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The Effect of Size of Aggregates and Nano Silica Dosage on the Fresh Properties of Self-Compacting Concrete

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Abstract: ***This work aimed to investigate effecting of using nano silica as partial replacement of fine aggregate, on the fresh characteristics of self-compacting concrete (SSC). For this purpose, different self- compacting concrete mixes were designed at constant water-to-binder ratio of 0.50 and 425 kg/m^3 of binder content. Class F fly ash was used as partial replacement of cement (30% by weight of cement). The three designated nano silica contents of 0, 1, and 2%.on each percentage of nano silica content we have to change in aggregate variations NSA, NSB, NSC were considered as experimental parameters. The workability properties of self-compacting concrete mixtures were performed regarding to slump flow diameter, T500 slump flow time, V- funnel flow time, L-box height ratio. The experimental results of this work are showed that the nano silica with the sizes and contents that used in this work can be used successfully as a fine aggregate in self-compacting concrete.***

Keywords: nano silica content; aggregate variation; Fresh property; Self-compacting concrete

1. Introduction

Self-compacting concrete (SCC), a new kind of high-performance concrete (HPC) with excellent deformability and segregation resistance is a special kind concrete that can flow through and fill the gaps of reinforcement and corners of molds without any need for vibration and compaction during the placing process [1].

Structures independent of the quality of construction work is the employment of self- compacting con- crete, which can be compacted into every corner of a formwork, purely by means of its own weight [2].

Properties of self-compacting concrete depend on type and amount of additive, which is used, and there are numerous research papers which consider that subject [3].

Nanotechnology has become widely spread in the field of construction because it can improve construction materials performance since it can modify or cater the microstructures at nano- and micro-levels [4].

Evaluating the effect of nano-silica (NS) on the hydration, the rheology and the strength development of cement pastes and by adding nano-silica particles speeds up the hydration of the cement paste [5].

The objective of this study is to assess and compare the effects of different nanoparticles, namely nano-TiO2, nano-Al2O3 and nano- Fe2O3, on the performance of self-consolidating concrete (SCC) [7].

The use of mineral admixtures of both mSi and nSi increases the compressive strength of SCCs: the greater the admixture quantity, the greater the compressive strength [8].

The use of mineral admixtures at microscale and recently at nanoscale has permitted high-performance SCC to be obtained. Over the past few years, micro silica (mSi) and nano silica (nSi) have been the most used admixtures in continuing research into the areas of civil and agricultural engineering [9].

Due to a variety of cement composites found at different parts of the world, rheological and strength properties which are key properties of self-compacting composites (SCC) world. The rheological property of SCC or SCM highly depends on its constituent materials and mixture composition [10].

According to the results, it could be possible to say that the highest compressive strength is achieved when the SCC compounds have a larger continuous particle-size distribution between the particle minimum size (nSi) and the larger particle(coarse aggregate) [11].

High performance concrete (HPC) offers high strength, better durability properties, and good construction. High strength is one of the important attributes of HPC [12].

In this research, the simultaneous incorporation of nano-carbon black and nano- silica in the concrete revealed that the addition of nanoparticles to the concrete considerably decreases permeability; while reducing the compressive strength in some mixtures and increasing the bending strength of the modified concrete in most of the studied cases [13].

In order to promote the utilization of waste marble powder (WMP) in cement-based materials, an attempt to improve the mechanical properties of cement-WMP system by incorporating nano silica(NS) was studied [14].

The SP demand of (MS + NS) is not higher than that of pure cement. More importantly, the combined usage of MS and

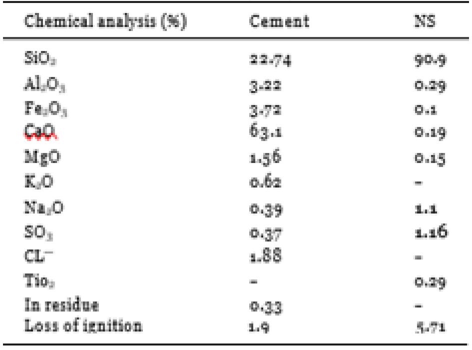
NS offers certain synergistic effect as evaluated can be incorporated [15].

