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MIXING DURATION EFFECTS ON THE PERFORMANCES OF SELF-COMPACTING CONCRETE WITH LIMESTONE'S FINE

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ABSTRACT

If it is true that we have always been able to produce very liquid concretes to facilitate the implementation, this has always been done in the past at the expense of the qualities of these currents concretes like strength and durability. Increasing attention is given to the behavior of fresh concrete and the facility with which it can be put in place in forms. The present paper is an effort to quantify the influence of mixing period (time delay) on the properties of fresh and hardened self-compacting concrete. The concrete mixtures were continuously agitated for up to 30 min using a low-shear rate mixer under controlled temperature of 25°C.

The workability retention of fresh SCC was observed through slump flow diameter, T_{50} times and air content test. The hardened properties that were included in this study were the compressive and tensile strength at 5 h, 1, 3, 7 and 28 days.

Initial results open perspectives in the field of rheology on the industrial scale of concrete and promoting the development of this new concrete in the Algerian context.

Keywords: self-compacting concrete, mixing period, limestone fillers, rheological properties, compressive strength, splitting tensile strength.

INTRODUCTION

Developments in concrete technology, especially the introduction of wide varieties of chemical admixtures, mineral additives and cementitious supplementary materials, have increased the importance of fresh concrete properties **(**Khrapko, 2012).

When the concrete plants are far from the construction sites the concrete must be transported; therefore the mixing time will be longer. From the quality and duration of mixing depends structural homogeneity of the concrete and like all types of concrete mixing time can generate differences in performance in hardened state which is connected directly to the fresh state.

What effect will have the additional time of mixing on the self-compacting concrete performances?

During long mixing time of SCC, the slump of concrete is reduced. This is because some water from concrete mix is lost by evaporation, especially if concrete is exposed to sun or wind, some water is absorbed by the aggregate if they are not fully saturated, and some water is removed by the initial chemical reactions. That's why we should evaluate the workability retention.

Maintaining the required workability of self-compacting concrete for a specific time is a task that requires knowledge and experience. Because the plastic properties of fresh SCC are very different from that of traditional concrete and also because of the fact that these properties depend on a wide number of factors that affect the control practices of SCC workability in time **(**Khrapko, 2012).

The behaviour of fresh concrete from rheological point of view deals with the slump flow, T_{50} and air continent. And these characteristics are the ones that change with time and are the ones that have to be maintained.

Tests conducted by the researchers (Boukendakdji, 2009), (Hossain, 2011), **(**Khrapko, 2012) have demonstrated that the slump of concrete is reduced as mixing time is increased. The exact value of workability loss depends on several factors, such as the types of additive, particle size distribution and their packing, cement chemistry, transport time and ambient conditions (temperature)…

T. Hossain and his co-workers (Hossain, 2011) investigated the effects of mixing duration on hardened properties of SCC, 90 minutes and 180 minutes of mixing period was selected along with the general mixing period of 5 minutes. Some parameters are kept constant for all batches of SCC sample. The authors concluded that compressive and splitting tensile strength decrease and amount of water added increases with the increase of mixing period of SCC. Furthermore, permeability of SCC also increases with the extended mixing period.

The present paper is an effort to quantify the influence of mixing period (time delay) on the properties of fresh and hardened self-compacting concrete with limestone's filler. The concrete mixtures were continuously agitated for up to 30 min using a low-shear rate mixer under controlled temperature of 25°C. The workability retention of fresh SCC was observed through slump flow diameter, T_{50} times and air content test. The hardened properties that were included in this study were the compressive and tensile strength at 5 h, 1, 3, 7 and 28 days.

MATERIALS AND CONCRETE MIXTURES

In production of SCC, Portland Cement CEM II/42.5 with a specific surface area of 3891cm²/g was used in this study. Crushed stone was used as coarse aggregate the size was 3/8 mm and 8/15 mm, a sand 0/3 mm, a limestone filler UF20, A superplasticizer MEDAPLAST SP 40 (High Range Water Reducer / Conforms with the standard EN 934), and tap water from the laboratory.

