AN INVESTIGATION ON THE EFFECT OF CEMENT AND SILICA FUME ON PROPERTIES OF SELF-COMPACTING CONCRETE

Farzad Moshiri[1*], Arash Atashnama[2],Mohammadreza Panahi[2], Rasoul Gharebaghi[3]

And Javid Mahlouji[4]

[1]*PhD candidate, University of Technology, Sydney, Australia (corresponding author)*
[2]*Research engineer, Zanjan University, Iran*
[3]*Undergarduate student, Sharif University of Technology, Iran*
[4]*Research engineer, Universiti Teknologi Malaysia (UTM), Malaysia*

ABSTRACT

Self-Compacting concrete (SCC) is identified as a high performance concrete with the ability of self compaction, using its own weight without any external vibration. SCC is able to fill congested area and voids, even in highly reinforced concrete members whilst it flows without segregation. The fresh properties of SCC such as workability can be determined using different tests including slump-flow, J ring, V-funnel, U box, L box, GTM and column technique. In this paper the effect of different amount of cementitious material, silica fume and W/C ratios on workability and compressive strength of SCC are investigated. The results indicate that the workability of mixtures is reduced by increasing the amounts of cement and silica fume. However, the effect of increasing in the silica fume is significantly more than that of cement. Furthermore, it has been found that the V-funnel test is more capable to measure the workability of SCC comparing to other aforementioned methods.

Keywords: Self-Compacting Concrete (SCC), Fluidity, Slump-flow, Compressive Strength

1. INTRODUCTION AND BACKGROUND

SCC has been using increasingly for more than two decades in pre-cast concrete technology whereas its application provides an interesting development in construction technology to increase the workability and compatibility of concrete without the need of external vibration which is favourable to flow over congested area properly (Ramezanianpour, Samadian et al. 2012). The main characteristics of SCC are high plasticity, significant passing ability and resistance to segregation within congested area. There are different ways to increase the workability of conventional concrete including: increasing water-cement (W/C) ratio, application of superplasticisers and use of fillers. Although, these methods increase the workability of concrete but also led to segregation and reduction in strength of concrete. Additionally, higher amount of cementitious material such cement

[*]Presenter and Corresponding author: Email: Farzad.Moshiri@uts.edu.au

and pozzolan such as silica fume can be used to overcome the drawbacks of aforementioned methods.

The paper represents an experimental investigation to study fresh and hardened properties of SCCs containing different amount of Silica Fume and cement associated with different W/C ratios.

2. EXPERIMENTAL TEST

Previous investigations on effect of silica fume on SCC denote that the fresh and hardened properties of SCC are affected by three main parameters of W/C ratio and cement and silica fume contents of mix. Totally 12 different SCC mixes were tested studying the effect of different W/C ratio, cement and silica fume contents on the fresh and hardened properties of SCC. The cement contents varied from 300 kg/m^{3}to 400 kg/m^3 whilst W/C ratios selected to be 0.4, 0.45 and 0.5. SCC mixes including Silica fumes with the value of more than 10% of cement content led to poor durability. Hence, the mixes including Silica fume 5% and 10% were selected. Slump-flow, J ring, funnel, GTM screen stability test and column technique tests were carried out to measure the fresh properties of SCC including filling ability, passing ability and resistance to blockage.

The aggregate were prepared in comply with (ASTMC33 2004) standard. The gradation curves of the sand and gravel aggregates are shown in Figure 1. Specific gravity of sand and gravel are 2530-2570 kg/m^{3}and absorption percentages are respectively 2% and 5%. The cement is Portland cement type 1 whereas, to achieve appropriate workability, superplasticiser based on polycarboxilate was used.

2.1. Mix design

Two different amount of silica fume (5% and 10%) were selected to be used for three different W/C ratios of 0.40, 0.45 and 0.50. Hence, the sensitivity of available workability test methods to different cement and silica fume contents was investigated. The mix designs of different mixes are illustrated in Table 1.