2. Materials and experimental procedure

2.1 Materials

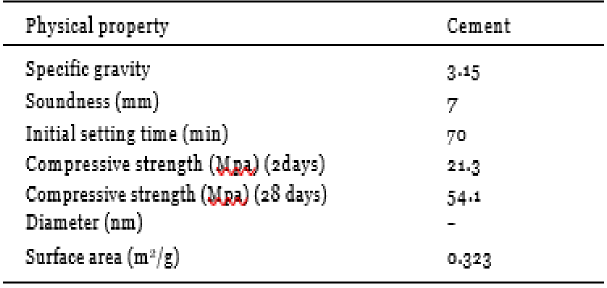
This study used an ASTM type I Portland cement (CEM I/42.5 R) to produce SCC mixtures. Commercial nano-silica (NS) particles were used in powder form as a partial replacement for cement admixtures. Chemical analysis and physical properties of cement and NS are shown in Tables 1 and 2 respectively. Crushed limestone was used as coarse aggregate with a nominal maximum size of 12.5 mm with bulk density and specific gravity of 1493 kg/m^3 and 2.67 respectively. The fine aggregate used was a mixture of limestone powder (as filler) and sand with a maximum size of 4.75 mm. The bulk density and fineness modulus of sand used were 1636 kg/m^3 and 2.632 respectively.

Table 1: Chemical composition of cement and nano-silica (NS)



Chemical analysis (%)	Cement	NS
SiO_2	22.74	90.9
Al_2O_3	3.22	0.29
Fe_2O_3	3.72	0.1
CaO	63.1	0.19
MgO	1.56	0.15
K_2O	0.62	-
Na_2O	0.39	1.1
SO_3	0.37	1.16
CL^-	1.88	-
Tio_2	-	0.29
In residue	0.33	-
Loss of ignition	1.9	5.71

Table 2: Physical properties of cement and nano-silica (NS)



Physical property	Cement
Specific gravity	3.15
Soundness (mm)	7
Initial setting time (min)	70
Compressive strength (Mpa) (2days)	21.3
Compressive strength (Mpa) (28 days)	54.1
Diameter (nm)	-
Surface area (m^2/g)	0.323

The particle size distribution of filler, coarse and fine aggregates is shown in Fig. 3. To obtain the required workability in all concrete mixes, an aqueous solution of modified polycarboxylates superplasticizer (SP) with a specific gravity 1.08 was used at a constant dosage 2% by weight of cement.

2.2 Mix design proportions

In this study, nine SCC mixes were designed with a total binder content of 425 kg/m^3 and the water/binder (w/b) ratio of and the two different aggregate variations

1) 10mm passed through the 4.75mm retained
2) 12mm passed through the 10mm retained

Samples of each series were prepared with 0%, 1%, and 0.75% (by weight) replacement of cement by NS. Table 3 shows the concrete mix designs for the samples.

Mixing procedure
SCC mixtures were prepared by mixing coarse aggregates, fine aggregates, and powder materials (cement and nano-silica) in a laboratory drum mixer. The powder materials and the aggregates were mixed in dry form for 2 min. Then the whole amount of superplasticizer dissolved in half of the water was poured and mixed for 3 min. After that, about 1 min rest was enabled and finally the rest of the water was added and mixed for 1 min [26, 28].

Preparation of the specimens, curing and test methods
Once the mixing process was completed, tests were performed on the fresh concrete to determine the workability of SCC. The workability of SCC can be characterized by Filling ability (flowability), Passing ability and Segregation resistance. Self-compacting Concrete must meet the requirements of the three characteristics. In this study, fresh properties of SCC mixtures were examined through the slump flow test, V-funnel test, J-Ring test, and L-box test according to EFNARC [17] standards. The slump flow time (T_{500}), slump flow diameter (D) and V-funnel flow time were measured to represent the filling ability. During the slump flow test, segregation was checked by visual inspection. The passing ability was determined by J-Ring flow time (T_{500}j), J-Ring blocking step (BJ), and L- box height ratio.