The Japanese approach has allowed us to select two compositions of SCC. Designations and notations of designed concrete are collected in the following table:

Table 2: The composition of concrete in 1m^3.

Compositions	**Designation**	
	SCC 10	**SCC 30**
coarse / fine aggregate	0.78	0.78
cement CEM II/42.5 (kg/m^3)	400	300
Limestone fillers UF 20 (kg/m^3)	48.8	136
fine aggregate 0/3 (kg/m^3)	961	961
coarse aggregate 3/8 (kg/m^3)	455.8	455.8
coarse aggregate 8/15 (kg/m^3)	297.2	297.2
Superplasticizer SP 40	10.5	9.5
total water	200	196
W/P	0.45	0.45

MIXING PROCEDURE

The concrete was prepared using w/p ratio of 0.45. SCC mixtures were prepared by mixing coarse aggregates, fine aggregates and powder materials (cement, limestone powder) in a laboratory drum mixer. The concrete mixer drum was moistened then the weighted powder material and aggregates were mixed in dry form for 2 min. thereafter tapped water was added in two stage, at first 50% of water added and rotated the mixing hopper for 2 minutes and the rest amount of water containing the whole amount of super plasticizer was poured and mixed for 3 min without stopping the mixer machine.

TESTING METHODS

Tests on fresh and hardened self-compacting concrete: 10×20 cm cylindrical molds were used for the determination of compressive strength, while prismatic molds 7×7×28 cm were used for the determination of tensile strength. Before casting, slump flow diameter, T_{50} times, V-funnel time, L-box ratio, GTM sieve stability test, Air void content and unit weight of fresh SCC were measured according to the French Association of Civil Engineering (AFGC 2000).

Specimens (prisms and cylinders) were then cast in steel molds and were not subjected to any compaction other than their own self-weights.

The specimens were left covered with a plastic sheet for 24 hours until demolding. Thereafter, the specimens were kept in a room ambient atmosphere until testing (compressive and tensile strength) which is performed at 3, 7, 14 and 28 days. The maximum strength of each specimen was recorded and the average of three samples was considered the compressive strength at the specific day.

Study of the effect of the mixing time on self-compacting concrete: It is therefore the object of our experimental program. In this experiment on the influence of mixing time, workability was measured immediately after mixing which takes about six (6) minutes. Concrete slump flow of 6 minutes mixing time was considered as reference. In addition to these tests, the slump flow, T_{50} times and air void content was measured at four different times after mixing to assess the workability retention. The four times were: 0, 10, 20 and 30 min after the end of the mixing.

Specimens were prepared for the measurement of the apparent mass of fresh concrete and subsequent mechanical testing at different maturities respectively cylindrical 10x20 cm and prismatic 7x7x28 cm. Compression and flexural tensile tests were achieved at 5 - 1d - 3d - 7d - 14j and 28 days of previous specimens.

RESULTS AND CONCLUSION

Properties of fresh self-compacting concrete: In this investigation the filling ability was evaluated by slump flow, T_{50} flow time and V-funnel tests for SCC (AFGC 2000). The passing ability was measured by the L-Box tests (AFGC 2000). The resistance to segregation was measured by GTM sieve stability test (AFGC 2000). Table 3 lists the test results performed on fresh concrete.

Table 1: Fresh properties of the SCC

	Slump flow D (cm)	**T_{50} (s)**	**L-Box**	**Sieve Stability (%)**	**V-Funnel (s)**	**Air void content (%)**	**Real density (Kg/m^3)**	**Calculated density (Kg/m^3)**
SCC 10	77	2.63	1	8.36	9.76	2.2	2360.8	2373.3
SCC 30	74	3	0.9	5.08	10	1.9	2326.2	2355.5

Table 3 summarises the fresh concrete tests results and shows that requirements specifications have been properly completed by the various concretes.

