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PROPERTIES OF SELF COMPACTING CONCRETE INCORPORATING ALGINATE AND NANO SILICA

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ABSTRACT

This paper presents an experimental study on the properties and the durability of self-compacting concrete (SCC) containing alginate in variety values with artificial stone resin, micro and nano silica. The values of 0.5 and 1% alginate, 10% micro silica, 0.5% nano silica and 0.5% artificial stone resin are used. Artificial stone resin is used as the super plasticizer. Properties of hardened SCC such as compressive, split tensile, flexural strength and water absorption are assessed and represented graphically. Eventually, based on comparisons and interpretations, conclusions are drawn.

Keywords: Self-compacting concrete; alginate; micro silica; nano silica.

1. INTRODUCTION

The use SCC has grown tremendously since its inception in the 1980s in Japan [1]. The differences between conventional concrete [2-7] and SCC are in the use of special admixture.

SCC is as a material that can flow through congested reinforcing bars without need for additional consolidation and without undergoing any significant separation under its own weight [8-9]. The fresh state properties like slump flow and L-box blocking ratio have been assessed using the methods as per EFNARC specification [10]. Adding a volume of powdered material such silica fume [11], inert filler or natural pozzolans [12] or viscosity modifying admixture can eliminate segregation. Due to the better performance properties, additions such as silica fume, nano silica, fly ash, granulated blast furnace slag and limestone powder are highly efficient pozzolanic material and has a considerable potential for use in concrete [13-15]. Alginate is one of the natural pozzolanic materials consisting of mineral materials.

The objective of this study is to understand the fresh state properties of SCC containing alginate in various proportions as partial additive to cement and small quantity of super plasticizer with micro and nano silica. In this study, it is aimed to investigate the effect of

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alginate, micro and nano silica as mineral admixtures on the fresh and hardened properties of SCC. Performance of mineral admixtures is established in SCC by fresh concrete tests such as slump flow, T50 time, and L-box ratio. Hardened concrete tests are compressive strength, split tensile, flexural strength and water absorption. Alginate is addition at two proportions (0.5% and 1%) to cement in a series. Cement is replaced at one proportion (0.5%) with nano silica in CNA series and in CMA series, cement is replaced at one proportions (10%) with micro silica. Resin is used at one proportion 0.5% with nano, micro silica and alginate in all series. Also respect of w/c (c is summation of cement, micro and nano silica) is 0.36. In this study calculation good relationship exists between compressive strength in 7 days value and compressive strength in 28, 56 and 90 days for all of SCC. In addition, relationship exists between compressive strength in 28 days value with split tensile and flexural strength.

2. MATERIALS AND METHODOLOGY

Cement: Portland cement Type I is used. Its physical properties are as given in Table 1. **Micro silica:** Micro silica is used as partial replacement of cement. By product in the reduction of high-purity quartz with coke in electric arc furnaces in the production of silicon and ferrosilicon alloys called micro silica is produced. The silica fume is in powder form with an average of 93 present silicon dioxide. The chemical and physical properties of micro silica are shown in Table 1.

Table 1: Properties of cement, nano and micro silica

Chemical properties	Percent			Physical properties	Value
	Cement	Nano silica	Micro silica		Cement
SiO_2	21.3	>99.8	94	Initial setting	85 (min)
Al_2O_3	5.4	<0.05	1.2	Final setting, (min)	160 (min)
Fe_2O_3	3.95	<0.005	1.3	Fineness (blain)	≥3000 (cm2/g)
L.O.I	≤1.2	<1.5	-	Autoclave expansion	≤0.15 (%)
CaO	65.2	-	0.6	3 Days compressive strength	≥150 (Mpa)
F.Cao	≤1.3	-		3 Days compressive strength	≥200 (Mpa)
MgO	≤1.65	-	0.2	7 Days compressive strength	≥330 (Mpa)
SO_3	≤2.0	-	-	28 Days compressive strength	≥500 (Mpa)
CL	≤0.3	-	-		
TiO2	-	<0.003	-		
Moisture	-	<1.5	-		
Loss on ignition	-	<1.5	-		

Total Alkali	≤2	-	-
C	-	-	0.4
Na2O	-	-	0.6
K2O	-	-	1.1
S	-	-	0.08
MnO	-	-	0.07

Nano silica: Nano silica with the surface area 200 m^2/g that was bought from WACKER chemical company is used in this study. The properties of nano silica are shown in Table 1.

