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Study on Effect of Self-Compacting Concrete with Partial Replacement of Mineral Admixtures Using Quarry Dust

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ABSTRACT:- This study presents an experimental investigation on self compacting concrete (SCC) with various partial replacements of fly ash, silica fume and combination of both fly ash and silica fume. Also the study made with fully replacement of natural sand by quarry dust. After various replacements, cube and cylinder specimens are cast and cured. The specimens are cured in water for 3, 7 & 28 days. The slump, V-funnel and L-Box test are carried out on the fresh SCC and in harden concrete compressive strength and split tensile strength values are determined. Attempts have been made to study the properties of such SCCs and to investigate the suitability of various replacements of fly ash, silica fume and quarry dust to be used in SCC.

I. INTRODUCTION

Self-compacting concrete (SCC) is considered as a concrete which can be placed and compacted under its self weight with little or no vibration effort, and which is at the same time cohesive enough to be handled without segregation or bleeding of fresh concrete. SCC mixes usually contain superplasticizer, high content of fines and/or viscosity modifying additive (VMA). Whilst the use of superplasticizer maintains the fluidity, the fine content provides stability of the mix resulting in resistance against bleeding and segregation.

However, the high dosage of super-plasticizer used for reduction of the liquid limit and for better workability, the high powder content as 'lubricant' for the coarse aggregates ,as well as the use of viscosity-agents to increase the viscosity of the concrete have to be taken into account.Super plasticizer enhances deformability and with the reduction of water/powder segregation resistance is increased. High deformability and high segregation resistance is obtained by limiting the amount of coarse aggregate. These two properties of mortar and concrete in turn lead to self compactability limitation of coarse aggregate content.

II. MATERIALS USED IN THIS EXPERIMENT

2.1Cement

In this experimental study, Ordinary Portland Cement conforming to IS: 8112-1989 was used. The physical and mechanical properties of the cement used are shown in Table1.

Table-1: Properties of Cement

Physical property	Results
Fineness (retained on 90-µm sieve)	8%
Normal Consistency	28%
Vicat initial setting time (minutes)	75
Vicat final setting time (minutes)	215
Specific gravity	3.15
Compressive strength at 7-days	20.6 MPa
Compressive strength at 28-days	51.2 MPa

2.2 Fly ash (Class –F type)

The flow ability of self compacting concrete depends on the powder and paste content. Hence, in order to increase the flow ability, mineral admixtures such as fly ash has been used. A class 'F' flyash obtained from Ennore Thermal Power Plant (Chennai, Tamil Nadu) was used. Table 2 gives the physical properties of the fly ash.

Table-2: Properties of Fly Ash

Physical Properties	Test Results
Colour	Grey (Blackish)
Specific Gravity	2.12

2.3 Silica 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 now is in a densified form. In developed countries it is already available readily blended with cement. The details of silica fume used in this experiment are in the Table-3

Table-3: Details of Silica Fume

Code	**920-D**
Type	**Densified (Non-Combustible)**
Main content	**Amorphous Sio_2**

2.4 Aggregates

Locally available natural sand with 4.75 mm maximum size was used as fine aggregate, having specific gravity, fineness modulus and unit weight as given in Table-4 and crushed stone with 12mm maximum size having specific gravity, fineness modulus and unit weight as given in Table-4 was used as coarse aggregate. Table-4 gives the physical properties of the coarse and fine aggregates.

Table-4: Physical Properties of Coarse and Fine Aggregates

Property	Fine Aggregate	Coarse Aggregate
Specific Gravity	2.56	2.7
Fineness Modulus	3.1	7.69
Surface Texture	Smooth	--
Particle Shape	Rounded	Angular
Crushing Value	---	17.40
Impact Value	---	12.50

2.5 *Super plasticizer (SP)*

The admixture used was a super plasticizer based on viscosity modified polycarboxylates, which was used to provide necessary workability. A new generation based Polycarboxylic ether (PCE) was used, which is known as PCE (Viscosity Modified). Table-5 gives the Properties of PCE.

Table-5: Properties of PCE

Name	CONXL-PCE 8860 (Viscosity Modified)
Color	**Dark Amber Color**
Solid Content	**40%**
Ph	**8.0**
Specific Gravity	**1.14**

2.6 Quarry Dust(QD)

Locally available quarry dust was collected from crushing quarry near Mailam. Quarry dust comprises of the smaller aggregate particles, so it was sieved to 1.18mm and then used for the replacement of fine aggregate.

