Civil and Environmental Research
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.6, No.12, 2014

New Concrete Technology Negates Traditional Concrete Placement in Sudan

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The research is financed by the Building and Road Research Institute (BRRI), University of Khartoum

Abstract

Self-consolidating concrete, also known as self-compacting concrete (SCC), is an innovative concrete that does not require vibration for placing and compaction. The mixture qualification process of Self Compacting Concrete consists from a small, well controlled laboratory batches are tested, second, the closest mixture/s is tested in production, which includes the use of batch mixing, and placing equipment, and finally a quality assurance/control plan for the fresh and hardened properties is developed. However, this paper presents a full research addressed only a small, well controlled laboratory batches and the laboratory testing phase of the mixture qualification process.

For the purpose of study, a small, well controlled laboratory batches are tested using available locally aggregates in Sudan. Therefore, Slumpflow, V-funnel, L-box shape, J-ring, and Sieve stability tests of concrete mixtures were used to determine the flowability, passing ability and segregation resistance of SCC mixtures. The produced self compacting concrete is successfully confirmed the fresh properties of SCC with Slumpflow in range of 650 to 850 mm with high viscosity and excellent segregation resistance. The hardened properties of concrete were also considered and tested. The strength of SCC was found to be same or higher than that of normally vibrated concrete with the same constituent materials. SCC has relatively higher dynamic modulus of elasticity ranged between 38 to 42 GPa, in comparison to normally vibrated concrete for the same strength range of 50 to 60 MPa. Whereas the Spilt Tensile and Flexural strength of SCC are of 2.5 MPa and 10 MPa respectively.

The major difficulty which was faced in development of SCC was on account of contradictory factors that the concrete should be fully flowable but without bleeding or segregation. It is required that the cement mortar of the SCC should have higher viscosity to ensure flowability while maintaining non-sedimentation of aggregates and that was achieved by using high content of powder (fine materials less than 0.15 mm includes cementitious materials).

Achievement of durable concrete structures independent of the quality of construction work by using Self Compacting Concrete (SCC) has been proposed to solve the problem of the durability of concrete structures due to the gradual reduction of adequate compaction and skilled workers and for complex shape for the prestressed and precast industries in Sudan. The features of high benefit of fluidity and self consolidation will result in a variety of potential benefits for the end-user. Other benefits of the application of this new concrete technology require effort to be achieved. Moreover, areas such as quality control, mixture development, and logistics may need modification or expand resources when develop self-compacting concrete in Sudan.

Keywords: Self Compacting Concrete (SCC), Sudan, Flowability, Passing ability, Segregation Resistance Slumpflow, V-funnel, L-box shape, J-ring, and Sieve stability, Powder content

1. Introduction

The application of concrete without vibration in the construction generally or in Sudan, is not new technique for placing concrete. All of concrete underwater is placed by the use of a tremie without vibration [1]. Masses concrete, shafts or piles are also successfully placed without vibration. However, these types of concretes are generally of lower strength, and difficult to attain consistent quality [31]. Moreover, the gradual reduction of adequate compaction, skilled labours, in addition to the pad quality assurance and control in construction industry in Sudan has led to similar reduction in the quality of construction work [32].

The same problem of the durability of concrete structures was also a major topic of interest in Japan to make durable concrete structures in the beginning of 1983 [32]. Recognizing the lack of uniformity and complete compaction of concrete by vibration, researchers at the University of Tokyo, Japan, started out in late 1980s to develop Self Compacting Concrete (SCC) [32]. By the early 1990s, Japan has developed and used SCC that does not require vibration to achieve full compaction.

Several European countries were interested in exploring the significance and potentials of SCC developed in Japan [32] [14] [20]. In addition, SCC is beginning to gain interest, especially by the precast concrete industry and admixture manufacturers in the United States. The precast concrete industry is beginning to apply the technology for complex structures [32]. Numerous laboratory and field studies have been carried out in developing and designing Self Compacting Concrete by many researchers to study the mix design principles to achieve the required combination of properties in fresh SCC mixes, such as the fluidity and viscosity of the paste. Others guidelines for design, use and production of SCC are also carried out such as EFNARC [20] and the European Guideline [14], etc.

Achievement of durable concrete structures independent of the quality of construction work in Sudan by using Self Compacting Concrete (SCC) have been proposed. Researchers at the Institute of Building and Road Research (BBRI), University of Khartoum, Sudan, in 2009 started to investigate the possibility of the production of Self Compacting Concrete (SCC) using locally available materials around Khartoum area [29].