Alginate: Natural alginate is used as mineral admixture. Alginic acid, also called alginate, is an anionic polysaccharide distributed widely in the cell walls of brown algae, where through binding with water it forms a viscous gum [16]. Alginate absorb water quickly, which makes it useful as an additive in dehydrated products such as slimming aids, manufacture of paper, textiles, waterproofing, fireproofing fabrics. It used extensively as an impression-making material in dentistry, prosthetics, life casting and occasionally for creating positives for small-scale casting. It is very fast setting, flexible, will not adhere to anything, and used in conjunction with ultra cal 30 plasters, offers excellent reproduction plaster castings in engineering and construction it has been reported and patents have been approved to use alginate for in situ stabilization of contaminated and not contaminated soils [17]. Few previous tests such as Friedemann et al. [18] have been done to use alginate in building materials. They obtained excellent results to improve the cement hydration using the alginate for internal post-curing with respect to compressive strength and to its frost de-icing salt resistance on high performance concretes. Conclusions on water retention of the alginate additive for internal post-curing and on temporal moisture requirement of the cement during hydration reaction were done. The physical properties of the alginate are given in Table 2.

Table 2: The chemical properties of the alginate

Chemical properties	**Percent**
Sodium Alginate	12
Paraffin	2
Diatomaceous earth	61
Calcium Sulphate	15
Sodium phosphate	2
Aluminium oxide	2
Magnesium oxide	1
Water	4

Plasticizer: Resin unsaturated polyester base down orthophenolic is used. The orthophenolic resin is good flexibility and resistant to influence, medium viscosity, good physical, limited shrinkage, mechanical properties after curing, and limited water absorption.

Water: The water used in this study is from the city of Shahrekord in Iran. The profiles of the water are shown in Table 3.

Table 3: Profile water

PH	Sulphate Content (mg/lit)	Chloride Content (mg/lit)	Total Hardness (mg/lit)
7.8	29	40	205

Aggregate: The sand and coarse aggregate used in concrete are crushed limestone aggregates. The water absorption, particle size distribution, sand equivalent and fineness modulus of the aggregates are specified. The physical properties of the aggregates are given in Table 4.

Table 4: Physical properties of the aggregates

Property	Sand aggregate	Coarse aggregate
Specific gravity	2.6	2.55
Fineness modules	2.9	-
Water absorption (percent)	1.8	0.5
Maximum size (mm)	4.75	12.5
Bulk density (kg/m^3)	1520	1575
Sand equivalent (percent)	87	-

Mix Design: Three groups of SCC are produced in this study. Nine mix designs of SCC are presented in Table 5 include alginate, micro and nano silica. The ratio of w/c is fixed as 0.36, and the amount of resin, water, fine and coarse aggregate are fixed as 2.05, 148, 1100 and 600 Kg/m^3, respectively. Control concrete (C) is produced with 0.5% resin without any additive and is combined by ratios of 0.5% and 1% with alginate (CA). The second and third groups are just an extension of the first group with ratio 0.5 % and 10% of nano and micro silica, respectively (CN and CM), added to the mixture. Nano and micro silica are replaced with cement to mix design. The concrete mixtures are prepared by using the following procedure: fine and coarse aggregate are mixed with some water for 2 min; then cement combination with alginate are added to the mixture and the mixing is continued for 3 min more. Then resin and water add to the mixture and remind water with Nano or micro silica mixed and added to the mixture.

