

# EFFECT OF SILICA FUME ON SELF-COMPACTING CONCRETE

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## ABSTRACT

*This paper presents the results of an experimental research on the workability and compressive strength of self-compacting concrete using local materials in Libya. The work focused on concrete mixes having water/ binder ratios (w/b) of 0.375, 0.40, 0.425 and 0.45. Total binder content, fine/total aggregate ratio (f/t) and fine sand/ crushed sand ratio (fs/cs) were kept constant at the values of: 450 Kg/m<sup>3</sup>, 1:1, and 1.5:1 respectively. During the research, Silica fume (SF) replaces Portland cement by percentages of 5, 10 and 15 %. Superplasticizers adjusted according to the SF percentage and w/b ratio in order to achieve a slump flow results in the range of 650-800 mm. Effect of altering the w/b ratio by addition of SF on some principle characteristics of fresh SCC was investigated. Further, compressive strength at the ages of 7, 28 and 90 days was also determined and results are included here.*

**Keywords: self-compacting concrete; flowability; stability; superplasticizers**

## INTRODUCTION

The term Self-Compacting Concrete (SCC) refers to a “new” special type of concrete mixture, characterized by high resistance to segregation that can spread into place, fill the form work, and encapsulate the reinforcement without any mechanical consolidation<sup>1,2</sup>. Researchers have set some guidelines for mixture proportioning of SCC, which include: i) reducing the volume ratio of aggregate to cementitious material<sup>3</sup>; (ii) increasing the paste volume and water-cement ratio (w/c); (iii) carefully controlling the maximum coarse aggregate particle size and total volume; and (iv) using various viscosity enhancing admixtures (VEA)<sup>1-4</sup>. For SCC, it is generally necessary to use superplasticizers and powder materials in order to obtain high mobility and eliminate segregation<sup>5</sup>. It is found From literature that the general procedure for design SCC mixes based on keeping, the coarse aggregate and fine aggregate contents fixed at certain ratio and self -compactibility is to be achieved by adjusting the water /powder ratio and super plasticizer dosage<sup>3,5</sup>. This paper summarizes and presents an output results from ongoing research to achieve self-compacting concrete using local materials of Libya. Silica fume as powder material has introduced to the mixes as a replacement of Portland cement and it is effect on fresh and hardened properties of SCC was studied. Test results for acceptance characteristics of fresh and hardened SCC such as: slump flow, J-ring, V-funnel, L-Box, absorption and compressive strength are presented.

## EXPERIMENTAL PROGRAM

### Materials used :

Cement — Ordinary Portland cement was used though out this research. The cement properties were tested according to the Libyan standards<sup>6</sup> and presented in Table 1.

*Table 1. Physical and mechanical properties of cement paste*

Property	Value
Standard Consistency	23%
Initial Setting Time	187 Minutes
Final Setting Time	4.52 Hours
Soundness	1 mm
Fineness	2512 cm <sup>2</sup> /gm
Compressive strength ( 3 Days)	28.9 N/mm <sup>2</sup>
Compressive strength (28 Days)	61 N/mm <sup>2</sup>

Silica Fume — Silica fume or micro-silica (very fine amorphous particles) imported from SIKA Company was introduced to the mixes as a partial replacement of Portland

cement. Only 5%, 10%, and 15% from the weight of cement was replaced by silica fume through this research.

**Coarse Aggregate** — The coarse aggregate used in the experiments was angular aggregate with maximum size of 14 mm. Tests were carried out to check the coarse aggregate suitability according to the Libyan standard specifications <sup>7,8</sup>. Its specific gravity, absorption, impact value and crushing value are: 2.65, 2%, 24%, 23.67% respectively. Its grading was confirmed with the specification limits<sup>7</sup>.

**Fine aggregate** — A blend of two types of fine aggregates was used in the mixes in order to improve the fineness of the aggregate and the flow-ability of the SCC. First type: was natural beach sand (NBS) has a size not exceeding 2 mm, fineness modulus of 1.4, absorption of 0.14%, and a specific gravity of 2.7. Second type: Is crushed rock sand (CRS), has a particle-size ranged from 0 to 5 mm, fineness modulus of 3.34, absorption of 0.72%, and a specific gravity of 2.65. First type blended with the second type with a blending percentage of 1: 1.5, and the fineness modulus of the obtained mixture was 2.17. Grading and combined curves of both aggregates are presented in Figure 1. Quality control tests of both aggregates were also conducted to check its properties according to the Libyan standards <sup>7</sup>.

**Water** — Fresh, dirt-free water is used, with a percentage of total dissolved salts not exceeding 2,000 particles per million as per Libyan standards <sup>8</sup>.