2. Literature Review

Self Compacting or Consolidating Concrete (SCC) is a highly flowable, non-segregating concrete that spreads into place, fills formwork, and encapsulates even the most congested reinforcement, all without any mechanical vibration. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete.

There are many procedures available in literature for design a Portland Cement Concrete such as ACI. However, there is no standard method for SCC mix design and many academic institutions [10], admixture, ready-mixed, precast and contracting companies have developed their own mix proportioning methods [5] [30]. Many methods often use volume as a key parameter because of the importance of the need to over fill the voids between the aggregate particles [30]. Some methods try to fit available constituents to an optimized grading envelope [2] [26] [27]. Another method is to evaluate and optimize the flow and stability of first the paste and then the mortar fractions before the coarse aggregate is added and the whole SCC mix tested [28].

The studies of develop self-compacting concrete in Sudan, including a fundamental study on the possibility of production of self-compacting concrete was carried out by the authors et al [29] at the University of Khartoum, started in 2009. The primary aim of this study is to explore the feasibility of producing SCC in Sudan by examining its basic properties, including engineering properties, materials, and either mix design. The study includes how to produce SCC by using local materials and testing self compactability of SCC mixtures by equipment fabricated according to standard dimensions (see Figure 1).

Figure 3. Locally fabricated V-funnel Apparatus by Murtada et al, 2009 [29]

The development of a suitable mix for SCC that would satisfy the requirements of the plastic state, casting of concrete samples and testing them for compressive strength has been studied by Murtada et al [29]. The significance of this work lies in its attempt to producing self compacting concrete in Sudan by using local materials.

A trial of five Powder type-SCC mixes of 35 MPa target strength had been investigated using Basalt crushed aggregates from TORYIA Mountain, with max size aggregate of 20 mm. Natural coarse sand had been used as fine aggregate. Table 1 shows the grading of the coarse aggregates. The grading of the fine aggregate is presented in Table 2. Class F - Pulverized fuel ash (PFA) was used as additive material to increase the cohesion and reduce sensitivity to changes in water content. Admixture based on Sulphonated Naphthalene polymer (NSFC) was also used in SCC mixtures for reducing the water/binder ratio of SCC and enhancing the workability.

Table 1. The grading of the coarse aggregates by Murtada et al [29]

Sieve opening in mm	Percentage of passing
50	100
37.5	100
20	100
14	65.2
10	31.7
5	6.6
Total	0

Table 2. The grading of the fine aggregate by Murtada et al [29]

Sieve opening in mm	Percentage of passing
10	98.3
5	96.2
2.36	89.9
1.18	70.1
0.6	43.3
0.3	19.1
0.15	6.7
Total	0

The mix proportions of these trial mixes were determined using the rational method by Okamura et al [30]. Table 3 present the mix proportions of the trial mixes by Murtada et al [29]. Whereas Self-Compactability properties of SCC mixtures are presented in Table 4.

The five trial mixes were prepared with varying proportional of mix constituent. The Cement and fly ash contents used in trial ranged between 350 - 400 Kg/m3, 90 - 130 Kg/m3 respectively. Thus the superplasticizer dosage was between 1.0 - 2.5 liter/100 kg of powder content, including the PFA.

Table 3. Proportions of the trial mixes of Possibility of Production of Self Compacting Concrete in Sudan by Murtada et al, 2009 [29]

Trial Index	FA/CA Ratio	CA Kg/m3	FA Kg/m3	Cement Kg/m3	Water Kg/m3	Fly ash Kg/m3	HRWR (Lt/m3)	Density Kg/m3
SCC1	1	850	850	350	180	110	5.25	2340
SCC2	1.1	800	880	400	190	100	7.5	2370
SCC3	0.92	880	812.3	400	185	90	8.82	2367.3
SCC4	1.1	850	935	400	190	0	6	2375
SCC5	1.1	800	880	370	190	130	7.5	2370

Table 4. Self-Compactability properties of SCC mixtures by Murtada et al, 2009 [29] Self-Compactability properties

Self-Compactability properties			
Trial No	Slumpflow (mm)	V-Funnel (sec)	U-Shape (mm)
SCC1	600	Fail	Fail
SCC2	850	6	5
SCC3	650	27	50
SCC4	670	15	520-Fail
SCC5	800	9	-

Parameters such as Fine/Coarse aggregate, Water to Powder ratio, Fine aggregate/Powder ratio were considered in the evaluation of mix design. Moreover, the effect of Pulverized Fuel Ash (PFA) in optimizing the self compactability and the hardened properties of mixtures have been also studied.

