Development of Self Compacting Concrete using Silica Fume

M.Rame Gowda[1] Naveen Kumar S M[2] Laxmisagar H Kalmani[3]
[1]Professor & Head [2]Assistant Professor [3]PG Student
[1,2,3]Department of Civil Engineering
[1,2,3]Adichunchanagiri Institute of Technology, Chikmagalur, India

Abstract— Development of SCC is a desirable achievement in the construction industry in order to overcome the problems associated with cast-in-place concrete. SCC is not affected by the skills of workers, shape, size and amount of reinforcing bars used or arrangement of different structural elements, but due to its high fluidity and resistance to segregation, it can be pumped to longer distances. The main reasons for the employment of self-compacting concrete is to shorten the construction period, and to assure compactions in the structure, especially in confined zones where vibration is difficult, and to eliminate noise due to vibration. A simple mix design for SCC proposed by Nan su et al. is used for achieving the trial mixes. The trial mix which satisfies the rheological properties as per EFNARC guidelines and the corresponding developed mix which gives maximum compressive and splitting tensile strengths are used in the present work. Cement is replaced with varying percentages of silica fume (SF) ranging from (0-15%) at an interval of 2.5%. SCC with 5% silica fume shows better results when compared to other replacement levels. Hence it is found that silica fume can be effectively used as an alternate for cement replacement.

Key words: Self-Compacting Concrete (SCC), Silica Fume (SF), Compressive Strength, Splitting Tensile Strength

I. Introduction

SCC development is a wonderful achievement in the construction industry in order to overcome problems associated with cast-in-place concrete. It is not affected by the skills of workers, but due to its high fluidity and resistance to segregation it can be pumped to longer distances depending upon the requirements. The concept of SCC was proposed in 1986, but the prototype was first developed during 1988 at Kochi University in Japan. SCC was developed at that time to improve durability, reduce construction period and to achieve good surface finishes of the concrete structures. To cast SCC no additional inner or outer vibration is necessary for the compaction. It flows like 'honey' and has a very smooth surface level after placing. With regard to its composition, SCC consists of the same components as conventionally vibrated concrete, which are cement, aggregates and water with the addition of chemical and mineral admixtures in different proportions.

II. Literature Review

SCC is an innovative concrete that does not require vibration for placing and compaction investigated by Bhaskar.et.al (1999).Further this paper deals with flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement.

Construction of durable concrete structures requires skilled labor for placing and compacting concrete. Therefore, there is a need to render the durability of concrete structures to be independent of the quality of the construction worker. For the above, SCC is an obvious answer reported by Nan Su et.al (2001). The proposed experimental programme is aimed to evaluate performance of SCC by varying the percentage of SF as a replacement to cement highlighted by Navaneethakrishnan et.al (2012).

Self-consolidating concrete has properties that differ considerably from conventional slump concrete reported by Manu Santhanam et.al. (2004). SCC is highly workable concrete that can flow through densely reinforced and complex structural elements under its own weight and adequately fill all voids without segregation, excessive bleeding, excessive air migration or separation of materials and without the need for vibration or other mechanical consolidation reported by Vengala et.al (2003).

III. Experimental Programme

The experimental investigation consists of testing of basic materials in the laboratory and then fixing the optimum mix for SCC taking into account the criteria for SCC as per EFNARC Guidelines and Nan-Su method. The design mix is worked out by Nan-Su method, and then the developed ratio is taken as trial mix ratio. As per EFNARC guidelines the trial mixes developed should satisfy the filling ability, passing ability and segregation resistance. The mix which satisfies all these cases is known as controlled mix concrete. For this mix cement is replaced by silica fume in the range of (0-15%) at an interval of 2.5% and these developed mixes should be designed and tested for their rheological and hardened properties of the concrete.

A. *Materials used*

The cement used in the work was ordinary Portland cement of 43Grade. Fine aggregate used was river sand passing through 4.75mm sieve and coarse aggregate of size 12mm downsize were used for the SCC mixes. Mineral admixture micro silica was used in the present investigation. Cement is replaced with SF ranging from (0- 15%) by weight of cement. To improve workability and reduce segregation Glenium $^{TM}B_{233}$ is used in the work.