All mixtures exhibited good workability with flow values of at least 74 cm. We notice that for a fixed flow time and slump flow, superplasticizer demand decreases with increasing the amount of fillers. We note that the flow time of SCC 30 is higher than those of SCC 10. So the amount of filler may affect the fluidity of the SCC.

On dynamic segregation of SCC, the results shown in Table 3 are consistent with what one would expect from a SCC. However, when the dosage of fine limestone increases, it causes an increase in viscosity resulting in a decrease in the filling rate h_2/h_1. The fill rate of SCC 10 is higher than SCC 30.

We retain a decrease in the amount of entrained air for concrete containing more limestone fillers. This decrease is translated by the better compactness of fresh concrete (Bensebti, 2008). In other term the introduction of mineral additives leads to a modification of the porosity of the cement matrix.

Properties of hardened self-compacting concrete: The compressive strength and split tensile strength test results are given in Table 4. This table presents the average of the compressive strength as determined from three cylindrical specimens and splitting tensile strength as reported from three prismatic specimens at each age. The table 2 shows the Compressive strength and tensile strength results.

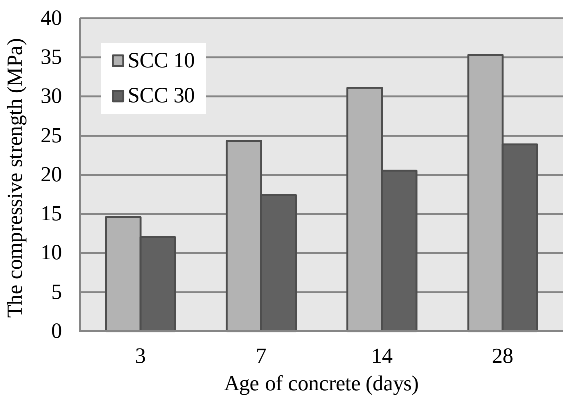

Fig 1: Compressive strength of SCC mixtures.

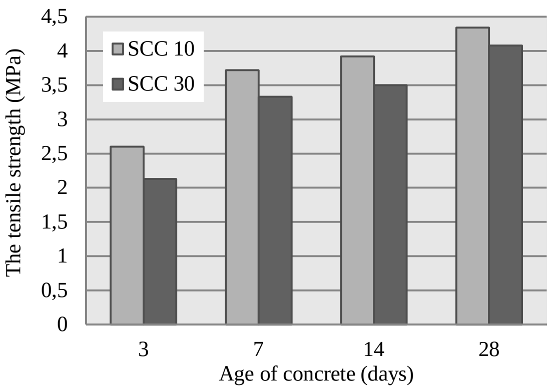

Fig 2: Tensile strength of SCC mixtures.

On the histogram in Figure 1, we can notice that increasing the rate of substitution of cement by limestone filler from 10 to 30%, brings down the compressive strength of 17% at 3 days 28% at 7 days, of 34% at 14 days and 32% at 28 days. However, it is interesting to note that even with 30% of the fillers compressive strength remains within reasonable limits (25 MPa).

The concrete made from local materials proved stable and satisfactory. The presence of limestone filler is a necessary or they not only improve the rheological proprieties but the mechanical performance as well.

The compressive strengths are inversely proportional to the rate of substitution of cement with limestone filler. This phenomenon is valid for properties investigated in this case, the compressive strength and tensile strength.

The effect of mixing time on the slump flow and T_{50}: We look for to assess the flow variation with mixing time of the two studied self-compacting concrete. The concrete mixtures were continuously agitated for up to 30 min using a low-shear rate mixer. Slump flow and the T_{50} were measured every 10 minutes under controlled temperature of 25°C. All the results obtained during the experiments are summarized in the following table:

Table 2 the effect of mixing time on the plasticity of concrete.