**Chemical Admixtures** — A viscocrete based superplasticizer imported from SIKA-company is the only kind of chemical admixtures used in this research <sup>9</sup>. A dosage of 0.8 to 2% from the weight of the cement has been used to obtain the required degree of workability.<sup>9,10</sup>

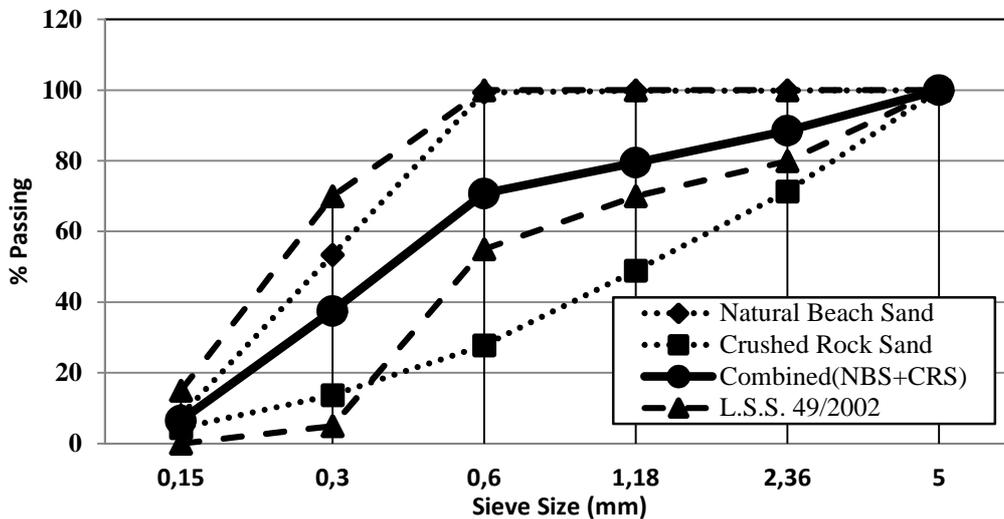


Figure 1. Sieve analysis of combined fine aggregate (NBS+CRS).

#### Design of concrete mixes

The American Concrete Institute (ACI) method was used during this research to obtain the control mixtures proportions, followed by adjustments to the mix constituents using trial and error method to characterize the mixes for filling ability, passing ability

and resistance to segregation <sup>4,5</sup>. Based on a previous preliminary trial and error investigations conducted by the authors and others <sup>9-11</sup> sixteen SCC mixes designed and implemented having the following definitions: 1 -The w/b ratio of: 0.375, 0.40, 0.425, and 0.45; 2-Cement content kept constant for all mixes at 450Kg/m<sup>3</sup>; 3- Silica fume used as a replacement from the weight of Portland cement for percentages of 0, 5, 10, and 15 ; 4-Fineness modulus of fine aggregate kept constant and the ratio of fine aggregate to coarse aggregate kept at 50%; 5- NBS (First type) blended with the CRS (second type) with a percentage of 1: 1.5; 6-Superplasticizers adjusted according to the SF percentage and w/b ratio in order to achieve a slump flow results in the range of 650-800 mm. Table 2 presents the contents of all the SCC mixes investigated.

#### Mixing procedure

All Concrete batches were prepared in rotating drum mixer having a capacity of 0.05 m<sup>3</sup>. First, the aggregates and cementing materials are introduced and mixed on dry condition for not less than 2 minutes to ensure the homogeneity of the blend. Both cement and Silica fume blended together carefully in a separate container before introduce them to the mixer. Superpalsticizer added to the mixing water in a clean container and then the mixture introduced to the mixer slowly. Mixing continues for three minutes and then stopped for one minute for absorption then the mixing resumed and continues for other 2 minutes.

*Table 2. Mix proportions of concrete used during the research*

Mix No.	W/B	Silica-Fume		Cement kg/m <sup>3</sup>	Water kg/m <sup>3</sup>	Aggregate (kg/m <sup>3</sup> )		S.P. %
		%	kg/m <sup>3</sup>			Fine	Coarse	
1	0.375	0	0	450	168.8	918	918	1.8
2	0.400				180	903	903	1.5
3	0.425				191	888	888	0.8
4	0.450				202.5	873	873	0.8
1	0.375	5	22.5	427.5	168.8	925	925	1.8
2	0.400				180	911	911	1.5
3	0.425				191	897	897	0.8
4	0.450				202.5	882	882	0.8
1	0.375	10	45	405	168.8	933	933	2.0
2	0.400				180	920	920	1.7
3	0.425				191	906	906	1.0
4	0.450				202.5	893	893	1.0
1	0.375	15	67.5	382.5	168.8	939	939	2.0
2	0.400				180	927	927	1.7
3	0.425				191	914	914	1.0
4	0.450				202.5	901	901	1.0

#### Test specimens and curing

Standard cubes of size 150\*150\*150 mm are used to investigate the compressive strength and absorptions of SCC. A total of 144 samples were casted in an average of 9

samples per mix. After conducting the workability characteristics experiments the concrete mix was poured in the moulds required for strength assessment. After 24 hours of casting the specimens were demoulded and were transferred to the curing water tanks. After the curing period of 7, 28 and 90 days specimen removed from curing tank and screed off the all face of specimen and taken for testing.