IV. Results and Discussion

The materials used in the present work are tested in the laboratory and results obtained are reported in Table 4.1

Material	Name of Tests	Results	As per IS requirements
Cement	Specific gravity	2.80	3.15
	Normal consistency (%)	28	
	Initial setting time(min)	68	30
	Final setting time (min)	346	600

	Fineness of cement (%)	9	10
Silicafume	Specific gravity	2.20	-
Fine Aggregate	Specific gravity	2.70	2.75
	Bulk density (Kg/m^3)	1088	1250
	Water absorption (%)	1.8	2
	Fineness modulus	2.30	3.2
Coarse Aggregate	Specific gravity	2.7	2.85
	Bulk density (Kg/m^3)	1148	1450
	Water absorption (%)	0.46	0.6

Table 1: Results of materials used

A. *Mix Design for SCC*

The mix design method proposed and used in the present work developed in Taiwan by Nan-Su is as listed below.

1) *Mix Design Procedure*

a) Calculation of coarse and fine aggregates content

The parameters considered in the mix design are

- S/a ratio: It is a ratio of fine aggregate to total mass of aggregate, which ranges usually from 50 to 57%, (S/a) is taken as 50%.
- Packing factor (PF): The value ratio of aggregate after lubrication and compaction in SCC is about 59-68%. In this study PF value selected is 1.2.
- Wfa = Mass of the fine aggregate
- Wca = Mass of the coarse aggregate
- Wfal = Bulk density of fine aggregate
- Wcal = Bulk density of coarse aggregate
- f_c = Grade of concrete
- CF = Correction factor

1) Step 1: Calculation of fine aggregate

Wfa = PF * Wfal* S/a

= 1.2 * 1088 * (50/100) = 652.8 Kg/m^3.

2) Step 2: Calculation of coarse aggregate

Wca =PF * Wcal * (1-S/a)

= 1.2 X 1148 X (1-50/100) = 688.8 Kg/m^3.

3) Step 3: Calculation of cement content

C = (f_c/0.14) * CF

= (35/0.14) X 1.535= 383.75 Kg/m^3.

4) Step 4: Calculation of mixing water content required by cement

The content of mixing water required by cement can be obtained by using the equation.

Wwc = [w/c] × C = [0.8] ×383.75 = 307 Kg/m^3.

5) Step 5: Final quantities

Cement = 383.75 Kg/m^3.

Fine aggregate = 652.80 Kg/m^3.

Coarse aggregate = 688.80 Kg/m^3.

Water content = 307 Kg/m^3.

ratio = 1:1.63:1.79

Mix proportion obtained by Nan-Su, method is 1:1.63:1.79 and w/p ratio 0.80.

B. *Trial Mixes*

The trial mix details achieved in the laboratory is as shown in Table 2.

Mix Designation	Mix ratio	SP (%)	w/p ratio	Slump flow (mm)	U-Box (mm)	V-Funnel T_{5min}(Sec)	Remarks
Mix-1	1:1.63:1.79	0.50	0.8	385	76	No flow	NS
Mix-2	1:1.58:1.74	0.60	0.85	430	67	No flow	NS
Mix-3	1:1.52:1.69	0.70	0.75	468	59	No flow	NS
Mix-4	1:1.47:1.64	0.80	0.65	513	51	59	NS
Mix-5	1:1.40:1.55	0.90	0.60	567	46	43	NS
Mix-6	1:1.35:1.48	1.00	0.55	610	37	35	NS
Mix-7	1:1.33:1.45	1.10	0.50	655	28	26	NS
Mix-8	1:1.30:1.42	1.15	0.45	680	19	18	NS
Mix-9	1:1.30:1.40	1.20	0.43	710	9	13	S

Table 2: Trial Mixes for SCC

*Note: NS-Not Satisfied, S-Satisfied

Several trial mixes are prepared by changing the volume ratio of fine aggregate, coarse aggregate, w/p ratio and Super plasticizer dosage. In this process Mix-9 with proportions (1:1.3:1.4), which satisfies the rheological properties as per EFNARC guidelines is chosen as control mix, corresponding to w/p ratio of 0.43 and SP dosage of 1.20%.

C. *Rheological Properties of Concrete*

The rheological property of different mixes obtained by trial procedure is as shown in Table 3.