Table 1: concrete mix designs.

Mix	Cement content (kg/m^3)	W/C	Silica fume(%)	Limestone powder Filler (kg/m^3)	Sand/Gravel ratio (by weight)
A1	350	0.4	5	100	1.5
A2	350	0.45	5	100	1.5
A3	350	0.5	5	100	1.5
B1	350	0.4	10	100	1.5
B2	350	0.45	10	100	1.5
B3	350	0.5	10	100	1.5
C1	450	0.4	5	100	1.5
C2	450	0.45	5	100	1.5
C3	450	0.5	5	100	1.5
D1	450	0.4	10	100	1.5
D2	450	0.45	10	100	1.5
D3	450	0.5	10	100	1.5

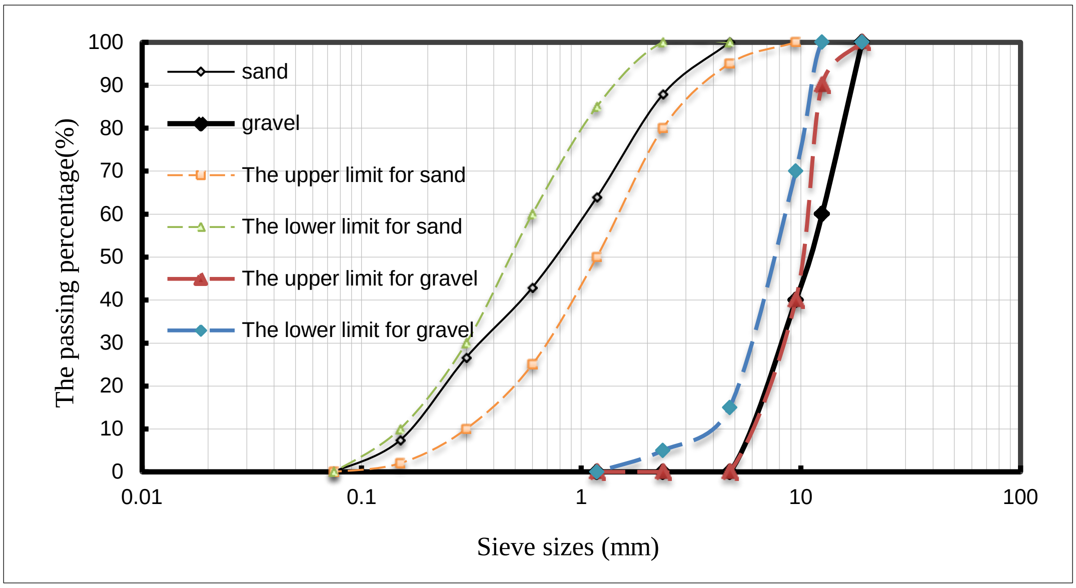

Figure 1:The gradation curves of the sand and gravel aggregates.

2.2. Test methodology

Different parameters including deformability, filling ability, passing ability and proper resistance to segregation are required to identify workability of SCC. There are different methods available to evaluate the filling ability, passing ability and resistance to segregation of SCC(Alyamaç & Ince 2009). In this study, slump-flow, J ring, V funnel, GTM and column technique tests all in comply with (EFNARC 2005) were conducted to measure the fresh properties of SCC including filling ability, passing ability.

Deformability and filling ability refer to ability of filling the spaces without the need to vibration using its weight whilst passing ability of SCC measures the possibility of concrete to flow through reinforcement bar without any blockage. Moreover, resistance against segregation is defined to be homogeneity of the concrete without separating of grout from the mix (Alyamaç & Ince 2009).

The slump flow test was used to give an indication on the flowability, passing ability and yield stress of SCC. The test involves filling an Abram's Cone with the SCC and placing it in the centre of a slump flow board in comply with (ASTMC143 2012). The Abram's Cone was lifted to a height of approximately 230mm in 3 seconds and allowed the concrete to flow out onto the slump flow board in a circular shape. The slump flow diameter is then measured as the diameter of the circle of concrete within two directions (d1 / d2) as shown in Figure 2.