Table-6: Properties of Fly Ash

Physical Properties	Test Results
Colour	Grey
Specific Gravity	2.4

2.7 Water

Ordinary tap water is used.

3. SCC Mix Design

Several methods exist for the mix design of SCC. The general purpose mix design method was first developed by Okamura and Ozawa (1995). In this study, the key proportions for the mixes are done by volume. The detailed steps for mix design are described as follows:

- Assume air content as 2% (20 litres) of concrete volume.
- Calculate the coarse aggregate content by volume (28 – 35%) of mix volume.
- Adopt fine aggregate volume of 40 to 50% of the mortar volume.
- Replace cement with Class F type fly ash, silica fume and the combination of both by weight of cementitious material.
- Optimize the dosages of super plasticizer (viscosity modified)

- Perform SCC tests.

Table 7: Mix Design Proportions SCC for Different Combination

Mix	Binder (kg/m^3)			Fine Agg kg/m^3	Coarse Agg kg/m^3	Water kg/m^3	S.P kg/m^3
	Cement	**Fly Ash**	**Silica Fume**				
SCC	536.00	---	---	836	771.84	192.26	4.824
				W/B= 0.36		**S.P %=0.9**	
FA10 %	472.00	52.45	---	836	771.84	188.82	4.721
FA20%	410.80	102.70	---	836	771.84	184.86	4.622
FA30%	351.75	150.75	---	836	771.84	180.90	4.523
SF5%	506.35	---	26.65	836	771.84	191.88	4.797
SF10%	477.00	---	53.00	836	771.84	190.80	4.770
SF15%	447.95	---	79.05	836	771.84	189.72	4.743
SF20%	418.80	---	105.00	836	771.84	188.46	4.712
SF5+FA30	324.68	149.85	25.00	836	771.84	179.82	4.500
SF10+FA20	355.25	101.50	50.75	836	771.84	182.70	4.570
SF15+FA10	378.00	50.40	75.60	836	771.84	181.44	4.536

1) Mixing procedure for SCC

Mixing procedure for SCC is described as follows:

- Binder and aggregate are mixed for one minute.
- The 1st part (70%) of water was added and mixed for two minutes.
- SP along with the 2nd part (30%) of water was added and mixed for two minutes.
- The mix was stopped and kept rest for 2 minutes.
- The mix was remixed for one minute and discharged for SCC tests

A. Testing Fresh Properties of SCC

1) Slump Flow Test

Slump flow test apparatus is shown in Figure 1(a). Slump cone has 20 cm bottom diameter, 10 cm top diameter and 30 cm in height. In this test, the slump cone mould is placed exactly on the 20 cm diameter graduated circle marked on the glass plate, filled with concrete and lifted upwards. The subsequent diameter of the concrete spread is measured in two perpendicular directions and the average of the diameters is reported as the spread of the concrete.

T50cm is the time measured from lifting the cone to the concrete reaching a diameter of 50 cm. The measured T50cm indicates the deformation rate or viscosity of the concrete.

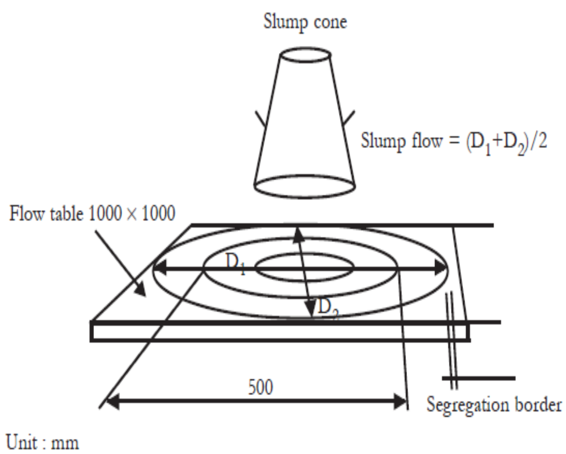


Figure 1(a): Slump flow& T50 sec Test

2. V-Funnel Test

V-Funnel test apparatus is shown in Figure 1(b). In this test, trap door is closed at the bottom of V-Funnel and V-Funnel is completely filled with fresh concrete. V-Funnel time is the time measured from opening the trap door and complete emptying the funnel. Again, the -Funnel is filled with concrete, kept for 5 minutes and trap door is opened. V-Funnel time is measured again and this indicates V-Funnel time at T5min.

