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MIXING TIME EFFECTS ON PROPERTIES OF SELF COMPACTING CONCRETE

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ABSTRACT

Self Compacting Concrete (SCC) is an innovative concrete that flows under its own self weight. Besides the composition and raw materials of SCC, mixing time has a great influence on the mechanical properties of SCC such as compressive strength, splitting tensile strength, amount of water added and permeability of concrete. These properties vary with general mixing time 5 minutes and extended mixing time 90 and 180 minutes. The observations show 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.

Keywords: self compacting concrete, mixing period, compressive strength, splitting tensile strength, slump flow, permeability.

INTRODUCTION

Self Compacting Concrete (SCC) can be defined as **"**a concrete that is able to flow under its own weight and completely fill the formwork, while maintaining homogeneity even in the presence of congested reinforcement, and then consolidating without the need for vibrating compaction**"** [1].

Thus, mixing duration of SCC should be selected in such a way that it will be cohesive and homogeneous enough to fill spaces of almost any size and shape without segregation or bleeding.

Different mixing durations have been already reported. An optimum mixing is achieved in a pan mixer in 4 minutes in total by first mixing the sand with parts of the water [2]. A mixing time of 3 minutes also can be chosen in total, for a forced twin shaft mixer [3]. A longer mixing procedure of 6 minutes can be used in total beginning with a dry processing with all materials except water [4].

In general, the mixing duration for SCC is longer than that for normal vibrated concrete to ensure complete homogeneity because of the difference in raw materials [5, 6]. A mixing period exceeding 5 minutes also preferred [7].

In this paper, to investigate 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. These are: i) surface conditions of aggregate, ii) gradation of fine and coarse aggregate and iii) water/cement (w/c) ratio. Among all mechanical properties, particular attention is given on strength and permeability of SCC in this research paper.

MATERIALS AND METHODS

Materials

Cement

In production of SCC, Ordinary Portland Cement was used in this study. Some physical and chemical properties of that cement are shown in Tables 1 and 2, which were collected from the cement manufacturer.

Table-1. Physical properties of cement.

Description		ASTM standard requirement	Test result
Fineness	Sieve No. 200 residue (%)	-	1.96
	Blaine (m^2/kg)	280	341.2
Setting Time	Consistency (%)	-	30.00
	Initial setting (min)	Not less than 45 min.	175
	Final setting (min)	Not more than 375 min.	270
Compressive Strength (MPa)	Age (Day)	MPa	MPa
	3	Min 12	20.30
	7	Min 19	27.83
	28	Min 28	43.45

Table-2. Chemical composition of cement.

Components	%
SiO_2	35.64
Al_2O_3	4.9
Fe_2O_3	2.54
CaO	48.63
MgO	1.7
SO_3	1.62
F/CaO	1.09
IR	0.55
LOI	2.93
Sum	99.60

Water

Drinkable tap water is used in this study.

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Sand dust

The sand dust is used in this research is the dust of river sand passing through the No. 100 sieve (ASTM standard sieve). This Sand Dust is used as a partial replacement of cement. In this Study 10% sand dust is used.

Coarse aggregate

In SCC, the maximum size of coarse aggregate should be limited to 12 ~ 20 mm, although larger size is also being used. Fresh properties of SCC are directly influenced by the particle size distribution and the shape of coarse aggregate. More spherical particles are less likely to cause blocking and increasing the flow because of reduced internal friction [8]. Crushed stone was used as coarse aggregate in production of SCC. The maximum aggregate size of coarse aggregate was 16 mm.

Fine aggregate

Fine aggregate greatly influenced the properties of SCC than of coarse aggregate. Particles size fraction of less than 0.125 mm should be taken into account in calculating the water/cement ratio. The large amount of paste in SCC mixes helps to reduce the internal friction between the sand particles but a good grain size distribution is still very important. Sometimes blended sands are used in SCC mix design methods to match an optimized aggregate grading curve and thus the paste content can also be reduced [9].