Murtada et al [29] reported that, the Self Compacting Concrete is successfully produced using available material in Sudan as (SCC2) and (SCC5), and recommended that these parameters shall be kept in the following ranges for producing SCC in Sudan. The Fine/coarse aggregate ratio is equal to 1.1 by mass, depending on granulometric characteristics of the aggregates used. And the water to powder ratio should not be greater than 0.38. Furthermore, the water content should be greater than 190 kg/m3 depending on the Superplasticizer dosage combined with the set of retardation effect if Type G HRWRA is used.

Murtada et al found that due to spherical shape of PFA particles, the decrease in PFA content was significantly affected the workability of Self Compacting Concrete, and increase the sensitivity mixture to changes in water content. The FA/CA and W/P ratios have a significant effect in rheology of SCC. Murtada et al also found that, the Slumpflow should have results more 650 mm to pass all tests of self compactability in hot weather concrete.

SCC5 mixture showed excellent segregation resistance by improving the workability and cohesion of mixture when the percentage of fly ash content increased. However, the increase of fly ash content decreased the 28 days compressive strength in comparison to SCC2 as shown in Table 5.

Murtada et al found that the percentage of compressive strength for different age's compressive strength found was greater than conventional concrete. Although of utilization of Fly Ash in SCC and sometimes the retardation effect have a significant influence on the strength development, the percentage of 3 days age to 28 days compressive strength is greater than 45%, and 72% for the 7 days and found that the 14 days had about 85% compressive strength of 28 days compressive strength, which indicated for the ability of fast construction.

Table 5. The Compressive Strength of Successful Self Compacting Concrete in MPa, Murtada et al 2009 [29].

Trial Index	3 days	7 days	14 days	28 days
SCC2	19.6	39.1	42.0	48.20
SCC5	19.3	28.5	34.5	45.20

3. Experimental Program

Total of 11 mixtures of non-air entrained Powder type Self Compacting Concretes were prepared for this study with crushed aggregates and two types of Sand, have been evaluated. The first six mixtures were investigated with high fine modulus crushed sand, whereas the other five mixtures were produced with natural Wade sand. Ordinary Portland Cement OPC was used for casting cubes according to ASTM C 150 [6], cylinders for all concrete mixes. Summary of the various tests conducted on cement are as under given below in Table 6.

Table 6. The physical properties of cement

Consistency of standard paste		29.25%
Setting time	Initial setting time	2:20
	Final setting time	4:00
Compressive strength	2 Days	23 MPa
	28 Days	48 MPa

The coarse aggregates used in SCC mixes, was crushed basalt obtained from TORYIA Mountain in Khartoum State, with maximum size of 20 mm. Crushed and natural coarse sand used as fine aggregate ranged in zone I and zone II for crushed basalt sand and the natural sand respectively. The results of various tests conducted on the coarse and fine aggregates according to ASTM C 136 [5], ASTM C 128 [4], ASTM C 117 [3], ASTM C 33 [10], British Standard BS 812: Section 103.2: 1989 [19], BS 812: Part 101: 1984 [17], and BS 812: Part 2: 1995 [18] are given below:

Table 7. Physical Properties of Coarse Aggregates

Characteristics	Value
Type	Crushed
Specific Gravity	2.66
Total Water Absorption	0.56
Fineness Modulus	6.83

Table 8. The Loose and Rodded Dry Density of Aggregates

Materials	5~10	10~20
Loose Density (kg/m^3)	1546.0	1516.1
Rod Density (kg/m^3)	1625.5	1650.5

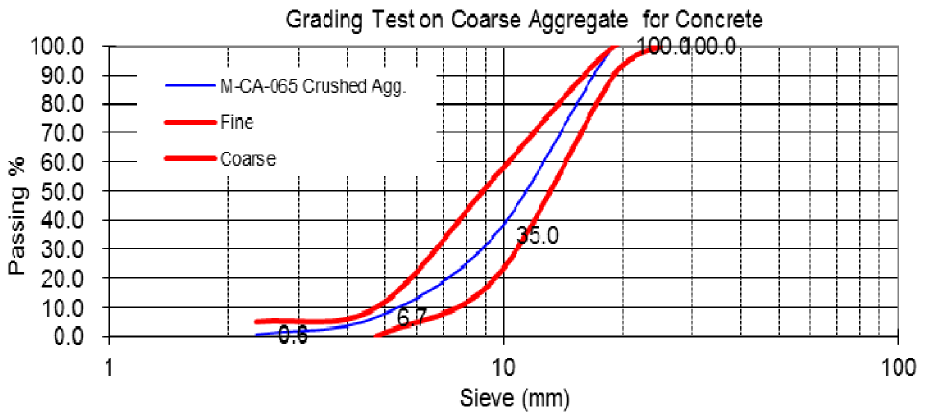

Figure 2. Particle Size Distribution (PSD) of Blended Aggregates with the ASTM C 33 jacket

