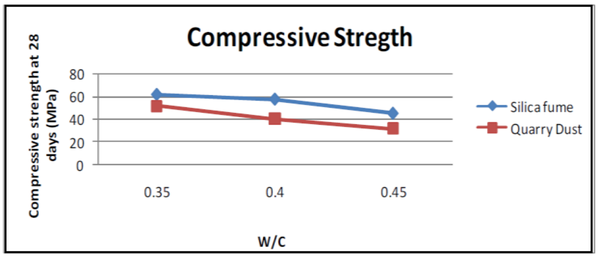

Fig. 8: Result of Compressive strength

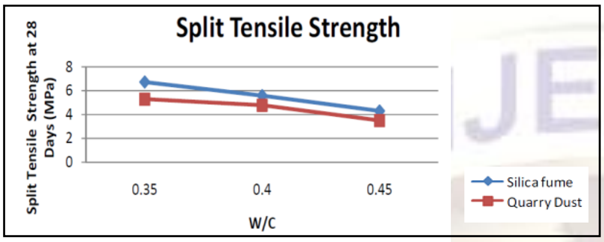

Fig. 9: Result of Split Tensile Strength

III. Conclusion

In the present comparative study of self compacting concrete using Silica Fume and Quarry Dust following conclusions were arrived from the experimental investigation. Because of extreme fineness and very high amorphous silicon dioxide content, silica fume is a very reactive pozzolanic material. Hence SCC with silica fume shows the good result in both tension and compression.

1. Silica fume was observed to improve the mechanical properties of SCC because of the pozzolanic action of silica fume.
2. Average compressive strength of SCC having silica fume at 28-days compared to SCC having quarry dust was increased by **25.51%.**
3. Average split tensile strength of SCC having silica fume at 28-days compared to SCC having quarry dust was increased by **18.06%.**
4. It has been indicated that SCC having Silica Fume have higher compressive strength and split tensile than those of SCC having inert powder as additional filler i.e. quarry dust. The silica fume has contributed to large extent in development of strength.
5. As the water cement ratio reduces and cements content increases, strength increases in SCC made with silica fume and SCC made with quarry dust.

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