In this research wok, local sand having fineness modulus 2.69 was used as fine aggregate.

Sample preparation

The concrete was prepared with 1:1.4:2 proportion using w/c ratio of 0.6. In mixing concrete, a tilting type concrete mixer was used. Each granulometric aggregate was weighted and kept submerged condition for 24 hours to achieve SSD condition. The concrete mixer drum was moistened then the weighted aggregate were poured in the mixer machine and rotated for 1 minutes and thereafter 2 minutes with addition of cement. Finally tapped water was added in two stage, at first 50% of water added and rotated the mixing hopper for 2 minutes and additional 3 minutes rotation was performed after mixing the rest amount of water without stopping the mixer machine. After this the mixer machine was continuously rotated about 5 minutes, 90 minutes and 180 minutes for the test. Concrete slump flow of 5 minutes mixing time was considered as reference and to obtain this value additional water was required in case of long time mixing. The additional water was added at regular interval throughout the mixing time.

The resulting concrete was poured in cylindrical moulds of 100 mm diameter and 200 mm height. Casting of SCC was made with traditional filling from above and thus manual compaction during casting was eliminated. After drying the samples for 24 hours, they were submerged in water for curing about 7 days, 28 days and 90 days as required for the test. Curing was performed according to ASTM C192 [10].

Experimental program

Several tests were performed on each concrete mix to determine the strength and permeability of SCC. In addition to the testing of the cylindrical concrete specimens, sieve analysis for each material was also examined. The testing procedures are summarized in this section.

Sieve analysis of fine and coarse aggregate

Gradation of coarse aggregate was performed according to ASTM C136 [11]. Coarse aggregate was in surface saturated dry (SSD) condition. The Gradation Curve for Coarse Aggregate is shown in Figure-1.

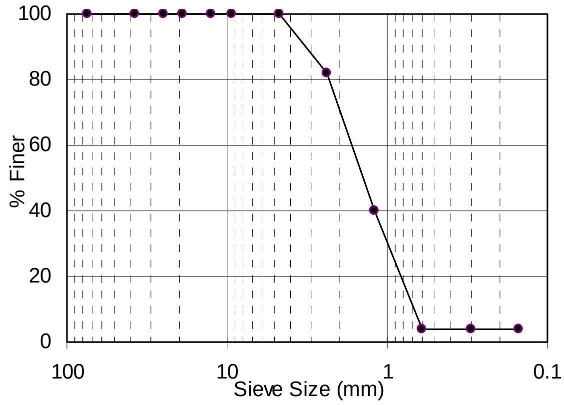

Figure-1. Gradation curve of coarse aggregate.

Determination of fineness modulus of fine aggregate was done according to ASTM C136 [11]. Fine aggregate was in surface saturated dry (SSD) condition.

The sieve analysis of fine aggregate is shown in Table-3.

Table-3. Sieve analysis of fine aggregate.

Total weight of sample (gm) = 500					
Sieve #	**Weight Retained**	**Cum weight retained**		**% Finer**	**FM**
	(gm)	(gm)	(%)		
#4	0.00	0.00	0.00	100.00	**2.69**
#8	24.00	24.00	4.80	95.20	
#16	93.00	117.00	23.40	76.60	
#30	159.50	276.50	55.30	44.70	
#50	168.00	444.50	88.90	11.10	
#100	40.80	485.30	97.06	2.94	
Sum of cumulative weight retained (%) =			269.46		

Slump flow test

Slump flow of fresh concrete was done according to ASTM C1611 [12].

A sample of freshly mixed concrete was placed in a mold shaped as the frustum of a cone. The concrete was placed in one lift without tamping or vibration. The mold was raised and the concrete was allowed to spread. After spreading was ceased, two diameters of the concrete mass were measured in approximately orthogonal directions, and slump flow was recorded as the average of the two diameters.

In this research, slump flow values of fresh concrete were maintained around 470 mm.

Compressive strength test

Compressive strength test of cylindrical concrete specimen of 10 cm diameter and 20 cm height was performed according to ASTM C39 [13].