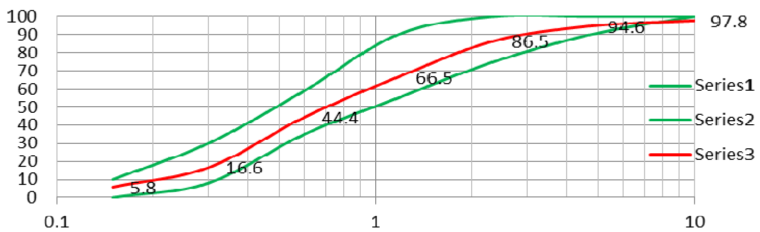

Figure 3. Particle Size Distribution (PSD) of Natural Sand

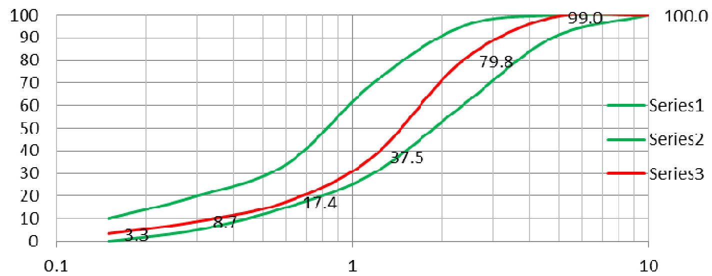

Figure 4. Particle Size Distribution (PSD) of Crushed Sand

Type F Fly ash obtained from Zou Xian manufactures was used. Where, the characteristics of Fly Ash for use as additive in Portland cement concrete according to ASTM C 618 are shown in Table 10.

Table 10. The characteristics of Fly Ash

Sample No.	M.C %	Density gm./cm^3	Difference of Initial Setting Time	Fineness %	Soundness %	Water Requirement %	Strength Activity Index %	
							28 days	90 days
1	0.1	2.16	27	10.3	0.5	92	100	101

A Certain amount of test always follows the development of new mixture to ensure the highest level of control. Small Laboratory batches are ran first. The mixture developed was tested for the target fresh properties. If the properties were not achieved, adjustments to the mixture proportions were made. If the fresh target achieved, then testing for the mixing robustness and for the required hardened properties was conducted. The performance of Self Compacting Concrete, details of mixture proportions is presented in Table 6.

Table 11. Mixture proportions for the possibility of producing SCC

ID	Cement Kg/m³	Fly Ash Kg/m³	Water Kg/m³	Powder Content Kg/m³	W/P ratio	Fine Aggregate Kg/m³	Coarse Aggregate Kg/m³	Fine/Coarse Aggregates ratio	SP/P%
1	280	120	145	400	0.36	1020	930	1.10	2
2	280	120	150	400	0.38	1020	930	1.10	2
3	280	120	155	400	0.39	1020	930	1.10	2
4	330	120	155	450	0.34	1020	930	1.10	2
5	330	120	175	450	0.39	1020	930	1.10	2
6	375	125	190	500	0.38	847	847	1.00	2
7	442	147	223	589	0.38	735	813	0.90	1.5
8	454	152	217	606	0.36	735	813	0.90	1.5
9	450	150	215	600	0.36	728	830	0.88	2
10	450	150	215	600	0.36	830	830	1.0	2
11	450	150	215	600	0.36	830	830	1.0	2

Methods for Testing Fresh Self Compacting Concrete

They are mainly methods, which have been devised specifically for SCC and used for testing the mixtures in this study. Existing rheological test procedures have not been considered here. Slumpflow, V-funnel, L-box shape, J-ring, and Sieve stability tests of concrete mixtures were used to determine the flowability, passing ability and segregation resistance of SCC mixtures according to EN 12350 Part 8, 9, 10, 11, and 12 [21][22][23][24][25]. No single test so far devised can measure all three properties and duplicate tests are advised by EFNARC 2002 [20].

The Slumpflow is used to assess the horizontal free flow of SCC in the absence of obstructions. It was first developed in Japan for use in assessment of underwater concrete. The test method is based on the test method for determining the slump [14] [20]. The diameter of the concrete circle is a measure for the filling ability of the concrete. The slump cone can be placed in the conventional, upright orientation or inverted [26]. Figure (5) and (6) show the Slumpflow Apparatus and measuring the final diameter of the concrete.