#### Fresh concrete investigations

Once, the mix was determined to have sufficient visual attributes of SCC, the rheological tests were performed in quick succession. Typically, the order of testing employed was as follows: 1-Slump Flow Test (T50); 2-J-Ring Test; 3- V-Funnel Test; 4- L-Box Test. Table 3 presents the results of workability tests, conducted to achieve SSC.

*Table 3. Test results of fresh concrete*

Mix No.	W/B	SF %	Slump Fow (mm)	T50 (Sec)	J-ring (mm)	L-box (H <sub>2</sub> /H <sub>1</sub> )	V-Funnel (Sec.)	Bleeding
1	0.375	0	730	3.7	10	0.89	10	Medium
2	0.400		730	3.4	10	0.89	6	Medium
3	0.425		760	1.2	10	0.94	6.9	Non
4	0.450		770	1	20	0.81	5	Non
1	0.375	5	700	5.3	20	0.71	6.2	Non
2	0.400		690	4	10	0.64	6	Small
3	0.425		750	1.2	20	0.88	4	Non
4	0.450		750	1.5	10	0.94	5.5	Non
1	0.375	10	700	3.2	30	0.76	7.3	Non
2	0.400		720	3	10	0.79	7	Small
3	0.425		720	2	10	0.9	5	Non
4	0.450		720	2	10	0.92	4	Non
1	0.375	15	660	5	30	0.61	7.4	Non
2	0.400		720	2	10	0.75	5	Non
3	0.425		720	3	10	0.89	5.1	Non
4	0.450		720	2.2	10	0.9	5	Non

#### Hardened concrete investigations

Only compressive strength and absorption were investigated for hardened concrete in this research. The compressive strength is determined using cube samples at the end of each curing regime (7, 28, and 90 days). The absorptions are determined also using the same cubes prepared to conduct compressive strength, and the test performed according to ASTM standards <sup>12</sup>. The test results are calculated as the mean of three samples per each mix as shown in Table 4.

Table 4. Test results of hardened concrete

Mix No.	W/B	SF %	Average compressive strength (N/mm <sup>2</sup> )			Absorption %
			7 Days	28 Days	90 Days	
1	0.375	0	30.5	43	54.5	6
2	0.400		24	39	52	5.76
3	0.425		37	40.5	54	5.9
4	0.450		32.5	41	49.5	6.46
1	0.375	5	28.5	45	56.5	4.7
2	0.400		33	44.5	55	4.52
3	0.425		33.5	46	57.5	5.7
4	0.450		29.5	44	52	5.8
1	0.375	10	21.5	42	59	2.2
2	0.400		28	49.5	56	2.64
3	0.425		30.5	50.5	57.5	3.7
4	0.450		26	46.5	54.5	4.58
1	0.375	15	22	47	64	2.01
2	0.400		29	55.5	62.5	2.1
3	0.425		33	55	65	3.2
4	0.450		27.5	54.5	60	4.05

## DISCUSSION OF RESULTS

According to the rheological and strength characteristics results presented in Tables 3 and 4 also Figures 2,3 and 4, the following brief discussion could be drawn: The slump flow characteristics of the mixes are ranged from 660 to 770 mm, which is between the acceptable criteria laid by EFNARC. Using superplasticizers plays an important role in adjusting the flow-ability of concrete when SF used. As far as filling ability of mixes in concern, the results of V funnel satisfied the standard requirement (6 to 12 seconds). The blocking ratio in the L-box was as per requirements of SCC as laid by EFNARC guidelines. As far as the passing ability of mixes in concern, It was noticed that as SF percentage increased to 15 % the passing ability of SCC reduced. It is clear from the results that SF has no significant effect on compressive strength on SCC at the age of 7 days and this is due to slow pozzolanic activities in this age. In general the strength increased as SF percentage increased. Therefore, mixes with 15% SF showed a higher strength gain after 28 days, and its value ranged from 39 to 55.5 MPa at 90 days. It was recorded that mixes without SF incorporation showed higher rate and value of absorption, while mixes with SF incorporation showed a decrease in the absorption as the percentage of SF increased. And this could be attributed to the densification of the pore structure due to the pozzolanic action of SF. Some variations recorded sometimes in compressive strength results and that is could be related to the

use of different superplasticizers dosages to keep the workability of SCC in the acceptable range.