Figure 1(b): V- Funnel Test

3. L-Box Test

L-Box test apparatus is shown in Figure 1(c). In this test, fresh concrete is filled in the vertical section of L-Box and the gate is lifted to let the concrete to flow into the horizontal section. The height of the concrete at the end of horizontal section represents h2 (mm) and at the vertical section represents h1 (mm). The ratio h2/h1 represents blocking ratio.

Figure 1(c): L-Box Test

Table 8: Result of Fresh Properties of SCC mixes with different partial replacement of mineral admixtures

S.No	Mix	Slump (mm)	T50 (sec)	V-Funnel (sec)	T5 min (sec)	L-Box (h_2/h_1)
1	SCC 0	675	4.4	12	13.5	0.9
2	FA10%	682	4.0	11.0	13.1	0.86
3	FA20%	692	3.6	10.8	12.8	0.84
4	FA30%	710	3.1	9.2	12.3	0.81
5	SF5%	670	4.6	10.2	13.0	0.9
6	SF10%	667	4.8	10.5	13.5	0.92
7	SF15%	660	4.9	10.7	13.8	0.96
8	SF20%	650	5.0	11.0	14.2	0.98
9	SF5+FA30	692	3.4	8.2	11.9	0.83
10	SF10+FA20	680	3.6	8.5	12.3	0.9
11	SF15+FA10	675	3.8	9.0	12.8	0.92
#	EFNARC	650-800	2-5	6-12	6-15	0.8-1.0

III. STRENGTH PARAMETERS OF SCC WITH DIFFERENT PARTIAL REPLACEMENT OF MINERAL ADMIXTURES

In order to study the effect on fresh properties of SCC when fly ash and silica fume as partial replacement of cement were tested for compressive strength and split tensile test. The result for compressive strength and split tensile strength were found at ages of 3, 7 and 28 days for cubes and cylinders respectively. Three specimens were crushed for the average of each age of compressive strength results are presented in Table 13 and Figure 26. The result shows that the SCC with the partial replacement of fly ash and silica fume has more compressive strength than the controlled SCC mix. And also the combination of fly ash and silica fume shows more compressive strength than the controlled SCC mix.

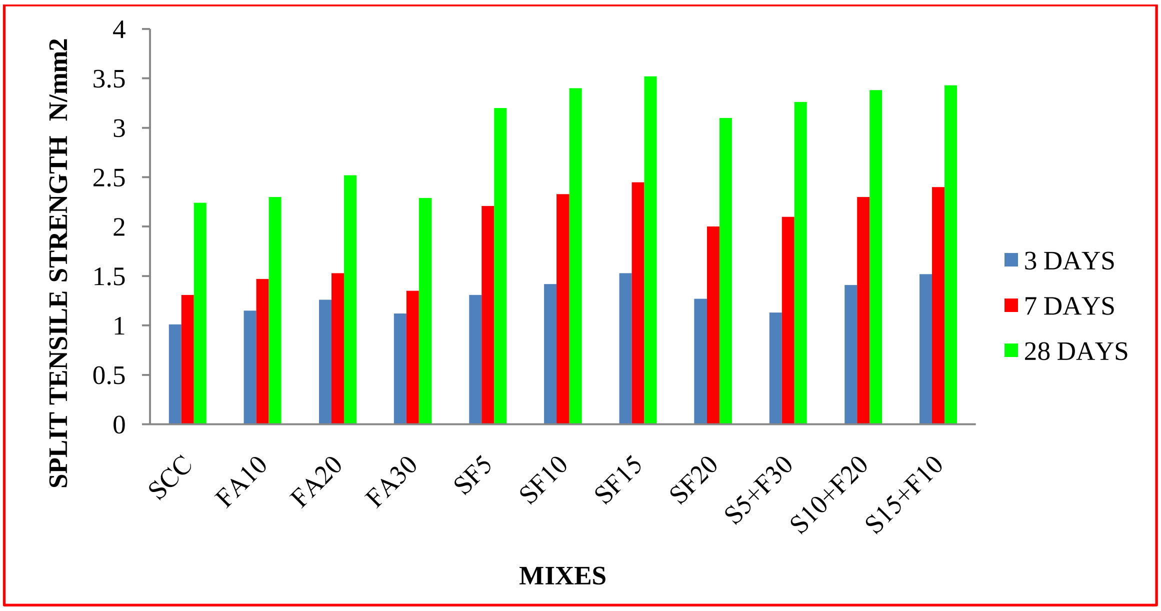
Table 9: Compressive strength of SCC mixes with different partial replacement of mineral admixtures