Figure 5. The Slumpflow Apparatus

Figure 6. Measuring the final diameter of the concrete in two perpendicular directions of Slumpflow

Whereas the J-ring test aims at investigating both the filling ability and the passing ability of SCC [14] [20]. It can also be used to investigate the resistance of SCC to segregation by comparing test results from two different portions of sample. The J-ring test measures three parameters: flow spread, flow time T50J (optional) and blocking step. The J-ring flow spread indicates the restricted deformability of SCC due to blocking effect of reinforcement bars and the flow time T50J indicates the rate of deformation within a defined flow distance. The blocking step quantifies the effect of blocking. Figure 7 describes the J-ring test dimensions and the three parameters of J ring test.

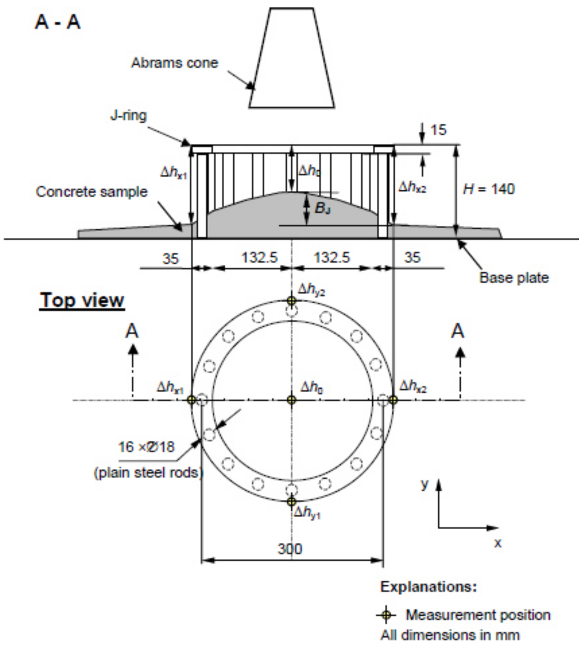

Figure 7. The J-ring test dimensions and the three parameters of J ring test.

Figure 8. Raising of the upright cone vertically and allow the concrete to flow out freely

The described V-funnel test is used to determine the filling ability (flowability) [14] [20]. The test was developed in Japan and used by Ozawa et al. The equipment consists of a V-shaped funnel, shown in Figure 9. The funnel is filled with about 12 litre of concrete and the time taken for it to flow through the apparatus measured.

After this the funnel can be refilled concrete and left for 5 minutes to settle. If the concrete shows segregation then the flow time will increase significantly.

Figure 9. V-funnel Test Apparatus

The L-Box test assesses the flow of the concrete [14] [20], and also the extent to which it is subject to blocking by reinforcement. The apparatus consists of a rectangular-section box in the shape of an 'L', with a vertical and horizontal section, separated by a moveable gate, in front of which vertical lengths of reinforcement bar are fitted as shown in figure 10. When the flow has stopped, the height of the concrete at the end of the horizontal section is expressed as a proportion of that remaining in the vertical section (H2/H1in the diagram). It indicates the slope of the concrete when at rest. This is an indication passing ability, or the degree to which the passage of concrete through the bars is restricted.

Figure 10. Free horizontal flowing, L-Box Shape test

Figure 10. A clear picture of obstacles of the L-Box Shape after (Blocking Indicator)

Sieve Stability Test or GTM was used to assess segregation resistance (stability) [14] [20]. It consists of taking a sample of 10 litre of concrete, allowing it to stand for a period of 15 min to allow any internal segregation to occur, then pouring about 4.8 Kg on to a 5mm sieve of 300mm diameter, which stands on a sieve pan on a weigh scale. After two minutes, the mortar which passed through the sieve is weighed, and expressed as a percentage of the weight of the original sample on the sieve. Figure (11), (12) and (13) describe the Sieve Stability Test.

Figure 11. Bucket with (10 ± 0.5) liters of representative fresh SCC, Sieve Stability test

Figure 12. The sample of SCC poured onto the sieve for the Sieve Stability test

Figure 13. The sample of SCC poured onto the sieve for the Sieve Stability test

Methods for Testing hardened Self Compacting Concrete

The hardened properties of concrete were also considered and tested. 100 mm concrete cubes were used for determine the compressive strength according to BS 1881-Part 116 [5] and Part III [16]. The Flexural and Spilt tensile strengths were also measured using (100 mm × 100 mm × 500) mm prisms and (150 mm dia × 300 mm) cylinders respectively according to ASTM C 293 [9] and ASTM C 496 [12]. The Young's Modulus of Elasticity (E-Modulus) was also considered and tested using the resonant method according to ASTM C 215 [8].