Mixing time	**SCC 10**		**SCC 30**	
(min)	**D (cm)**	**T_{50} (s)**	**D (cm)**	**T_{50} (s)**
0	77	2,63	74,5	3,86
10	73,5	3,20	76	2,30
20	56,5	7	69	4
30	33,5	-	31,5	-

Slump flow is attenuated at least 26% until 20 min of mixing. Then the slump flow is reduced by about 56% in the best case.

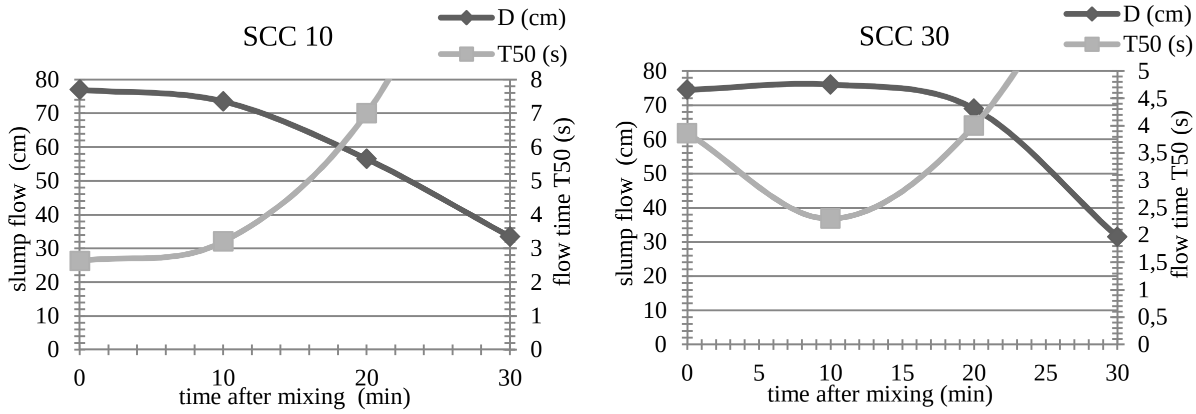

Fig 3: The effect of mixing time on the plasticity of SCC 10 and SCC 30.

Fig 3 shows the workability retention at 0, 10, 20 and 30 min after mixing. Workability retention is a rheological parameter; it gives deformation (in terms of loss of workability) of the mix with respect to time. It is mentioned that the flow time T_{50} increases and the slump flow decreases with increasing mixing time.

In the first 20 minutes both SCC 10 and SCC 30 are still satisfactory the self-compacting concrete recommendations. But after 30 minutes the two mixtures have lost their fluidity and instead of a spread were observed a slump. This phenomenon is illustrated by the Figure below (Fig 4):

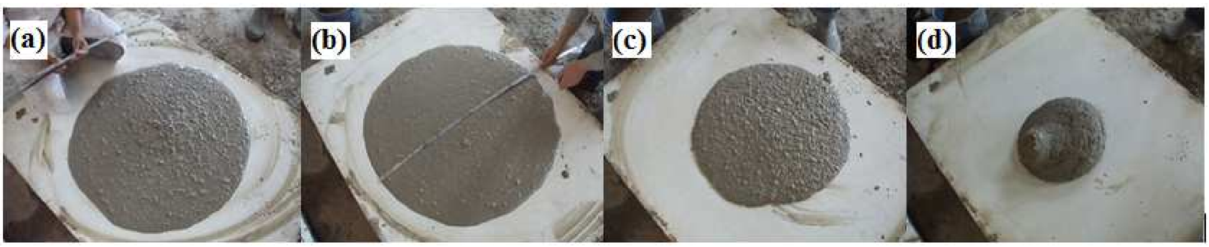

Fig 4: The influence of mixing time on slump flow.

These lower values are mainly from the lack of mixing of materials that are sufficiently dispersed. These general observations are accompanied by the observation of poor homogeneity within this SCC kneaded for 30 minutes because the relative dispersion values of the slump flow is much higher than for other mixing times.

From these two figures we can conclude that for the two mixes we have 20 min to put the concrete in place. The authors have earlier; found that concrete mixes without slag or with 10% slag lost a part of their workability even at 30 min after mixing (Boukendakdji, 2009).