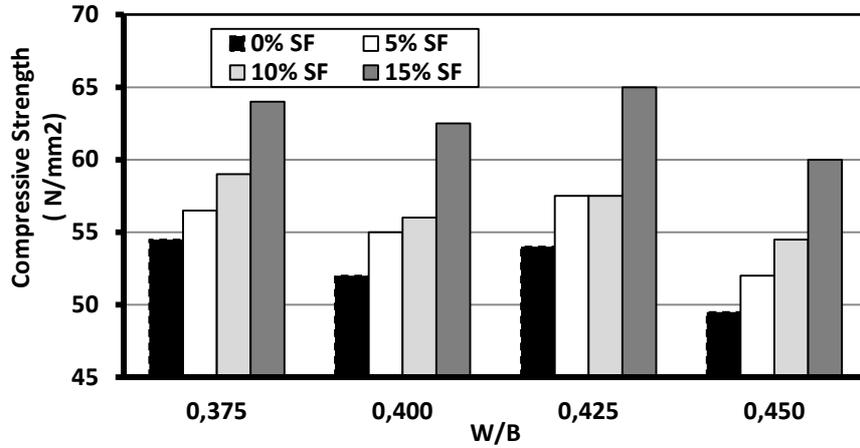


Figure 2 . Compressive strength of SCC after 7 days of curing

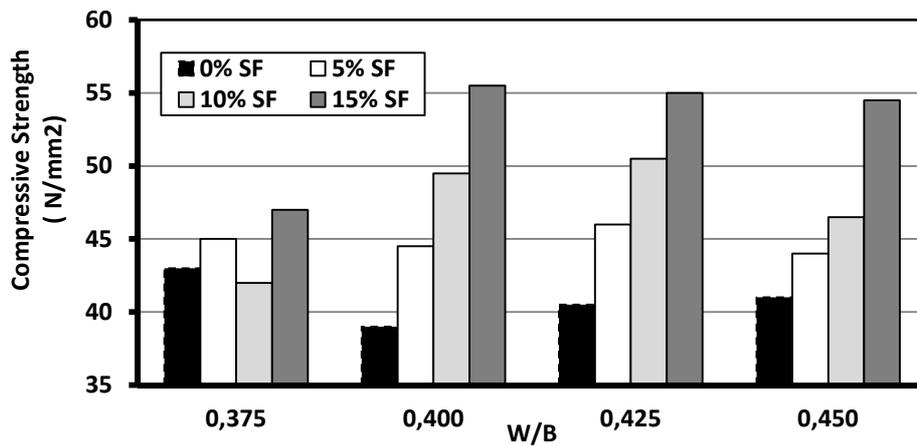


Figure 3 . Compressive strength of SCC after 28 days of curing

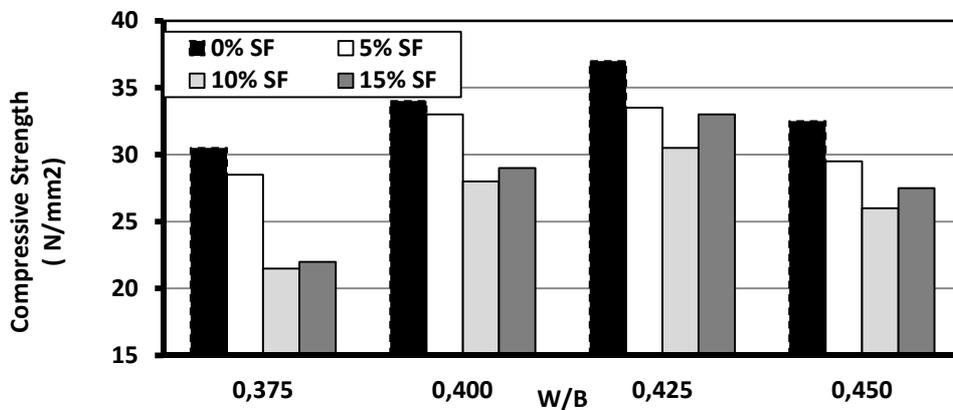


Figure 4 . Compressive strength of SCC after 90 days of curing

## CONCLUSIONS

On the basis of the experimental investigations carried out, the following conclusions can be drawn: with appropriate choice of materials and mix proportions, it is possible to produce SCC using any local materials. In order to control the flow ability of the SCC special attention should be made to control the fineness modulus of fine Aggregate. Using SF as a replacement of Portland cement is a good solution to prevent bleeding and improve the consistency and prevent segregations of SCC. SCC mixes with 15% SF replacement gave higher value of concrete compressive strength than those without or with lower percentage of SF. From the other hand SF reduces the absorption dramatically.

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