Investigating the Properties of Concrete Specimens Using Nano-materials

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Abstract

This review paper examines the relationship between nanotechnology and the study of engineering properties of Self Compacting Concrete. In order for concrete nanotechnology to be brought to the forefront of the construction industry, the benefits of the technology must be clearly demonstrated by the research community. In this study, two mixes of SCC, I (included only microsilica and ii) consist of both microsilica and nanosilica were investigated to find out engineering properties of fresh and hardened SCC experimentally at short and long terms. The results show that the use of both microsilica and nanosilica in SCC mixes can improve the Engineering properties of SCC.

Keywords: *Self compacting concrete, Microsilica, Nanosilica, Engineering properties*

1-Introduction

There is widespread agreement that nanotechnology has the potential to revolutionize the world of concrete materials sciences. The fundamental processes that govern the most pertinent issues to the study of concrete technology (strength, ductility, early age rheology, creep and shrinkage, fracture behavior, durability, etc.) all are affected, if not dominated, by the performance of the material at the nanoscale. Yet, there is a lack of agreement about how to pursue concrete materials science research at the nonoscale, to improve the value of the material, and how to develop these nanosclae ideas and bring them to the industry. It would greatly benefit the research community to have well-defined goals in the pursuit of nanotechnology in concrete materials science.

In many ways, the aspects of concrete that make it such an appealing building material make it a difficult material to modify at the nanosclae. Concrete is an engineered product, but not in the same sense that a nano-electromechanical (NEMS) device is an engineered product. Whereas a NEMS device can be rigorously engineered from the atomic scale upwards, for concrete the Portland cement and aggregate must, on some level, be considered a "given" in the process. When constructing a multistory concrete structure, attention to the nanosclae variations in the cement and aggregate are not a possibility [1].

Self-Compacting Concrete (SCC) is a new type of concrete, which has generated tremendous interest since its initial development in Japan by Okamura in the late 1980s in order to reach durable concrete structures [2]. SCC is expected to flow by only its own weight, without influence from external forces or vibration. Because of that ability, it fills the formwork completely without any voids, it joins to the reinforcement, and it desecrates and levels itself without segregation. To fulfill this request, concrete needs to have special properties in the fresh state.

The advantages of SCC offers many benefits to the construction practice: the elimination of the compaction work results in reduced costs of placement, equipment needed on construction, shortening of the construction time and improved quality control [4,5].

2- Materials used

The concrete mixtures investigated in this study were prepared with Portland cement type II, microsilica powder and nanosilica solution. The specific gravity of microsilica and nanosilica is 2.17 and 1.03, and they are silica particles with a maximum size of 0.2 µm and 50 nm, respectively. In addition, nanosilica is a water emulsion with 50% of dry solid and PH of 10.

Continuously graded aggregate with nominal particle size of 20 mm and well-graded sand with a fineness modulus of 2.92 were employed. The particle size distributions of both coarse and fine aggregates were within ASTM C-33 limits. The relative density values of the coarse and fine aggregates were 2.7 and 2.49 and their absorption rates were 1.2 and 1.92%, respectively. The superplasticizer used in all mixtures, was Poly-Carboxylic Ether (PCE) and had a specific gravity of 1.03 and PH of 7. In addition, Lime tone Powder (LSP) with maximum size of 0.3 mm and relative density of 2.65 was employed.

3- Workability of SCC

There is yet no universally accepted standard for characterizing of SCC. Nevertheless, a few testing methods seem to reappear several times in literature and tend to become internationally recognized as suitable methods to characterize the self compatibility of a concrete [6]. The same testing methods were prepared in this research.

3.1- Slump Flow test

The Slump Flow test specified by the Japan Society of Civil Engineers evaluates the capacity of a concrete to deform under its own weight without any restraint, except from the friction of the surface and the test is based on the slump cone test, used for traditional concrete. To measure the slump flow, an ordinary slump test cone is filled with SCC without compaction and leveled. The cone is lifted and the average diameter of the resulting concrete spread is measured. A slump flow value ranging from 500 to 700 mm for a concrete to be self compacted [7].