Cylindrical specimens were tested at 7, 28 and 90 days using Universal Testing Machine at a constant loading rate. In order to ensure uniform loading on the cylinder, each Specimen was capped with sulfur. The maximum strength of each specimen was recorded and the average of three samples was considered the compressive strength at the specific day.

Splitting tensile strength test

Splitting tensile strength test of cylindrical concrete specimen of 10 cm diameter and 20 cm height was done according to ASTM C496 [14].

A cylinder was placed along its long side and tested at 7, 28 and 90 days using Universal Testing Machine at a constant loading rate. Three bearing rods were used to distribute the load applied along the length of the cylinder. The maximum load sustained by the specimen was divided by appropriate geometrical factors to obtain the splitting tensile strength. The maximum strength of each specimen was recorded and the average of three samples was considered the splitting tensile strength at the specific day.

Water absorption test

Water absorption test of specimen was done according to ASTM C642 [15].

The specimen was dried in an oven at a temperature of 105 ^{0}C for 24 hours. The mass was determined and designate as oven dried mass. After final drying, cooling, and determination of mass, specimen was immersed in water for 48 hours. The mass of the specimen was measured in surface dry condition and was being marked as surface dry mass. The increase of mass in percentage was recorded as water absorption.

Permeability test

Permeability test of samples were done according to ASTM C1202 [16].

In this test method, 50 mm thick slices of 100 mm nominal diameter cores or cylinders were collected from cylindrical samples of 100 mm diameter and 200 mm height. The sides of the cylinder specimen were coated with epoxy and the epoxy was left to be dried. Then it had been put in vacuum chamber for 3 hours. The specimen had been kept for vacuum saturation for 1 hour and allowed to soak for 18 hours. It was then assembled with the test device. The left hand side (-) of the cell was filled with a 3% NaCl solution. The right-hand side (+) of the test cell was filled 0.3N NaOH solution. Figure-2 illustrates rapid chloride permeability test setup [17].

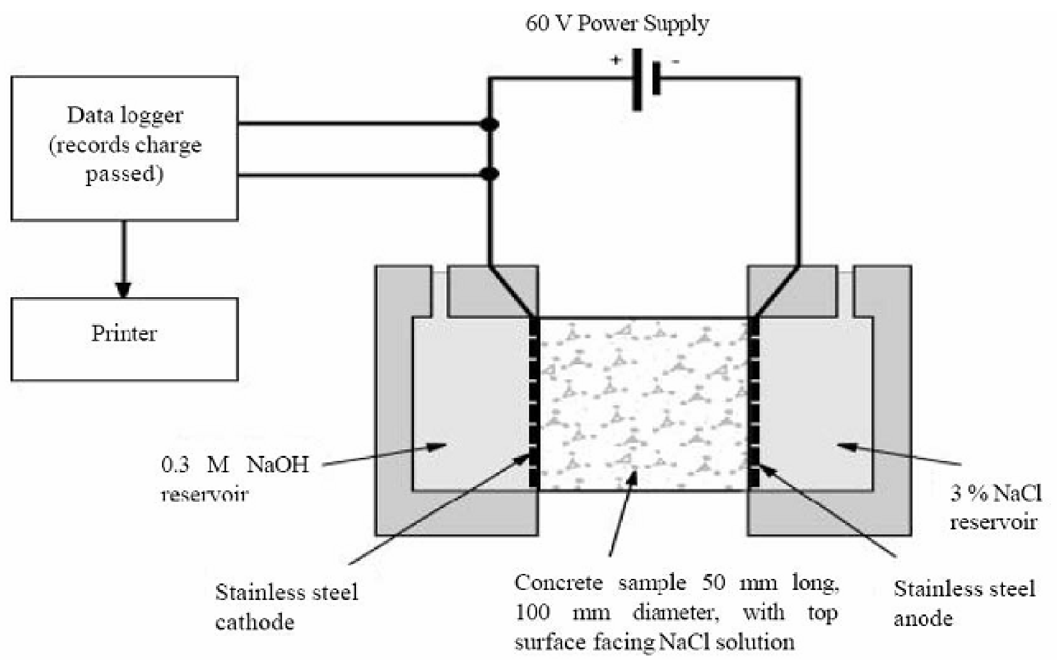

Figure-2. Rapid chloride permeability test setup.