3. Results and discussion

Slump flow diameter

The self-compacting nano silica concrete with slump flow diameter values between 600-750 mm, which were determined as the average of two measured diameter of flowed concrete fig
(1) The slump flow diameter of plain self- compacting concrete was 710mm.Test results indicated that the producing self-compacting concrete with nano silica as cement and according to EFNARC (table 5.1), can be categorized as SF2 fig (2), which is suitable for many normal applications such as walls and columns.

Table 2: Mix proportions for self-compacting nano silica concrete

MIX ID	Cement Kg/m^3	Fly Ash Kg/m^3	NS Gm	Coarse Aggregates (Kg)		Fine Aggregates (Kg)	Water Lt	Super Plastcizer Lt
				4.75-10 mm	10–12.5 mm			
SCC 0% NSA	425	92.35	0	0	667.50	988.07	212.61	4.138
SCC 0% NSB	425	92.35	0	66.7	600.80	988.07	212.61	4.138
SCC 0% NSC	425	92.35	0	135.5	534	988.07	212.61	4.138
SCC 1% NSA	420.75	92.35	75	0	534	988.07	212.61	4.138
SCC 1% NSB	420.75	92.35	75	53.4	480.6	988.07	212.61	4.138
SCC 1% NSC	420.75	92.35	75	96.12	384.48	988.07	212.61	4.138
SCC 2% NSA	419.50	92.35	150	0	384.48	988.07	212.61	4.138
SCC 2% NSB	419.50	92.35	150	38.448	346.03	988.07	212.61	4.138
SCC 2% NSC	419.50	92.35	150	69.20	276.83	988.07	212.61	4.138

T50 slump flow and V-funnel flow times:

T50 slump flow and V-funnel flow times for self-compacting nano silica concrete are given in fig 3 and fig 4, respectively. Moreover, T500 slump flow time via V-funnel flow time for each mixture is illustrated in fig 6 with respect to viscosity class according to EFNARC (2005). Slump flow time was also influenced by nano silica content. Increasing the nano silica content resulted in increasing the slump flow time. Also, as clearly seen from fig 3.V- funnel flow time of mixtures showed the almost same trend with T500 slump flow time. Increasing the nano silica content also systematically increased the V-funnel flow time. V-funnel flow times of mixtures were between 8 and 13s.

When Fig. 4 was considered, it was determined that all self-compacting nano silica mixtures were in the boundaries of the VS2/VF2 viscosity specified by EFNARC (2005) while the reference mixture was in the VS1/VF1. It was also can be seen that such concretes help enhancing segregation resistance and limiting the formwork weight Bayasi and Zeng (1993).

L-box height ratio and T20 and T40 flow time

The L-box height ratio by means of H2/H1 ratio was also determined to specify the passing ability of the produced SCCs. The test carry out using three bar L-box test which simulates the case of more congested reinforcement (EFNARC, 2005) as shown in fig 1 (c). The L-box height ratio must be equal to or greater than 0.8 to certify and ensure that the self-compacting concrete has the required passing ability. For perfect fluid behavior of self-compact concretes, L-box height ratio value is 1.0.