Table 5: Self-compacting concrete mixture proportions (kg/m^3)

Mixture Name	Cement	Alginate	Nano silica	Micro silica
C	410	0	0	0
CA0.5	410	2.05	0	0
CA1	410	4.1	0	0
CN	407.9	0	2.05	0
CNA0.5	407.9	2.05	2.05	0
CNA1	407.9	4.1	2.05	0
CM	369	0	0	41
CMA0.5	369	2.05	0	41
CMA1	369	4.1	0	41

Slump flow and L-Box tests are carried out on the fresh concrete batches. After completion of these tests, the fresh concrete is cast into moulds to obtain test specimen in water tank with the temperature of 23±2°C. For each concrete mixture, four 100 mm cubes, two 150 × 300 mm cylinders and three 160×400×400 mm prisms specimens are cast. The cubes are used for the determination of compressive strengths and water absorption. Also the cylinders are used for the determination of split tensile strengths and the prisms are used for the determination of flexural strength. The specimens are taken out from the moulds after 24 h, and are cured for 7, 28, 56 and 90 days until the time of compressive strengths test. Water absorption, split tensile strength and flexural strength testes are done at 28 days.

3. RESULTS AND DISCUSSIONS

Fresh SCC Tests: The results of L-Box blocking ratio (ratio of heights at the two edges of L-box) and slump flow are shown in Fig. 1. The slump-flow test is for the ability of concrete to deform under its own weight against the friction of the surface with no external restraint present [19]. Then properties of fresh SCC such as workability are determined through the measurement of slump flow diameter to reach a concrete 500mm spread circle. Result defined flow slump test for three classes (SF1, SF2 and SF3). SF1 between 550mm to 650mm that is suitable for plain concrete, injection and concrete piles. SF2 650mm to 750mm that is suitable for typical applications such as walls and columns. SF3 between 760mm to 850mm that is suitable for concrete with high compacting reinforcement [10]. Three samples (CA1, CMA1 and CMA0.5) are in range SF1 and remainder samples are in range SF2. With add nano silica to samples increase SCC workability. There is a reduction in slump flow diameter compared with the control and those containing other mineral admixtures. This might be explained by the increased surface area of the diatomaceous soil and particles increasing the water demand various percentage.

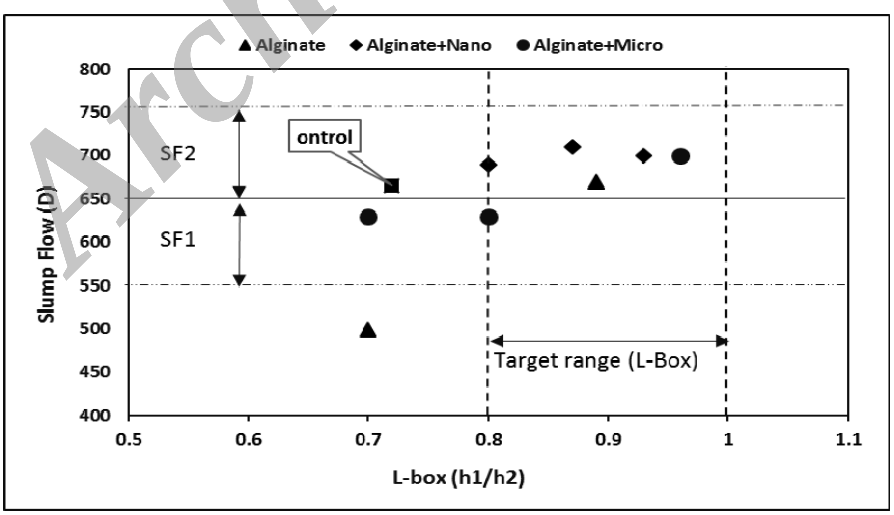

Figure 1. L-Box and slump flow tests for all samples

The L-box ratio characterizes the passing ability and filling of SCC. The blocking ratio (h_2/h_1) should be 0.8 to 1.0. The all mixtures except C, CMA1 and CA1 exhibit good workability are within this target range. Used of 0.5% alginates improve SCC properties.