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After that the system was connected and a 60-volt DC current had been applied for 6 hours. Readings were taken at regular interval of 30 minutes. At the end of 6 hours the sample was removed from the cell and amount of coulombs passed through the specimen was calculated. Test setup is shown in Figure-3.

Figure-3. Test setup for permeability test of concrete.

RESULTS AND DISCUSSIONS

Slump flow test

Table-4 shows the water-cement ratio to maintain the slump value around 470 with different mixing time of 5 min, 90 min and 180 min.

Table-4. Slump flow test results.

Mixing time	Cement	Fine aggregate	Coarse aggregate	Stone dust	Slump flow	Water-cement ratio		
						Initial	Additional	Total
(min)	(Kg/m^3)				(mm)	(%)		
5					470	60	0	60
90	370	518	740	37	465	60	3	63
180					480	60	13	73

Figure-4 shows that for mixing time of 5 min and 90 min there is a little increase in water-cement ratio to obtain slump flow value of approximately 470. But at 180 min mixing, there is a significant increase of 13% in water-cement ratio for maintaining the slump flow value of 480.

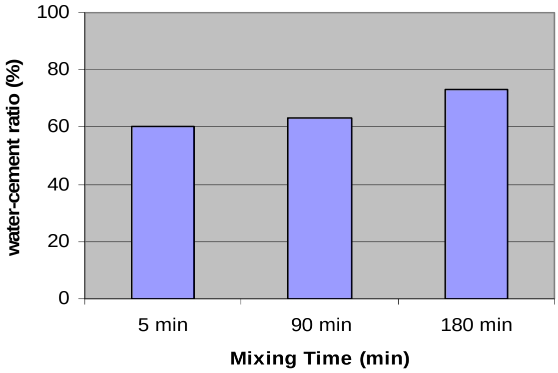

Figure-4. Effect of mixing time on total water-cement ratio.

Compressive strength

Table-5 shows the compressive strength test results for 7 days, 28 days and 90 days with different mixing time of 5 min, 90 min and 180 min.

Table 5. Compressive strength test result.

Mixing time	Compressive strength		
(min)	(MPa)		
	7 days	28 days	90 days
5	13.78	18.66	26.15
90	13.17	15.44	22.32
180	10.86	12.01	17.02

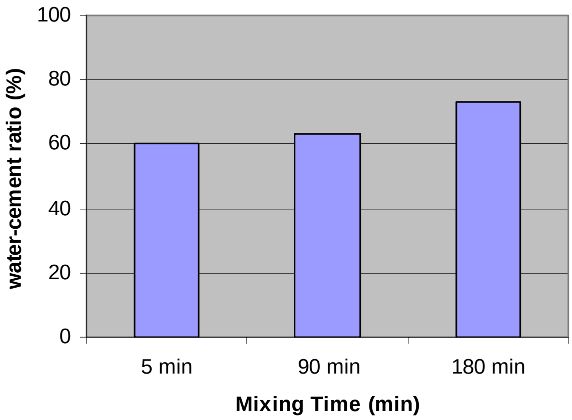

Figure-5. Mixing time effect on compressive strength for 7 days, 28 days and 90 days.

Figure-5 shows that compressive strength decreases with the increase of mixing time at all ages of concrete. The rate of decrease is also increased with the age of concrete.