4. Discussion of the Effect of Material Constituents on Performance of SCC

4.1. Effect of Aggregates and Powder

The mixture proportioning criteria used in this research, uses the aggregate characteristics such as grading curve, specific gravity (SG), loose and rodded dry density, and water absorption have been used to predict the voids of coarse aggregates to approximate the paste volume required at the saturated surface dry (SSD) condition.

The first six SCC mixes were investigated with high fine modulus crushed sand, whereas the other five mixtures were produced with natural Wade sand. The trial mixes were prepared with varying proportional of mix constituent as shown in Table 11 whereas the results of Self-compactability for the trials presented in Table 12.

Table 12. The Self-compactability results for the trials of producing Self Compacting Concrete

Mix ID	W/P ratio	Vw/Vp	Slumpflow	T50	V-Funnel	V-Funnel T5 min	J-ring Diameter	Bj (mm)	L-Box (ΔH) mm	Sieve Stability	Remark
TRIAL 1	0.36	1.24	-	-	-	-	-	-	-	-	not achieved
TRIAL 2	0.38	1.28	-	-	-	-	-	-	-	-	not achieved
TRIAL 3	0.39	1.32	-	-	-	-	-	-	-	-	not achieved
TRIAL 4	0.34	1.17	-	-	-	-	-	-	-	-	not achieved
TRIAL 5	0.39	1.32	450	-	-	-	-	-	-	-	not achieved
TRIAL 6	0.38	1.28	450	-	-	-	-	-	-	-	not achieved
TRIAL 7	0.38	1.11	550	2	15.5	8.9	-	-	-	-	not achieved
TRIAL 8	0.36	1.05	480	-	-	-	-	-	-	-	not achieved
C.SCC	0.36	1.05	720	2.5	15	6	100	20	-	-	achieved
TRIAL 9	0.36	1.05	755	6	9	7	750	10	63	4.8	Adjusted
Control SCC	0.34	1	800	5	10	11.3	775	8	NA	2.6	Success

Different w/p ratios were used. The powder content ranged from 400 kg/m3 to 500 kg/m3 for the first six mixes which were investigated with high fine modulus crushed sand. The fine/coarse aggregate ratio was fixed to 1.1 for trial mix No 1 to No 5, as recommended by Murtada et al [29]. The different low w/p ratios and different high contents of powder were used to increase the viscosity of SCC paste.

The workability of SCC positively increased, when the paste viscosity was increased by increasing the powder content from 400 to 450 kg/m3 with an increase in water content (0.39 w/p ratio used.)

For the same proportion of mix constituent of trial mix No 3 and No 5, the increase of powder content had a significant effect. The Slumpflow increased from zero to 450 mm since the suspension consists of a matrix of smaller particles filled the hollow spaces between the coarser.

The SCC had not successfully achieved yet. In trial mix No 6, the powder content was increased to 500 kg/m3 with w/p ratio of 0.38. Whereas the fine/coarse aggregate ratio decreased from 1.1 to 1.0. In addition, 847 kg/m3 of coarse aggregate was used for this trial. The Slumpflow was not affected.

The successful SCC mixes by Murtada et al [29] had 500 kg/m3 powder content comprised of 400 kg/m3 of cement and 100 kg/m3 of fly ash for SCC2, and 370 kg/m3 of cement and 130 kg/m3 of fly ash for SCC5. Whereas the w/p ratio was 0.38. The recommended fine/coarse ratio is 1.1 and 880 kg/m3 of natural sand content was used.

The powder content and w/p ratio are same for those SCC trial mix No 6, SCC2 and SCC5. Nevertheless, in trial mix No 6, less sand content and fine/coarse aggregate ratio were used. Based on the fresh properties especially the Slumpflow, there are huge differences in the fresh characteristics between trial mix No 6 and SCC2 and SCC5. This was due to the influence of shape, type and grading of fine aggregate corresponding to the size particle distribution of coarse aggregate.

Other five trials were conducted using natural wade sand. When the specific gravity (SG) and the water absorption of sand have been used to predict and approximate the paste volume, the mix proportions were totally changed. The powder content increased to 590 kg/m3 with the same w/p ratio of 0.38. The predicted fine/coarse aggregate ratio was 0.9 and the coarse content was 713 kg/m3.