The J Ring test was conducted to evaluate the passing ability of the SCC mix through blockage. The J Ring test is very similar to the slump-flow test, with the only difference being the incorporation of the J Ring which is placed in the centre of the slump-flow board and in which the Abram's Cone sits inside. Again, the Abram's Cone is lifted to a Height of approximately 230mm over 3 seconds and the mix flows outwards through the reinforcing bars on the J Ring. Slump-flow diameter is again measured along with the time the mix takes to flow to its final testing position. The testing procedure for Slump-flow and J Ring test is shown in Figure 2.

Elsewhere, V funnel test was employed to measure filling ability and viscosity of SCC using a V-shaped funnel. V-shaped funnel is filled with concrete and then opening cap, the time for the concrete to flow out of the funnel (t_v) is measured (Alyamaç & Ince 2009).

Column technique test includes the determination of static segregation of SCC by measuring the coarse aggregate content in the top and bottom portions of a column specimen in compliance with (ASTMC1610/C1610M 2010). A sample of fresh SCC is placed on top of column without any vibration. The height of column is divided into three sections whilst top and bottom portions of concrete are washed on a 4.75 mm (No. 4) sieve, leaving the coarse aggregate on the sieve. The masses of coarse aggregate in the top and the bottom sections are measured and the static segregation is determined (ASTMC1610/C1610M 2010).

GTM developed by the French contractor was carried out to assess segregation resistance stability. The test includes 10 litre of concrete, allowing it to stand for a period to observe any occurred internal segregation, half of the 10 litre is poured on a 5mm sieve of 350mm diameter, which stands on a sieve pan following a weigh scale. The passed mortar is weighed and the proportion of the passed mortar to initial concrete on the sieve is reported (EFNARC 2005).

Furthermore, the 28day compressive strength of different test series was determined using Cubic specimens, 150/150 mm. the demolded specimens at 1 day were cured at 28 days in a moist room of 95% relative humidity and temperature of about 23 °C. The specimens were loaded subjected to monotonic loading until failure following a constant loading rate. The mean values of compressive strength, f_c at 28 day were reported.

Figure 2: Slump-flow (on left) and J ring (on right) tests.

3. EXPERIMENTAL RESULTS

The fresh properties of SCC mixes were measured using different test methods such as slump-flow, J ring, GTM, column technique and V funnel as depicted in Figure 3Figure 6. It is noted that increasing W/C ratio results in higher workability. Moreover, comparing available test methods of SCC, column technique is identified as most sensitive test to W/C ratio whereas, the least sensitive test is slump-flow.

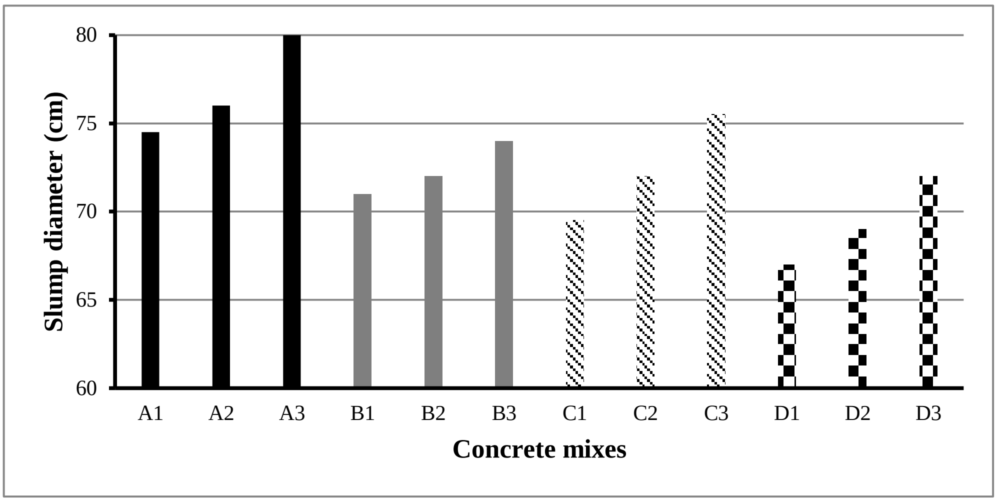

Figure 3: The results of slump-flow test for different mixes.