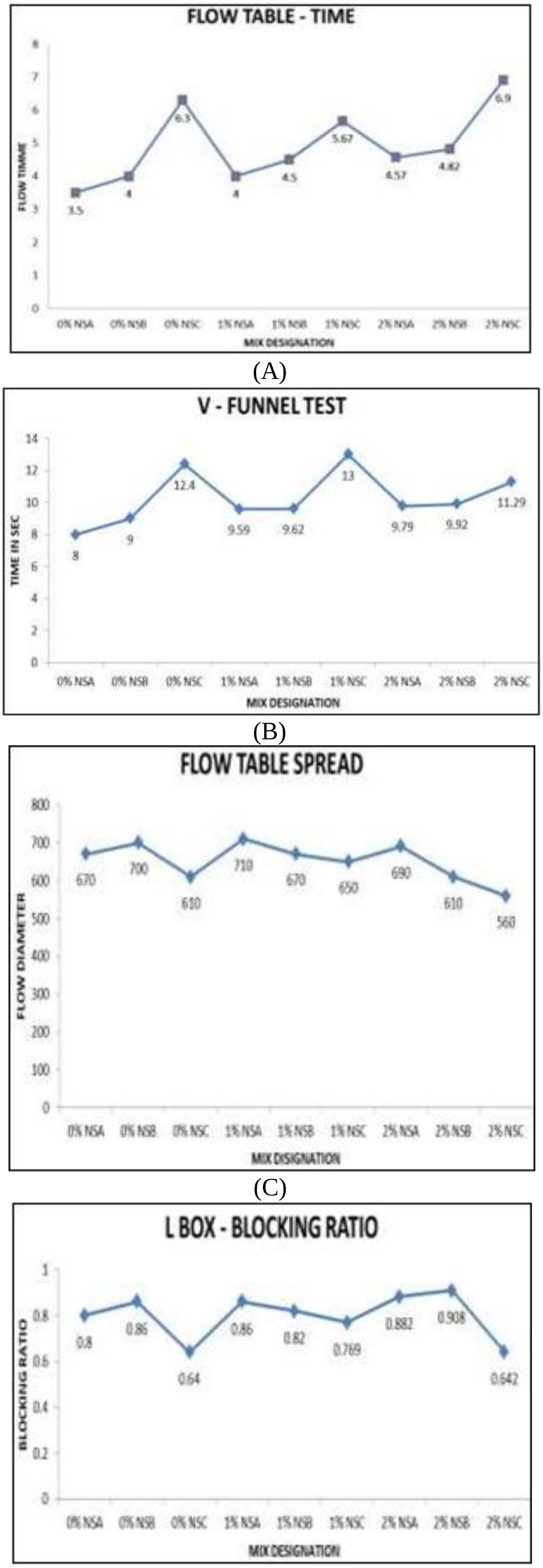
Table 3: Slump flow, viscosity, and passing ability classes according to EFNARC

Class		Slump flow diameter (mm)
Slump flow classes		
SF1		550–650
SF2		660–750
SF3		760–850
Class	T50 (s)	V-funnel time (s)
Viscosity classes		
VS1/VF1	2	8
VS2/VF2	>2	9–25
Passing ability		

classes 0.8 with two
PA1 PA2
Rebar 0.8 with three rebar

(a) Slump Flow Test (b) V-funnel flow time test (c) L-box test

Figure 1: Fresh Properties Tests



(A)

(B)

(C)

(D)

Figure 2: (A) Shows variation of flow time at different percentages of nano silica in SCC mix, (B) Shows variation of flow diameter at different percentages of nano silica in SCC mix, (c) Shows variation of passing time at different percentages of nano silica in SCC mix, (D) Shows variation of blocking ratio at different %ges of nano silica in SCC mix.

4. Conclusions

Based on the results of presented work, the following main conclusion’s made in all the SCC mixes:

The Slump flow ranging from 600-750 mm was obtained with replacement of nano silica from 0-2%.

These outline the use of nano silica and replacement of cement and change in size of aggregate in mostly satisfies the EFNARC guidelines. The SCC at 0%, 1% and 2% of nano silica as cement replacement fails at blocking ratio and not satisfies the EFNARC guidelines.

The fig 5.2 shows the flow values ranging from 560mm to 670mm it satisfies the passing ability of slump flow classes of EFNARC guidelines and IS: 10262-2019

The fig 5.1 shows the slump flow time ranging from 3.5 sec to 6.9 sec, its satisfies viscosity classes of EFNARC.

The fig 5.3 shows the viscosity properties of V-funnel ranging from 8sec to 11.29 sec, it satisfies EFNARC guidelines.

The fig 5.4 shows the passing ability of all the SCC mixes the blocking ratio ranges from 0.782 to 0.908.

The SCC 0% of NSC fails at the L-box is 0.64 blocking ratio, SCC 1% of NSC fails at the blocking ratio 0.769 ad SCC 2% of NSC fails at the blocking ratio 0.782 is not satisfies EFNARC guidelines. The increasing the nano silica concrete resulted in reducing in the slump flow diameters of concretes, the results were acceptable for many normal application of self-compacting concrete .using nano silica as partial replacement of cement increased both T500 slump flow time, V-funnel flow times and the blocking ratio but SCC at 0%, 1% and 2 % of NSC affected blocking ratio .

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The effect of size of aggregate and re and replacement of cement at 1% of nano silica dues the good co-relation among all the mixes and satisfies the EFNARC guidelines and IS: 10262-2019.