3.2- J-Ring test

The J-Ring test is used to determine the blocking characteristics of self-compacting concrete. The equipment consists of a ring placed on several rebar with adaptable gap widths, combined to the Abram's cone or the Orimet test. Both blocking and segregation can be detected visually [8].

3.3- L-Box test

With the L-Box apparatus, it is possible to measure different properties such as flow ability, blocking and segregation of the concrete [9,10,11]. The height of concrete remaining in the vertical section (h_1) and the height of concrete at the end of the horizontal part (h_2) are determined, and then the (h_2 /h_1) value is calculated. The ratio between these two heights (h_2 /h_1), which is usually 0.7-0.9 for SCC [12], was used to evaluate the ability of the SCC mixtures to flow around obstructions. This limit, however, has been proposed to be within 0.8 and 1.0 by EFNARC guidelines [13]. A typical test is shown in Figure (1).

Figure 1: *L-Box test*

Figure 2: *V-Funnel test*

3.4- V-Funnel Flow time test

The test was developed in Japan and used by Ozawa et al. [14]. This test covers evaluation of narrow-opening possibility, which involves viscosity of freshly mixed self-compacting concrete from observation of flow speed of the sample through the specially designed funnel under self-weight. This test also covers evaluation of segregation resistance of freshly mixed self-compacting concrete by the observation of the variation on the flow speed due to the difference of the sample's remaining period in the funnel [15,16]. In this test, the funnel is filled completely with concrete and the bottom outlet is opened, allowing the concrete to flow out. The flow of the concrete is noted as the lapse of time between the removal of the outlet and the seizure [17]. Acceptable value range is between 4 and 10 s [18]. A typical test is shown in Figure (2).

4- Mix Design

To produce the SCC , First, different mix design of SCC were casted and tested to find out the fresh concrete properties such as values of the Slump Flow, L-Box tests and hardened concrete properties such as 3, 7 and 28 days compressive strength. The brief summary results of the some trial mixes are shown in Table 1.

Based on these results, the following two mixes, i) SCC included only microsilica (SM), ii) SCC with both microsilica and nanosilica (SMN) were selected for further investigation of the properties of fresh and hardened concrete. Properties of selected mixes were shown in Table 2.

Table 1: *Trial Mixtures Characteristics*

Mix No. Material		1	2	3	4	5	6	7	8	9	10
Cement (Kg)		360	360	400	360	360	360	360	360	360	360
Microsilica (Kg)		40	40	--	40	40	40	40	40	40	40
Nanosilica (Liter)		--	2.4	--	2.5	--	3	--	--	--	3
Water (Kg)		168	168	152	152	152	152	146	148	148	148
LSP (Kg)		100	100	100	100	100	100	100	100	100	100
Coarse Aggregate (Kg)		750	750	750	750	750	750	750	750	750	750
Fine Aggregate (Kg)		870	870	870	870	870	870	870	870	870	870
PCE (Liter)		2.4	2.4	2.6	2.6	3.2	3.2	3.2	3.2	3.6	3.6
W/CM*		0.42	0.42	0.38	0.38	0.38	0.38	0.365	0.37	0.37	0.37
Fresh Properties											
Slump Flow (mm)		620	630	630	--	660	680	--	--	660	690
L-Box (h_2/h_1)		0.80	0.84	0.78	--	0.7	0.78	--	--	0.77	0.80
Hardened Properties											
Compressive Strength	3 days	30	29	23	--	27	25	--	--	28	25
	7 days	38	39	30	--	35	38	--	--	34	34
	28 days	50	53	41	--	52	56	--	--	56	47