Regardless the decrease in superplasticizer demand, the Slumpflow of trial mix No 7 was positively increased and the viscosity had enhanced similarly when a rounded shape of fine aggregate was used.

The viscosity of paste was increased significantly due to the increase in the powder content from 500 kg/m3 to 590 kg/m3. In addition, the Slumpflow increased from 450 mm to 550 mm.

Moreover, when the powder content had been increased again in trial mix No 8 and the water content decreased to 217 kg/m3, the Slumpflow decreased significantly to 480 mm. The use of 1.05 volumetric water/powder ratio instead of 1.11 without increasing the superplasticizer dosage was negatively affected the self-compactability properties.

In trial mix No 9 the sand content was slightly decreased corresponding to decrease the fine/coarse aggregate ratio from 0.9 to 0.88. While the superplasticizer dosage was increased to 2.0% of the total powder per mix. The fresh properties of SCC was significantly enhanced accordingly. The Slumpflow increased positively from 480 mm to 720 mm. The mix may was stable according to the less value of T5min of V-Funnel Test in comparison to the time of V-Funnel. And the visual test had shown that there was no any significant bleeding or segregation.

Therefore, from the self-compactability properties of (C.SCC), the production of Self Compacting Concrete was achieved. Other trials were conducted to optimize the mix stability by increasing the fine/coarse aggregate ratio to 1.0 when other ingredient proportions were remained constant. The Slumpflow of trial mix No 9 was positively increased and the other self-compactability properties of mixture positively affected. However, the value of T5min of V-Funnel was also less than the time of V-Funnel. Whereas the H2/H1 was 63 mm, which is good passing ability, when the L-Box shape test was used.

Another adjustment done by decreasing the water content and similarly the w/p ratio decreased. The produced concrete had high Slumpflow of 800 mm and T50, greater than 2 sec of 5 sec, which indicated of high viscosity of SCC mixture. The produced SCC was very stable with 2.6% segregation percent instead of 4.6% for the previously trial mix. The V-Funnel results showed also high viscosity of SCC mixture in the range of 9 to 25 sec. whereas the high T5min of V-Funnel than the time of V-Funnel test indicated for a good segregation resistance. The produced SCC mix had also good Passing-ability where the flow time (T50J) was 7 sec, 775 mm value of flow spread and 8 mm blocking step of the J-ring test.

However, some of the hardened properties was adversely affected. The 28 days age was less by 15% than (C.SCC). Nevertheless, based on the w/p ratio and the development of strength of both mixes corresponding to the positively increase of the spilt tensile and flexural strength, the 28 days result may be is not ok. However, the dynamic modulus of elasticity (E-Modulus) was also decreased significantly from 41.63 GPa to 38.6 GPa. Which was expected due to increase of concrete paste by increasing of sand content. Table 4 2 shows the hardened properties of the successful SCC.

Table 13. The Self-compactability results for the trials of producing Self Compacting Concrete

ID	STRENGTH				E-MODULUS	SPLITTING TENSILE	FLEXURAL STRENGTH
	3 days	*7 days*	*14 days*	*28 days*			
C.SCC	*25.2*	*36.5*	*43.4*	*59.5*	*41.63*	*2.5*	*9.4*
Control SCC	*27.1*	*37.1*	*43.4*	*50.7*	*38.60*	*2.6*	*10.4*

4.2. Effect of Superplasticizer

Superplasticizer was extensively used in the production of self-compacting concrete to improve the flowability and workability retention of mixtures. Addition of this admixture influenced the results of Slumpflow measurements, which are related to the yield stress as shown in Table 3 11 and Table 4 1 especially mixes No 8 and No 9. It provided a high level of fluidity without the use of water by dispersing the cement grains, thereby the potential for bleeding or segregation was decreased significantly as shown by the results of V-Funnel test. Both parameters, the yield stress and viscosity had influenced the static and dynamic segregation. The segregation portion decreased from 4.8% to 2.6%, when the water content was decreased in trial mix no 11 (Control SCC). The same result achieved without the use of water by decreasing of the dosage of superplasticizer. However, when the water content decreased the hardened properties were positively affected. Moreover, the viscosity was also affected similarly.

Figures 14, 15, and 16 show the clear increase of Slumpflow diameter with the increase of superplasticizer dosage. The both parameters, the yield stress and viscosity were influenced the static and dynamic segregation. The segregation resistance of was also significantly affected by the addition of this admixture as shown in Table 10. A severe over dose of superplasticizer will result in high segregation percent. Figures 17 and 18 illustrate the effect of over dosage of superplasticizer on the stability of self-compacting concrete.