Mixes ID	**Slump Flow (mm)**	**Slump Flow $T_{5min(Sec)}$**	**V-Funnel (Sec)**	**V-funnel T_{5min} (Sec)**	**J-ring (mm)**	**U-box (mm)**
SCC	710	3.46	8	1.53	4	9
SCC_SF (2.5%)	706	3.34	9	2.06	4	13
SCC_SF (5.0%)	702	3.12	9	2.10	5	17
SCC_SF (7.5%)	700	3.04	10	2.22	6	19
SCC_SF (10.0%)	696	2.97	10	2.35	7	22
SCC_SF (12.5%)	689	2.90	11	2.46	8	26
SCC_SF (15.0%)	682	2.82	12	2.52	8	28

Table 3: Rheological Properties of SCC

From the above table it is observed that flow ability decreases as passing ability increases for SCC mixes. As flow ability decreases, but it increases the segregation resistance of the mixes.

D. Hardened Properties of Concrete

The hardened properties of concrete such as compressive and splitting tensile strengths computed are reported in Tables 4 and 5.

Mix Specifications	Compressive strength (MPa)	
	7-days	28-days
SCC	27.20	44.60
SCC_SF2.5%	28.70	46.30
SCC_SF5%	30.10	47.20
SCC_SF7.5%	29.70	47.00
SCC_SF10%	29.00	45.90
SCC_SF12.5%	27.70	45.20
SCC_SF15%	25.80	42.70

Table 4: Results of compressive strength

From the above table it is observed that compressive strength at 28-days is more than 7-days. The optimum strength gain is at 5% and the lowest strength is at 15% replacement levels of silica fume with cement corresponding to both the ages. It is seen that as the age increases strength increases marginally but as the percentage increases strength decreases slightly.

Mix Specifications	**Splitting tensile strength (MPa)**	
	7- days	**28- days**
SCC	2.80	3.10
SCC_SF2.5%	2.90	3.30
SCC_SF5%	3.00	3.50
SCC_SF7.5%	2.90	3.40
SCC_SF10%	2.85	3.30
SCC_SF12.5%	2.80	3.10
SCC_SF15%	2.60	3.00

Table 5: Results of splitting tensile strength

From the above table, it is observed that the splitting tensile strength of 28-days is more than that of 7-days. The optimum strength gain is at 5% and the lowest strength is at 15% replacement levels of silica fume with cement corresponding to both the ages. This fact is same both in compressive and splitting tensile strengths evaluation. Further marginal gain in strength corresponding to age but slight decrease in strength corresponding to increase in percentage of the silica fume.

V. Conclusions

On the basis of laboratory investigations the following conclusions can be drawn.

- Self-compacting concrete mixes can be developed with silica fume without sacrificing the strength.
- Self-compacting concrete mixes requires high powder content and all most equal quantity of coarse and fine aggregates proportion.
- Super plasticizer is always necessary to full fill the rheological properties of SCC.
- The density of SCC is slightly increases for cubes and cylinders with the addition of silica fume.
- Silica fume can be effectively used as a partial replacement up to 12.5% by weight of cement without decreasing the strength and thus reduces the consumption of cement which in turn reduces the cost of concrete.
- Percentage increase of silica fume in the range of (2.5-15%) at an interval of 2.5% reduces the flow ability of concrete.
- Self-compacting concrete with 5% replacement of cement with silica fume shows better results both in compressive and splitting tensile strengths.
- It can be seen from the results of rheological properties, addition of silica fume improves the filling ability and segregation resistance compared to controlled concrete mixes.

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References

[1] Bhaskar I, Ramanathan P, Venkatasubramani R, (1999), “Influence of silica fume on properties of Self-compacting concrete,” Journal of Research of NIST, Vol. 104, No. 5, pp.461-478.
[2] Nan Su, Kung-Chung Hsu and His-Wen Chai,(2001), “A simple mix design method for Self-compacting concrete,” Cement and Concrete Research, 2001, pp.1799-1807
[3] Vengala, Jagdish, Sudarshan, M.S and Ranganath, R.V, (2003), “Experimental study for obtaining Self-compacting concrete,” Indian Concrete Journal, Vol.77, No.8, pp.1261-1264.
[4] Manu Santhanam (2004), “Current developments in Self-compacting concrete,” Indian Concrete Journal (11) -Vol. 78, No. 6, pp. 1-34.
[5] Salem Al-Sanusi and Hakeem Esmoue and Waneisa A. Gumma (2012), “Influence of silica fume on the properties of Self-compacting concretes,” International Journal of emerging trends in engineering and developments, Issue 2, Vol. 4, May, pp. 1-7.
[6] Navaneethakrishnan and V. M. Shanthi, (2012), “Experimental study of Self-compacting concrete using silica fume,” 3rd International Conference on Engineering Optimization Rio Janeiro, Brazil, July, pp.475-482.