* CM: Cement + Microsilica

Table 2: *Properties of Selected Mixes*

Mix Labels Material	SM	SMN
Cement (Kg)	360	360
Microsilica (Kg)	40	40
Nanosilica (Liter)	--	2.4
Water (Kg)	168	168
LSP (Kg)	100	100
Coarse Aggregate (Kg)	750	750
Fine Aggregate (Kg)	870	870
PCE (Liter)	2.8	2.8
W/CM	0.42	0.42
Fresh Properties		
Slump Flow (mm)	620	630
L-Box (h_2/h_1)	0.79	0.82
Slump Flow + J-Ring (mm)	590	610
V-Funnel, 1 minute (s)	4.5	4
V-Funnel, 5 minute (s)	7.2	7

5- Experimental Tests and Results of Hardened Concrete

In this study, twodifferent curing conditions were assumed. All of concrete specimens were made and covered with a plastic sheet and burlap for the first 24 hours to prevent moisture loss. After 24 hours, the specimens were demolded and immediately placed in the water, which was saturated with the lime. After 7 days, some of the specimens were transferred to a room with the temperature of 28 ± 4^{o}C and a relative humidity of 30 ± 5%, called as dry (D) condition and the remaining were kept in water up to 28 days age, called as (W) condition and then they were cured in the same condition of (D).

5.1- Compressive strength tests and results

For twocases of studied at twostorage conditions, concrete cube specimens of $10 \times 10 \times 10$ cm were casted and tested at 3, 7, 14, 28 and 90 days age. The results are shown in Figures (3 and 4).

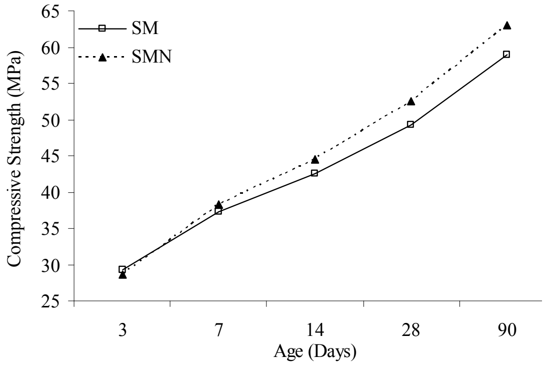

Figure 3: *The compressive strength of mixes for (W) curing condition in different ages*

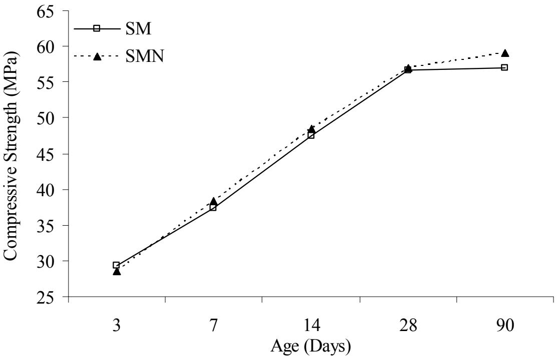

Figure 4: *The compressive strength of mixes for (D) curing condition in different ages*

The results at different ages show that for any storage condition, either short or long term, the compressive strength of SMN specimens was higher than SM mix.

Furthermore, by comparison of the strength results of two mixes, it can be concluded that, at 28 days age, the mixes had a better behavior for (D) storage condition (see Fig. 5), whereas, the results show higher compressive strength for (W) storage condition at 90 days age (see Fig. 6).