Figure 14. Slumpflow diameter of very low dosage of Superplasticizer

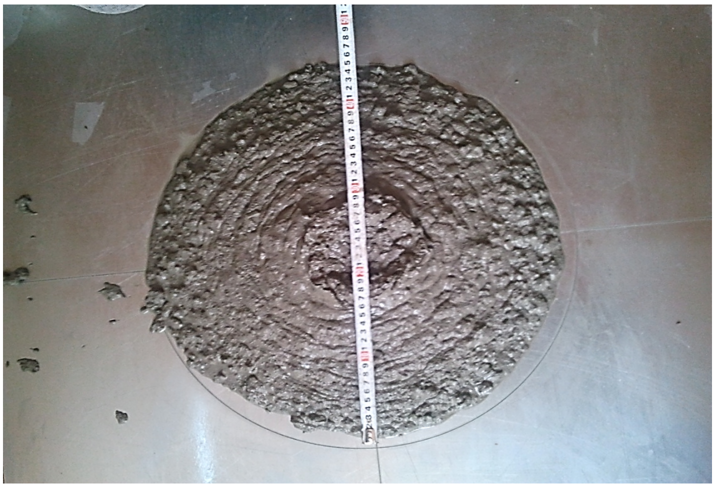

Figure 15. The Slumpflow diameter with the increase in dosage of Superplasticizer

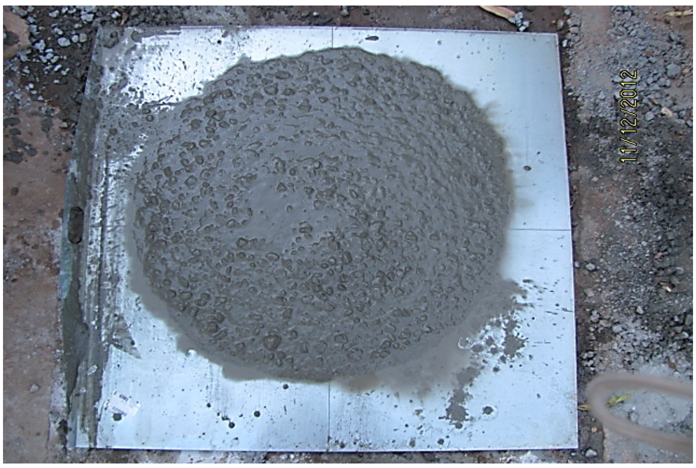

Figure 16. The Target Slumpflow diameter of Self Compacting Concrete after increase dosage of Superplasticizer

Figure 17. Unstable Self Compacting Concrete due high dosage of superplasticizer

Figure 18. High Percentage of the Portion of Segregation due to high superplasticizer dosage

5. Conclusion

The development of a suitable mix for SCC that satisfied the requirements had been achieved successfully. The major difficulty which was faced in development of SCC was on account of contradictory factors that the concrete should be fully flowable but without bleeding or segregation. It is required that the cement mortar of the SCC should have higher viscosity to ensure flowability while maintaining non-sedimentation of aggregates and that was achieved by using high content of powders (fine materials less than 0.15 mm includes the cementitious materials).

When performing concrete laboratory experiments, good experience and good practice is followed. Also the effect of specific and controlled adjustments is learned.

The produced self compacting concrete is successfully confirmed the fresh properties of SCC with Slumpflow in range of 650 to 850 mm with high viscosity and excellent segregation resistance. The hardened properties of concrete were also considered. The strength of SCC was found same or higher than that of normally vibrated concrete with the same constituent materials. SCC has relatively higher dynamic modulus of elasticity ranged between 38 to 42 GPa, in comparison to normally vibrated concrete for the same strength range of 50 to 60 MPa. Whereas lower Spilt Tensile of SCC was found of 2.5 MPa, and Flexural strength of 10 MPa.

Achievement of durable concrete structures independent of the quality of construction work in Sudan by using Self Compacting Concrete (SCC) have been proposed. The benefits of the application of this new concrete technology require effort to be achieved. Moreover, areas such as quality control, mixture development, and logistics may need modification or expand resources when develop self-compacting concrete in Sudan. The focus especially on the ability of the concrete producers and contractors to effectively apply SCC technology to their portion of the concrete construction process. Some concrete producers may be limited in their ability to consistently produce good-quality SCC. These limitations are rather to the time, equipment, and resources needed to fully implement SCC.

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