S.No	Mix	Average Compressive Strength (MPa)		
		3 days	**7 days**	**28 days**
1	SCC 0	18 N/mm^2	35 N/mm^2	40 N/mm^2
2	FA10%	22 N/mm^2	36 N/mm^2	43.2 N/mm^2
3	FA20%	25 N/mm^2	38 N/mm^2	45.5 N/mm^2
4	FA30%	17 N/mm^2	34 N/mm^2	42.6 N/mm^2
5	SF5%	24 N/mm^2	37 N/mm^2	43.2 N/mm^2
6	SF10%	26 N/mm^2	39 N/mm^2	46.3 N/mm^2
7	SF15%	27 N/mm^2	42 N/mm^2	52.2 N/mm^2
8	SF20%	16 N/mm^2	32 N/mm^2	36.8 N/mm^2
9	SF5%+FA30%	18 N/mm^2	28 N/mm^2	34 N/mm^2
10	SF10%+FA20%	21 N/mm^2	36 N/mm^2	44.5 N/mm^2
11	SF15%+FA10%	23 N/mm^2	37 N/mm^2	48.2 N/mm^2

The split tensile strength of SCC mixes with various partial replacement of fly ash and silica fume by cement. Three specimens were crushed for the average of each age of compressive strength results are presented in Table14 and Figure 27. The result shows that the SCC with the partial replacement of fly ash and silica fume has more split tensile strength than the controlled SCC mix. And also the combination of fly ash and silica fume shows more split tensile strength than the controlled SCC mix.

Table 10: Split tensile strength of SCC mixes with different partial replacement of mineral admixtures

S.No	Mix	Average Split tensile Strength (MPa)		
		3 days	**7 days**	**28 days**
1	SCC	1.01 N/mm^2	1.31 N/mm^2	2.24 N/mm^2
2	FA10%	1.15 N/mm^2	1.47 N/mm^2	2.3 N/mm^2
3	FA20%	1.26 N/mm^2	1.53 N/mm^2	2.52 N/mm^2
4	FA30%	1.12 N/mm^2	1.35 N/mm^2	2.29 N/mm^2
5	SF5%	1.31 N/mm^2	2.21 N/mm^2	3.2 N/mm^2
6	SF10%	1.42 N/mm^2	2.33 N/mm^2	3.4 N/mm^2
7	SF15%	1.53 N/mm^2	2.45 N/mm^2	3.52 N/mm^2
8	SF20%	1.27 N/mm^2	2.0 N/mm^2	3.1 N/mm^2
9	SF5%+FA30%	1.13 N/mm^2	2.1 N/mm^2	3.26 N/mm^2
10	SF10%+FA20%	1.41 N/mm^2	2.3 N/mm^2	3.38 N/mm^2
11	SF15%+FA10%	1.52 N/mm^2	2.4 N/mm^2	3.43 N/mm^2



IV. COMPARISON OF SCC WITH FULLY REPLACEMENT OF NATURAL SAND BY QUARRY DUST

The reduction in the sources of natural sand and the requirement for reduction in the cost of concrete production has resulted in the increased need to identify substitute material to sand as fine aggregates in the production of concretes especially in Self Compacting Concrete. Quarry dust, a by-product from the crushing process during quarrying activities is one of such materials. Granite fines or rock dust is a by-product obtained during crushing of granite rocks and is also called quarry dust. Table 22 and Fig 36 & 37 shows compressive strength and split tensile strength at 3, 7 and 28 days.

Table 11: Comparison of SCC with Fully Replacement of Natural Sand by Quarry Dust

Mix	Average Compressive Strength (MPa)		
	3 days	**7days**	**28 days**
SCC 0%	16N/mm^2	35 N/mm^2	40 N/mm^2
SCC 100%	28N/mm^2	46 N/mm^2	55.5 N/mm^2
Mix	**Average Split Tensile Strength (MPa)**		
	3 days	**7days**	**28 days**
SCC 0%	1.05 N/mm^2	1.6 N/mm^2	2.9 N/mm^2
SCC 100%	1.15 N/mm^2	2.43 N/mm^2	3.8 N/mm^2

Note: SCC 0%=Fully River Sand, SCC 100%= 100% Quarry Dust.