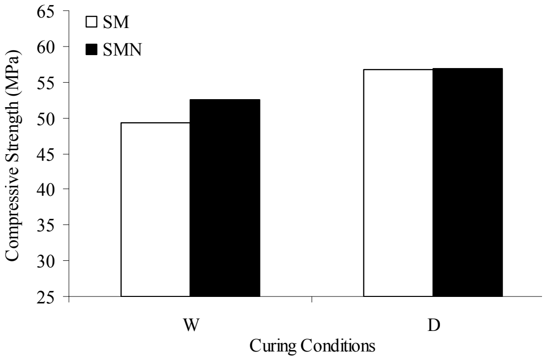

Figure 5: *The compressive strength for different curing conditions at 28 days age*

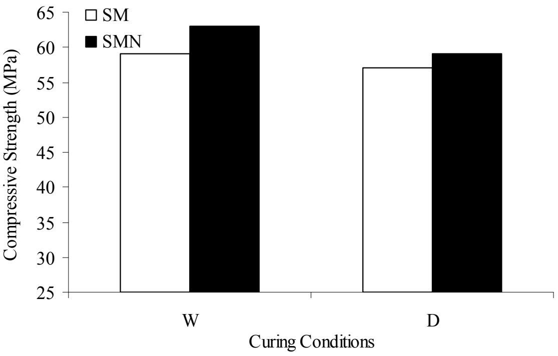

Figure 6: *The compressive strength for different curing conditions at 90 days age*

5.2- Flexural strength tests and results

For all cases of studied at two curing conditions (W and D), concrete prism specimens of $10 \times 10 \times 45$ cm were casted and tested at 28 and 90 days age, and test results have been shown in Figures (7 and 8).

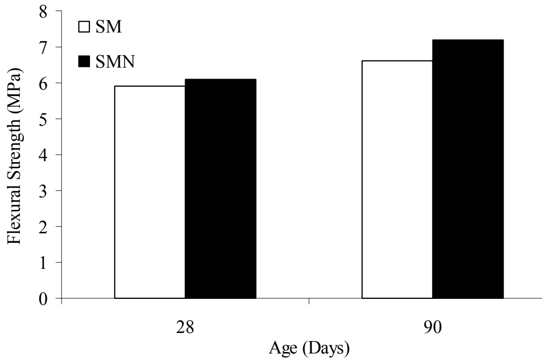

Figure 7: *The flexural strength of mixes for (W) curing condition*

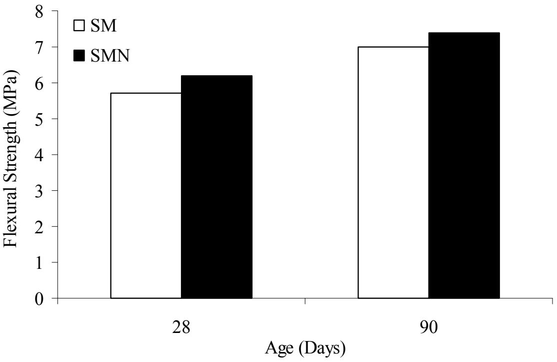

Figure 8: *The flexural strength of mixes for (D) curing condition*

The results show that a similar trend was observed for flexural strength, i.e., a better behavior obtained for SMN.

5.3- Shrinkage tests and results

In this investigation, the prism specimens of $10 \times 10 \times 45$ cm was casted and at the age of one day, the specimens were demolded and the Demec points were glued on two opposite surfaces of the specimens with a fast-setting epoxy. Then they were kept either at (D) or at (W) storage conditions. At different ages, the amount of shrinkage was measured by the mechanical strain gauge and the average values for two opposite surface of specimens were plotted in Figures (9 and 10).

As shown, the amount of shrinkage for the samples kept at (D) condition was equal to values for (W) condition in the mixes.

In addition, by literature search, it can be found that the amount of shrinkage was high for SCC mixes.

In another research by the authors, the use of only microsilica in SCC reduce amount of shrinkage, clearly (about 70%) by comparison of SCC without microsilica. In this investigation, for two curing conditions, the shrinkage amount of mixes consists of microsilica was low and it was also found that the mixes consists of both microsilica and nanosilica had the lowest shrinkage values of 350×10^{-6} for (D) curing conditions, i.e. the values reduced by 13%.

In other words, shrinkage values for SCC mixes can be improved by adding both microsilica and nanosilica to SCC mixtures.