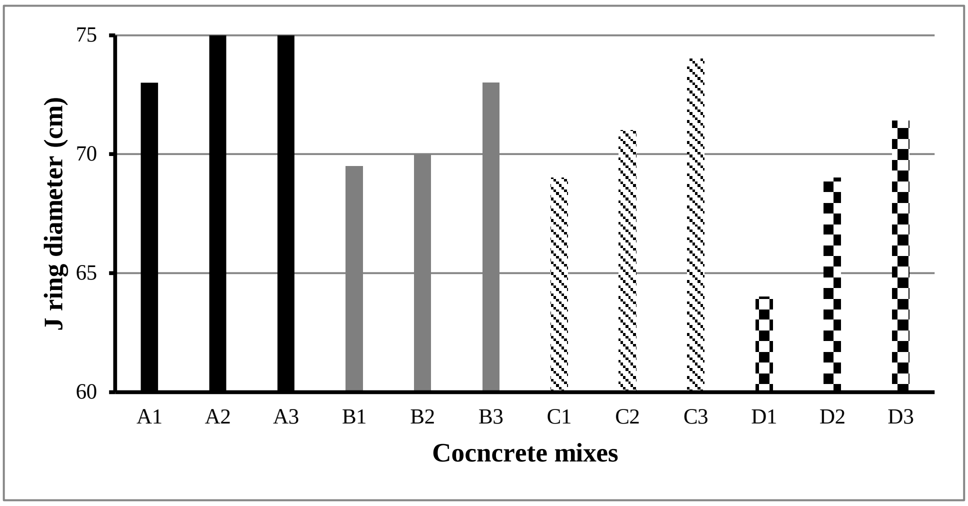

Figure 4: The results of J ring test for different mixes.

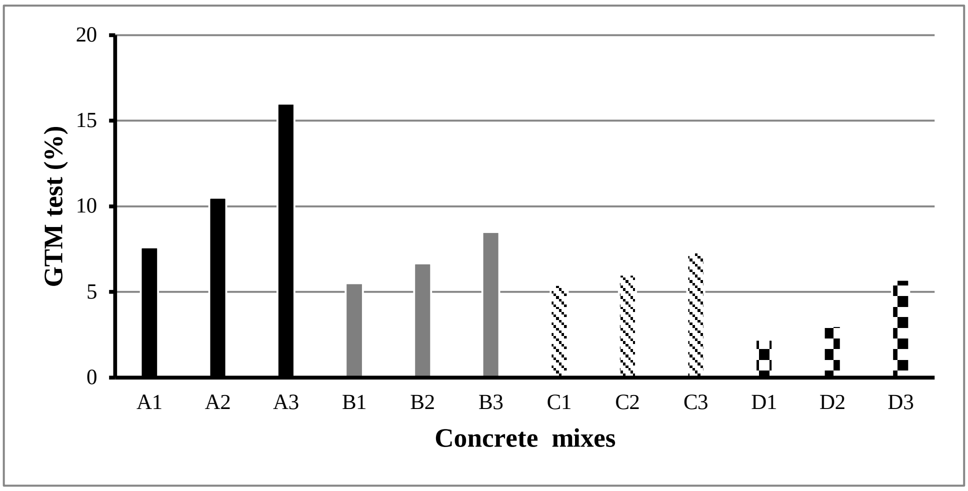

Figure 5: The results of GTM test for different mixes.