In the case where the places of manufacture and casting are not the same, it requires an adequate admixture to give the SCC an instant fluidity, but also maintained over time.

The effect of mixing time on slump flow and air content: The influence of mixing time is clearly felt on the air content.

Table 3 the evolution of slump flow and air content as a function of mixing time**.**

Mixing time	**SCC 10**		**SCC 30**	
(min)	**D (cm)**	**Air content (%)**	**D (cm)**	**Air content (%)**
0	77	2,2	74,5	1,9
10	73,5	2,6	76	2,1
20	56,5	2,9	69	2,7
30	33,5	3,2	31,5	3,1

It should also be recalled to clarify that the increase in air content generally increases the plasticity of concrete and the results obtained go in this direction. There is a prolonged mixing time increases the air content. The increase is about 27% after 20 minutes and 35% after 30 minutes on average values.

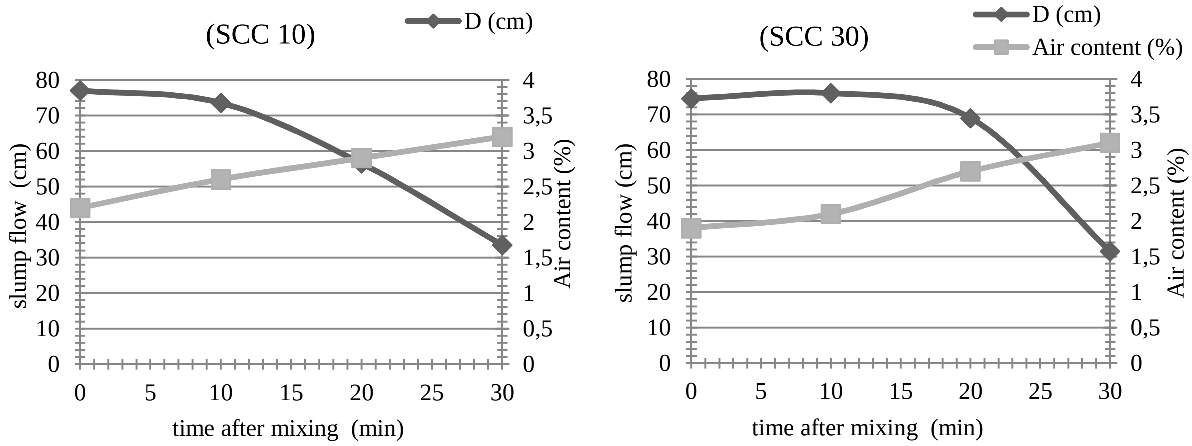

Fig 5: The evolution of slump flow and air content as a function of mixing time of SCC 10 and SCC 30.

According to figures 5, It was found that the increased slump flow causes a reduction of the air content therefore the relationship between workability and air content is inversely proportional. Our results are in coherence with those of Girish (Girish, 2010).

The effect of mixing time on compressive strength: Compressive strength test of cylindrical concrete specimen of 10 cm diameter and 20 cm height was performed. Cylindrical specimens were tested at 5 hours, 1, 3, 7, 14 and 28 days. The maximum strength of each specimen was recorded and the average of three samples was considered the compressive strength at the specific day. The overall results are detailed in the following tables (tables 5 and 6).

Table 5 the compressive strength test result of SCC 10.

Mixing time (min)	**5 hours**	**1 day**	**3 days**	**7 days**	**14 days**	**28 days**
0	0,99	12,05	14,62	24,35	31,12	35,33
10	1,00	12,19	15,8	23,71	30,69	34,85
20	1,04	12,20	15,97	23,39	28,4	33,42
30	1,10	12,24	16,66	22,99	27,98	34,98

Table 5 represents the compressive strength test result of SCC 10. The level of performance achieved at 7days requires only one significant point: The results obtained on the least mixed concrete are higher.