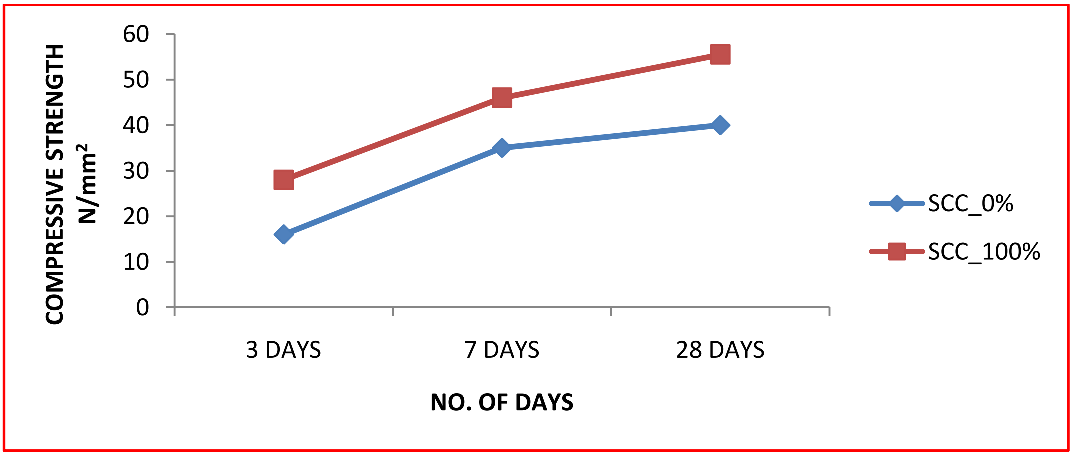


Figure 36: Compressive strength of cube with 100% Quarry Dust

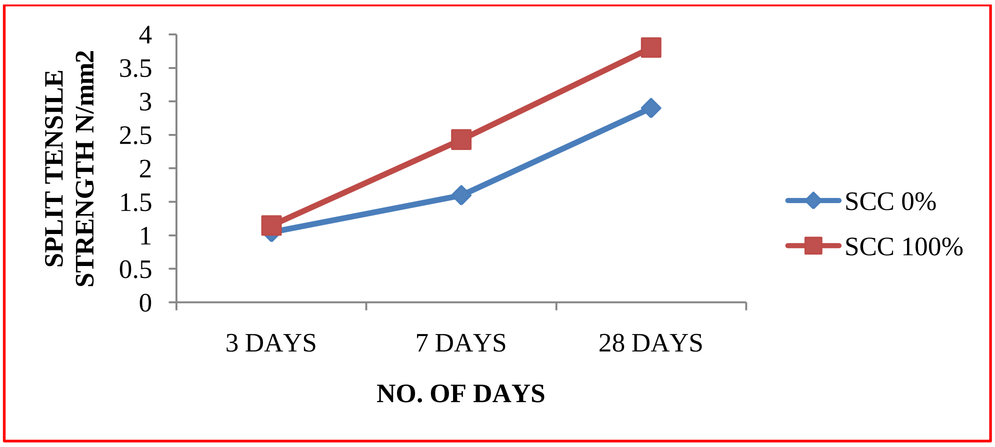


Figure 37: Split tensile strength of cylinder with 100% Quarry Dust

V. CONCLUSION

Self compacting concrete mix design tool is developed based on the key proportions of the constituents. This tool is very simple and user friendly for the self compacting concrete mix design.

As per the mix design addition of Silica Fume and fly ash decreases the demand of HRWRA in SCC Mixes. Replacement of cement by 5%, 10%, 15% and 20% Silica Fume in SCC & Replacement of cement by 10%, 20% and 30% Fly Ash in SCC, the super plasticizer cum retarder demands may be decreased when compare to Controlled SCC.

The compressive Strength and Split Tensile Strength result of SCC with various Partial replacement of cement by Fly Ash and Silica Fume Shows that the 20% replacement of Fly Ash, 15% replacement of Silica Fume and combination of 10% Fly Ash and 15% Silica Fume gives maximum Compressive Strength and Split Tensile Strength. And finally the 100% replacement of River Sand by Quarry Dust result shows that increase in compressive strength of 28% when compare to 100% sand and increase in Split Tensile strength of 23.68% when compare to 100% sand.

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