Compressive Strengths Tests: As seen in Fig. 2, the compressive strength of samples reduces in all days by adding alginate. The reduction is mitigated with add nano and micro silica and is often compensated. Too when compared to the alginate with nano and micro silica together the use of nano and micro silica in upper percent of alginate increase the strength. Add 10% micro silica to C sample reduces 9% as average in all days. Also adding 10% micro silica to CA0.5 and CA1 samples increases 28% and 66%, respectively. In addition, nano silica improves compressive strength. In fact, with add nano and micro silica to alginate improves some of SCC properties. In Fig. 2 seeing in upper ages increase compressive strengths samples except nano silica samples. In Fig. 3 show good relationship exists between compressive strength in 7 days value and compressive strength in 28, 56 and 90 days for all of SCC. Based on graphs, the following equations are generated for between compressive strength in 7 days value and compressive strength in 28, 56 and 90 days.

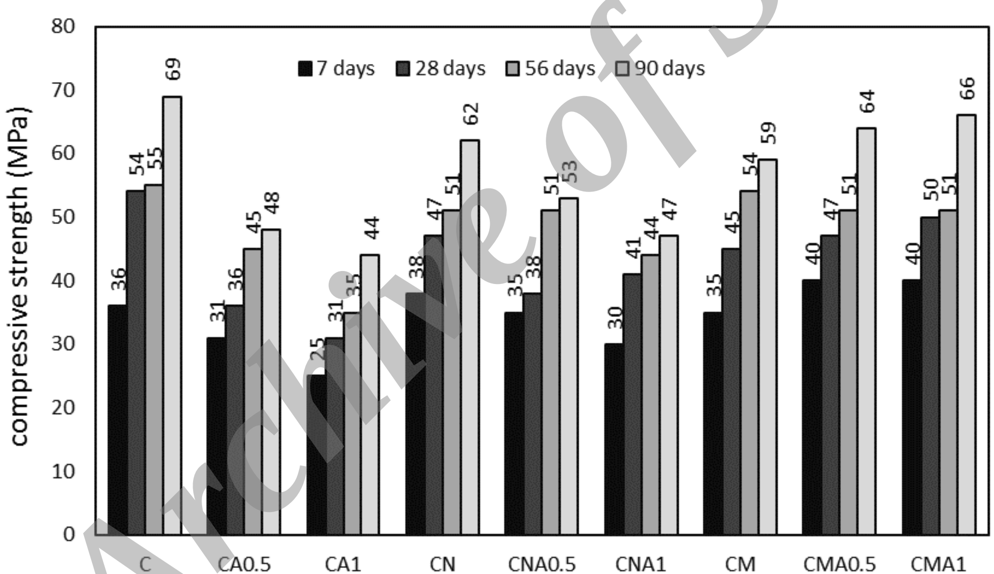

Figure 2. Compressive Strength (MPa) for all mixes

$$f_{c28} = f_{c7} + 1.26\sqrt{f_{c7}} \tag{1}$$

$$f_{c56} = 0.7 f_{c7} + 3.9\sqrt{f_{c7}} \tag{2}$$

$$f_{c90} = 1.4 f_{c7} + 0.7\sqrt{f_{c7}} \tag{3}$$

The f_{c7} is compressive strength in 7 days with unit MPa in 1 to 3 equations. The f_{c28}, f_{c56} and f_{c90} are compressive strength in 28, 56 and 90 days that computation of f_{c7}. The root mean squares value to be highly satisfied for compressive strength in all days.