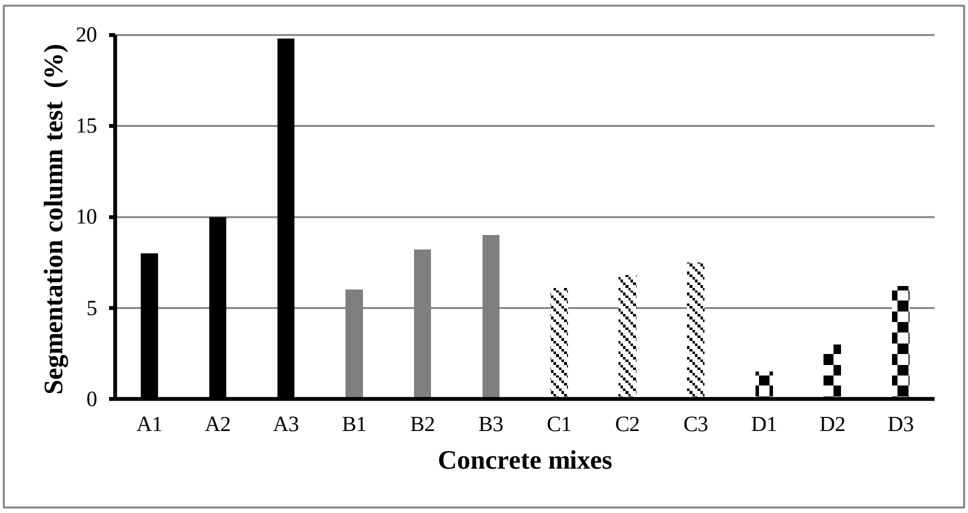

Figure 6: The results of column technique for different mixes.

Figure 7 represents the effect of silica fume content on workability of different mixes measured by column technique. The results indicate that the high specific surface area (surface to volume ratio) of the silica fume particles decrease the workability of the concrete, Hence the mixes including higher silica fume content represent lower workability. Similar to silica fume content, increasing cement content of mixes reduces the workability of SCC as shown in Figure 8.

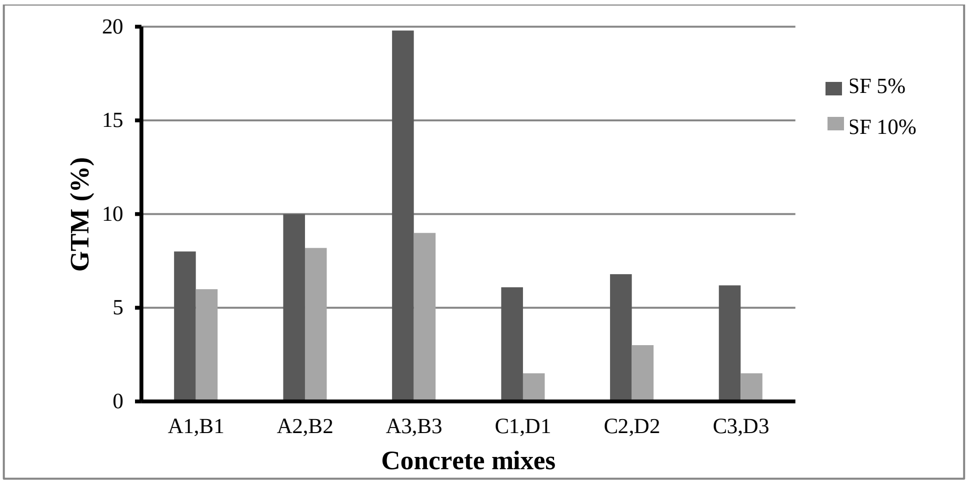

Figure 7: Effect of different silica fume contents on workability of SCC mixes.