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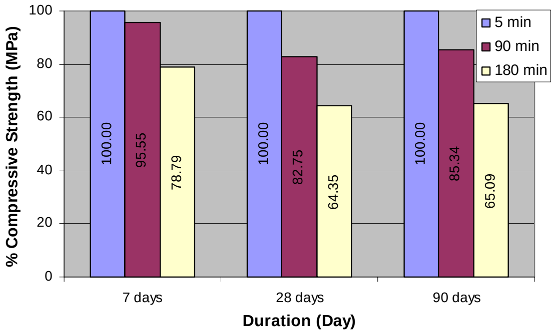

Figure-6. Compressive strength change in percent based on mixing time of 5 minutes in 90 minutes and 180 minutes for 7 days, 28 days and 90 days.

At the age of 7 days, there is a slight decrease in compressive strength for mixing time of 90 min with respect to that of for mixing time of 5 min followed by a significant decrease for mixing time of 180 min. But at the age of 28 days and 90 days, there is a considerable percent of decrease in compressive strength for mixing time of 90 min compare to that of for mixing time of 5 min followed by also an equal percent of decrease compared to mixing time of 90 min.

Splitting tensile strength

Table-6 shows the tensile strength results for 7 days, 28 days and 90 days with different mixing time of 5 min, 90 min and 180 min.

Table-6. Tensile strength test result.

Mixing time	**Splitting tensile strength**		
(min)	(MPa)		
	7 days	28 days	90 days
5	2.04	2.48	3.67
90	2.01	2.39	3.55
180	1.93	2.19	3.23

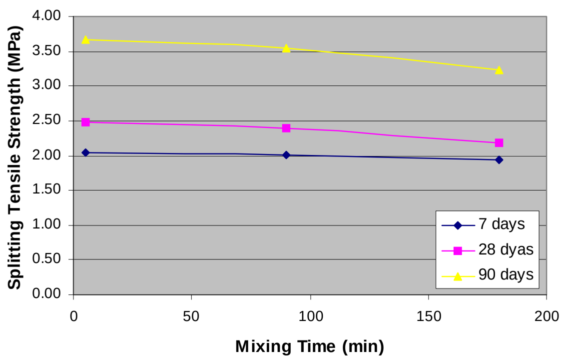

Figure-7. Effect of mixing time on splitting tensile strength for 7 days, 28 days and 90 days.

Figure-7 shows that tensile strength decreases with the increase of mixing time at all ages of concrete. The rate of decrease is also increased with the age of concrete.

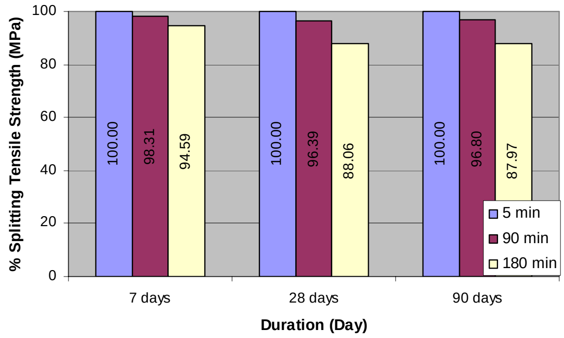

Figure-8. Splitting tensile strength change in percent based on mixing time of 5 minutes in 90 minutes and 180 minutes for 7 days, 28 days and 90 days.

At the age of 7 days, there is a little variation of about 5% in tensile strength for mixing time of 90 min and 180 min with respect to that of for mixing time of 5 min. but at the age of 28 days and 90 days tensile strength for mixing time of 90 min and 180 min decrease of around 4% and 12%, respectively compared to that of for mixing time of 5 min.

Water absorption

Table-7 shows the Water Absorption test results for 7 days, 28 days and 90 days with different mixing time of 5 min, 90 min and 180 min.

Table-7. Water absorption test result.