At the age of 7 days, there is a slight decrease in compressive strength of 4% for mixing time of 20 min and of 6% for mixing time of 30 min with respect to that of reference mixing time of 0 min. The same trend on the results obtained at the age of 14 days with an increase in the rate of strength loss.

But at the age of 28 days, there is a slight percent of decrease in compressive strength for mixing time of 20 min compare to that of reference mixing time of 0 min followed by an equal percent of increase compared to mixing time of 20 min.

Table 6 the compressive strength test result of SCC 30.

Mixing time (min)	5 hours	1 day	3 days	7 days	14 days	28 days
0	<1	10	12,07	17,42	20,52	23,87
10	<1	9,25	10,52	16,85	17,2	21,51
20	<1	7,88	12,02	17,55	18,08	19,71
30	<1	10,47	13,3	19,86	21,92	24,36

Table 6 represents the compressive strength test result of SCC 30. The evolution of slump flow affects the strengths obtained because the increase in slump flow caused a chute in resistance at different ages.

At the age of 7 days, there is a slight decrease in compressive strength for mixing time of 10 min with respect to that of reference (mixing time of 0 min) followed by a significant increase for mixing time of 30 min. But at the age of 28 days, there is a considerable percent of decrease in compressive strength of 18% for mixing time of 20 min compare to that of reference (mixing time of 0 min) followed by a significant increase of 41% for mixing time of 30 min.

With long mixing time of concrete, the pores in concrete are increased. That's why the compressive strength of SCC decreases with the increasing of mixing duration.

The effect of mixing time on tensile strength: Tensile strength test of prismatic concrete specimen of 7 × 7 ×28 cm was performed. The maximum strength of each specimen was recorded and the average of three samples was considered the splitting tensile strength at the specific day. The test results (from 5 hours to 28days) are shown in tables 7 and 8:

Table 7 the tensile strength test result of SCC 10**.**

Mixing time (min)	5 hours	1 day	3 days	7 days	14 days	28 days
0	<1	1,45	2,6	3,72	3,92	4,34
10	<1	1,62	2,88	3,84	3,95	4,34
20	<1	1,90	3,27	4,27	4,31	4,38
30	<1	2,35	4,20	4,96	4,00	4,48

Table 8 the tensile strength test result of SCC 30.

Mixing time (min)	5 hours	1 day	3 days	7 days	14 days	28 days
0	<1	1,69	2,13	3,33	3,51	4,08
10	<1	1,60	1,98	3,20	3,69	4,24
20	<1	1,74	2,28	3,64	3,58	4,25
30	<1	2,10	3,21	3,85	5,33	6,28

Tables 7 and 8 represent the evolution of Tensile strength as a function of mixing time at different ages of SCC 10 and SCC 30 respectively. The results obtained increases with increasing mixing time.

CONCLUSION

This work gives attention to the effect of the time delay or the time elapsed during the mixing process, which affects the performance of SCC mix adversely and hence, its hardened properties also. In the case where the places of manufacture and casting are not the same, it requires an adequate admixture to give the SCC fluidity instant, but also maintained over time. Reading various works led to make several criticisms of this point.

- The higher the initial workability, the greater the loss and the rate of workability loss is higher in rich mixes i.e. concrete highly dosed with cement.
- The mixing time affects the air content, the increase in air content generally increases the plasticity of concrete and the results achieved go in this direction.
- The level of performance achieved on the less mixed concrete are the highest, which is normal given the other parameters recorded elsewhere (higher compactness, lower air content, setting and hardening earlier).
- The characteristics required to qualify a self-compacting concrete are not verified after a certain mixing time. Mixtures made after 30min did not lead to optimal performance of adjuvanted concrete.

Workability time means the duration of workability retention which is the time of initial setting. These two properties of workability retention and considerable resistance in the short term afford the opportunity to make a concrete composition precursor in concrete mixing plant and then transport by truck mixer on site, the composition hardens quickly after implementation.

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