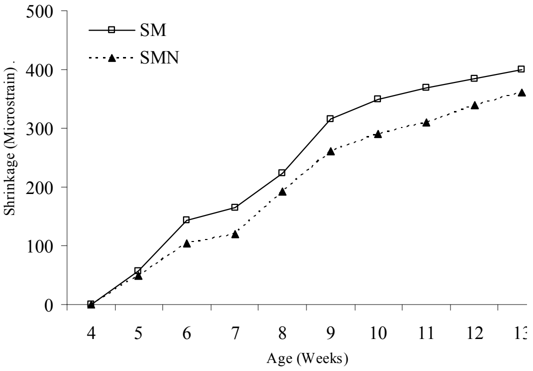

Figure 9: *Shrinkage values for (W) condition at different ages*

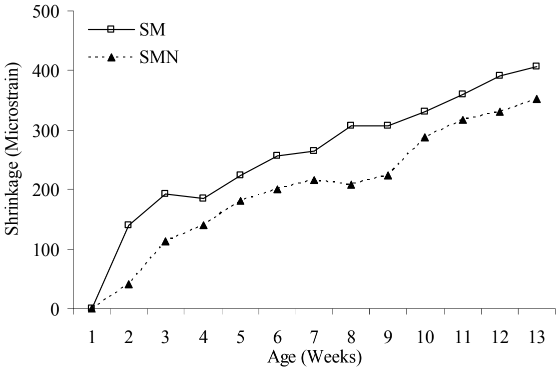

Figure 10: *Shrinkage values for (D) condition at different ages*

5.4- Swelling tests and results

For two mixes, the prism specimens were prepared and the Demec points were glued on surfaces of the specimens similar to shrinkage test. Then specimens were kept in water for all ages and at different ages, the amount of swelling was measured by the mechanical strain gauge and its results were drawn in Figure (11).

From the results, it is clear that the amount of swelling for SMN was lower than the mix of SM.

Considering the specimen SMN with compare to SM, the reduced swelling amount is about 33%. Again, it can be concluded that swelling value for SCC mixes can be improved and decreased by adding both microsilica nanosilica to the SCC mixtures.

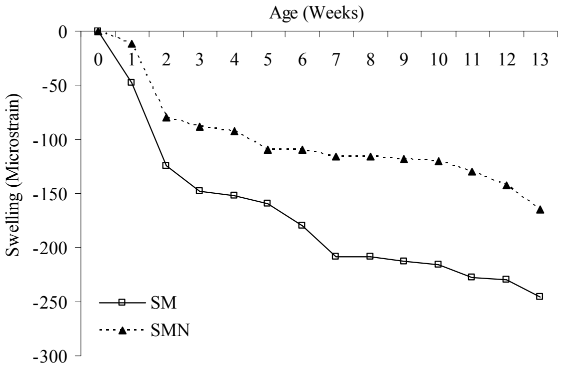

Figure 11: *Swelling values at different ages*

6- Conclusions

Based on experimental research for two self-compacting concrete mixes, the following conclusions can be drawn for short (up to 28 days) and long (up to 90 days) term:

1- The compressive and flexural strength of SCC mixes can be increased while the SCC design was consist of both microsilica and nanosilica. The amount of increase in compressive strength was about 7% and 1% at the age of 28 days and about 7% and 4% at the age of 90 days, respectively under curing conditions of (W) and (D).

2- One of the disadvantages of SCC is its high amount of shrinkage with respect to the normal concrete. Therefore, it was possible to over come by such a disadvantage, by designing the SCC with microsilica in mixtures. The shrinkage value can be decreased more, with use of both microsilica and nanosilica to SCC mixes. It was possible to reduce amount of shrinkage about 13% under curing condition of (W) and (D), by adding both microsilica and nanosilica to SCC with compare to SCC included only microsilica.

3- The swelling amount of SCC mixes can be decreased while designing the SCC with both microsilica and nanosilica. The amount of decrease in swelling values was about 33%.

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