Mixing time	**Water absorption**		
(min)	(%)		
	7 days	28 days	90 days
5	8.16	7.99	7.86
90	9.86	9.61	9.54
180	11.4	11.1	11.02

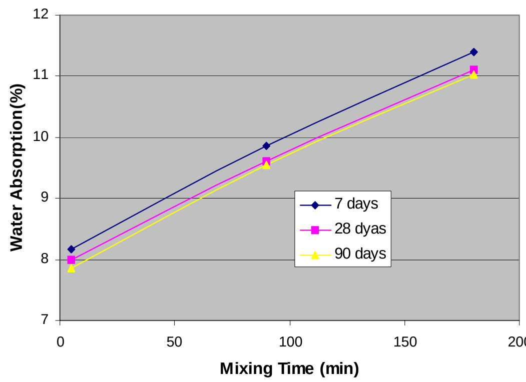

Figure-9. Effect of mixing time on water absorption for 7 days, 28 days and 90 days.

From Figure-9, it is clear that water absorption increases with increase in mixing time for all age of concrete. However, for all age of concrete, water absorption increases almost linearly with increase in mixing time at nearly same rate.

Permeability test

Table-8 shows the permeability test results for different mixing time of 5 min, 90 min and 180 min.

Table-8. Permeability test result.

Time (hr)	**Mixing time** (min)					
	5		**90**		**180**	
	Current (Amp)	**Electric** Charge (C)	**Current** (Amp)	**Electric** Charge (C)	**Current** (Amp)	**Electric** Charge (C)
0	0	0	0	0	0	0
0.5	0.11	198	0.12	216	0.14	252
1	0.11	396	0.12	432	0.14	504
1.5	0.12	648	0.13	702	0.14	756
2	0.12	864	0.13	936	0.14	1008
2.5	0.12	1080	0.15	1350	0.16	1440
3	0.13	1404	0.15	1620	0.16	1728
3.5	0.13	1638	0.16	2016	0.17	2142
4	0.13	1872	0.16	2304	0.17	2448
4.5	0.12	1944	0.16	2592	0.17	2754
5	0.13	2340	0.17	3060	0.17	3060
5.5	0.13	2574	0.17	3366	0.17	3366
6	0.13	2808	0.17	3672	0.17	3672

Figure-10 demonstrates that after 6 hours total amount of electric charge passed is slightly increase for 90 and 180 minutes of mixing than that of 5 minutes of mixing. But for these three different mixing times, amount of charge passed varies from 2808 to 3672 Coulomb, which are fall in the same moderate chloride permeability category. So, there is no significant change in the category of permeability of concrete due to mixing time of 5, 90 and 180 minutes.

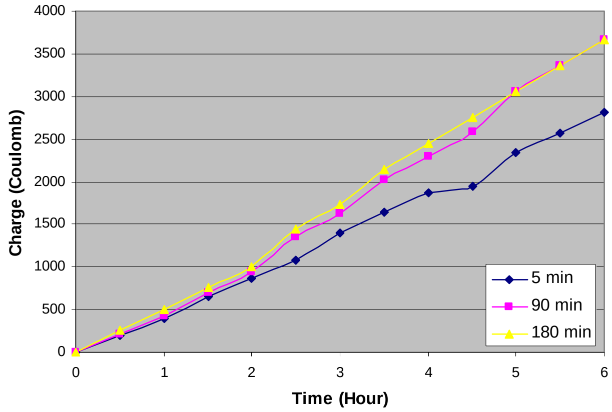

Figure-10. Effect of mixing time on chloride ion permeability.

CONCLUSIONS

This work gives attention to an effect, which affects the performance of SCC mix adversely and hence, its hardened properties also. This effect is the time delay or the time elapsed during the mixing process.

As soon as water applied to the cement, chemical reaction starts simultaneously between them. During long mixing time of SCC, some portion of water are used in the hydration of cement and some portion of water evaporate to the atmosphere and that's why, amount of added water is increased with long mixing time for maintaining constant workability.

After adding water for maintaining constant flowability, the amount of water/cement ratio increases in SCC for prolonged mixing time, which affects the cohesion among the constituents of concrete. So, compressive and tensile strength of SCC decreases with this water quantity.

With long mixing time of concrete, the pores in concrete are increased. That is why the water absorption and the chloride ion permeability increase with increase in mixing time.

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