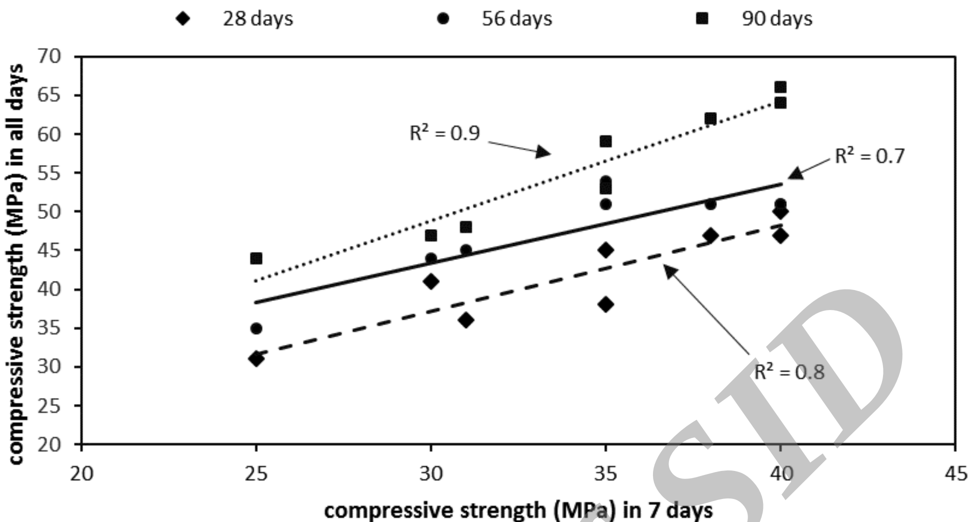

Figure 3. Compressive strength in 7, 28, 56 and 90 days

Flexural Strength Tests: Table 6 shows the 28-days flexural strength and split tensile strength values of built samples. CNA1 and CA0.5 have flexural strength values more than other mixes.

In Fig. 4 shows good relationship exists between compressive strength in 28 days and flexural strength for all of SCC. Based on graphs, the following equations are generated for between compressive strength and flexural strength.

$$f_r = 2.5\sqrt{f_{c28}} \quad (4)$$

Equation 4 is for all mixes.The "f_r" is value flexural strength and "f_{c28}" value compressive strength. The root mean squares value to be highly satisfied for alginate.

Table 6: Flexural strength and split tensile strength in 28 days (MPa)

Mixture Name	**flexural strength**	**split tensile strength**
C	18.8	3.7
CA0.5	16.7	2.2
CA1	13	2.9
CN	16.5	3.7
CNA0.5	16.5	1.9
CNA1	17.5	2.5
CM	16.2	3.2
CMA0.5	16	2.6

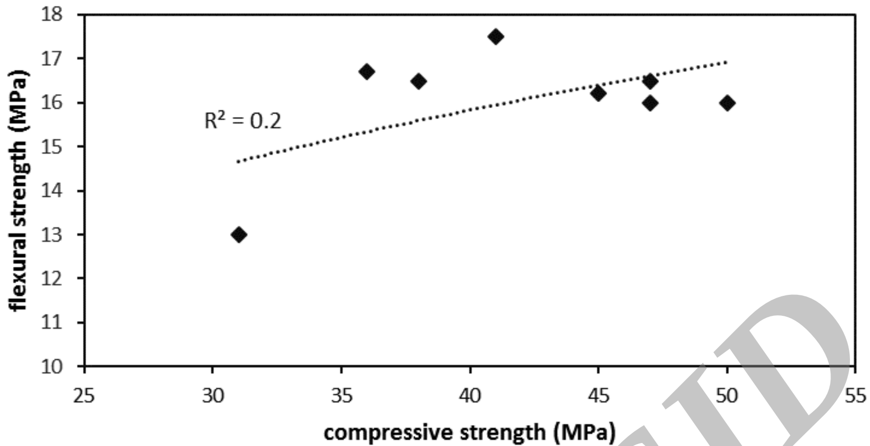

Figure 4. Compressive strength in 28 days with flexural strength.

Tensile Strength Tests: Tensile strength of the samples is determined with half way up. In Table 6 it can be seen that addition of nano silica decreases tensile strength but addition of micro silica increases tensile strength. In Fig. 5 shows good relationship exists between compressive strength in 28 days and tensile strength for all of SCC. Based on graphs, the following equations are generated for between compressive strength and tensile strength.

$$f_t = \%6.7\sqrt{f_{c28}} \quad (5)$$

Equation 5 is for all mixes.The "f_t" is value tensile strength and "f_{c28}" value compressive strength.