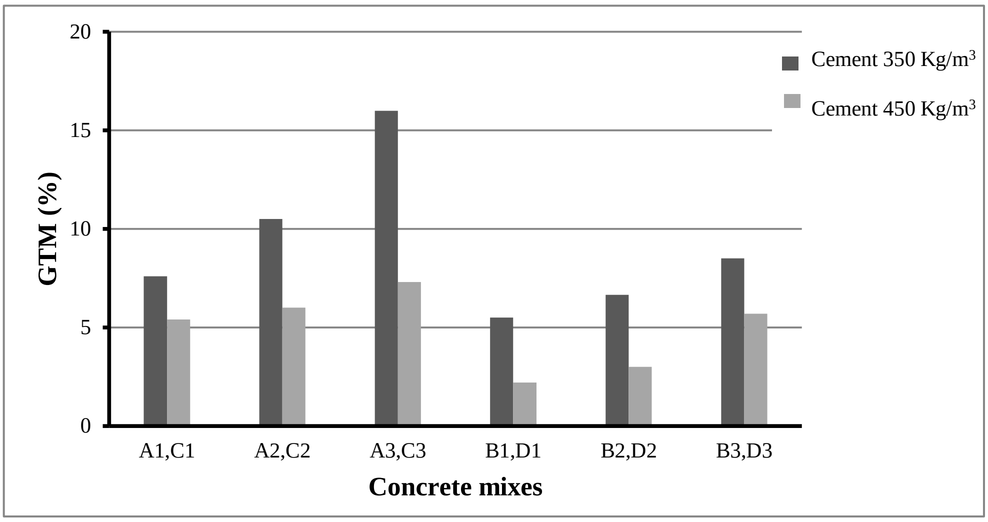

Figure 8: Effect of different cement contents on workability of SCC mixes.

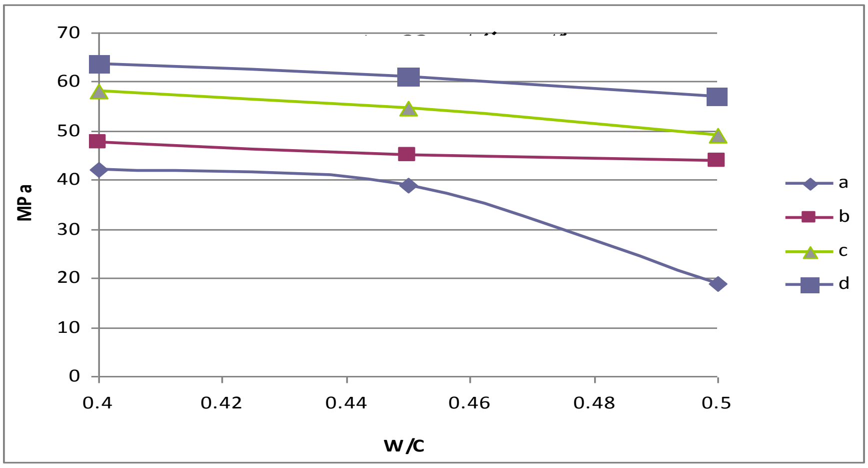

Figure 9: 28-day compressive strength of different concrete mixes.

In addition to fresh properties of SCC, Figure 9 indicates 28 day compressive tests of different mixes and as expected, increasing W/C ratio reduces the compressive strength whilst in contrast, increasing cement content increases the cement paste content which results in higher compressive strength. Increasing the silica fume content of the mixes improved the boundary region between aggregates and hydrated cement paste which increases compressive strength of the samples as displayed in Figure 9.

4. CONCLUSIONS

The experimental results of fresh and hardened properties of 12 SCC mixes combining different Silica Fume and cement contents associated with different W/C ratios are presented in this paper. Based on the aforementioned results, the following points are concluded:

- Increasing silica fume and cement content of SCC mixes reduces the workability.

- Comparing available test methods of SCC, column technique test is found to be most sensitive test to variation of W/C ratio, cement and silica fume contents whereas, slump-flow is identified to be the least sensitive test.

-Increasing cement and silica fume contents of mixes result in enhanced cement paste and improved boundary region between aggregates and hydrated cement paste respectively which results in higher compressive strength.

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