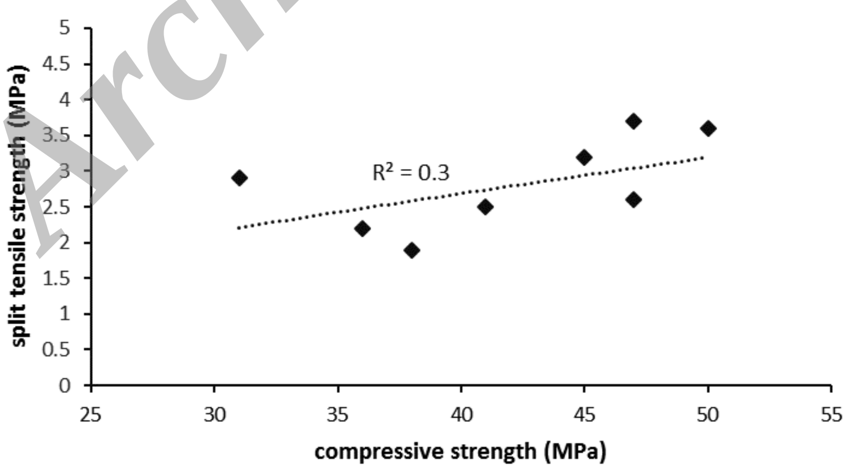

Figure 5. Compressive strength in 28 days with tensile strength

Water Absorption Test: The water absorption test according to ASTM C 642 is conducted at the end of the 28th days. The cube specimen is dried in an oven at a temperature of 110˚C for 24h then immersed in water tank for 48h and its saturated surface dry weight of the specimen is measured.

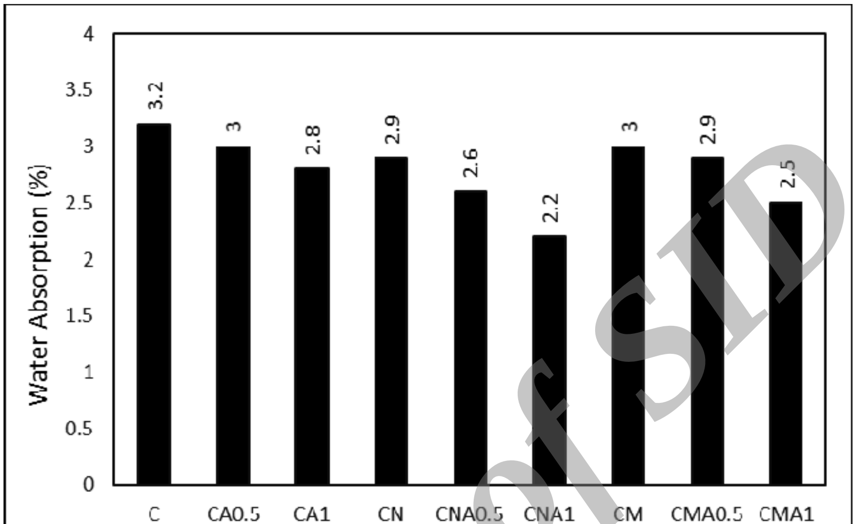

Figure 6. Water absorption test for all mixes

The ratio of the difference between the weight of sample after immersion and the weight of oven dry sample to the weight of oven dry sample is percentage of water absorption. The water absorption test is performed on all mixtures; the result on the 28th day of curing is shown in Fig. 6. The results show that alginate concrete possesses a lower water absorption capacity. Cause of the decrease in the water absorption is existence 61% diatomaceous soil as a filler of pore space of SCC. With add nano and micro silica decrease value water absorption.

4. DISCUSSION OF TEST RESULTS

On the basis of the results and discussions on this investigation the following conclusions are drawn:

- In general the use of alginate improved the performance of SCC in fresh state and also avoided the use of viscosity modifying admixtures.
- Must samples were in range SF2. Add nano silica to samples increased SCC workability.
- When compared to the alginate with nano and micro silica together the use of nano and micro silica in upper percent of alginate increased the strength. Add 10% micro silica to C sample reduces 9% as average in all days. Also adding 10% micro silica to CA0.5 and CA1 samples increases 28% and 66%, respectively.
- It is observed that the split tensile strength of concrete decreased in 0.5% alginate and

in all mixes receptacle 0.5% alginate. Add micro silica to alginate increase the split tensile strength. The CMA1 had the most split tensile strength than other mixes.

- Adding nano and micro silica decreased values water absorption. The CA1 mix gived minimum water absorption with adding 0.5% nano silica to it.

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