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References

[1] Nan Su, Kung-Chung Hsu, His-Wen Chai, “A simple mix design method for self- compacting concrete”, *Cement and Concrete Research* 31 (2001) 1799 – 1807

[2] Hajime Okamura and Masahiro Ouchi, “Self-Compacting Concrete”, *Journal of Advanced Concrete Technology* Vol. 1, No. 1, 5-15, April 2003.

[3] Zoran Jure Grdic, Gordana A. Toplicic- Curcic, Iva M. Despotovic, Nenad S. Ristic, “Properties of self-compacting concrete prepared with coarse recycled concrete aggregate”, *Construction and Building Materials 24* (2010) 1129–1133.

[4] Alireza Habibi, Jian Ghomashi, “Development of an optimum mix design method for self-compacting concrete based on experimental results”, *Construction and Building Materials* 168 (2018) 113-123.

[5] Mohamed Salhi, Mohamed Ghrici, Turhan Bilir, MuctebaUysal, “Combined effect of temperature and time on the flow properties of self-compacting concrete”, *Construction and Building Materials* 240 (2020) 117914.

[6] S. Santosa, P.R. da Silvab, J. de Britoc, “Self-compacting concrete with recycled aggregates – A literature review”, *Journal of Building Engineering* 22 (2019) 349–371.

[7] Erhan Güneyisi, Mehmet Gesoglu, ZeynepAlgın, HalitYazıcı, “Rheological and fresh properties of self-compacting concretes containing coarse and fine recycledconcrete aggregate”, *Construction and Building Materials* 113 (2016) 622–630.

[8] A.R. Esquinas, D. Motos-Pérez, M.E. Jimenez, C. Ramos, J.R. Jimenez, J.M. Fernandez, “ Mechanical and durability behaviour of self-compacting concretes for application in the manufacture o hazardous waste containers”, *Constructioand Building Materials* 168 (2018) 442–458

[9] O. R. Khaleel, S. A. Al-Mishhadani And H. Abdul Razak, “The Effect of Coarse Aggregate on Fresh and Hardened Properties of Self-Compacting Concrete (SCC)”, *Procedia Engineering* 14 (2011) 805–813.

[10] Deepankar Kumar Ashish, Surender Kumar Verma, “Determination of optimum mixture design method for self-compacting concrete: Validation of method with experimental results”, *Construction and Building Materials* 217 (2019) 664–678.

[11] Wei-Ting Lin, “Effects of sand/aggregate ratio on strength, durability, and microstructure of self-compacting concrete”, *Construction and Building Materials* 242 (2020) 118046.

[12] Morteza Nematollahzade, Azim Tajadini, Iman Afshoon, Farhad Aslani, “Influence of different curing conditions and water to cement ratio on properties of self-compacting concretes”, *Construction and Building Materials* 237 (2020) 117570.

[13] Nadine Hani, Omar Nawawy, Khaled S. Ragab, Mohamed Kohail, “The effect of different water/binder ratio and nano-silica dosage on the fresh and hardened properties of self-compacting concrete”, *Construction and Building Materials* 165 (2018) 504– 513.

[14] F. Lavergne, R. Belhadi, J. Carriat, A. Ben Fraj, “Effect of nano-silica particles on the hydration, the rheology and the strength development of a blended cement paste”, *Cement and Concrete Composites* 95 (2019) 42–55.

[15] Jordi Massana, Encarnacion Reyes, Jesús Bernal, Nestor Leon, Elvira Sanchez-Espinosa, “Influence of nano- and micro-silica additions on the durability of a high- performanc self-compacting concrete”, *Construction and Building Materials* 165 (2018) 93–103.

[16] Alireza Joshaghani, Mohammad Balapour, Mohammad Mashhadian, Togay Ozbakkaloglu, “Effects of nano-TiO2, nano-Al2O3, and nano-Fe2O3 on rheology, mechanical and durability properties of self- consolidating concrete (SCC): An experimental study”, *Construction and Building Materials* 245 (2020) 118444.

[17] J. Bernal, E. Reyes, J. Massana, N. Leon, E. Sanchez, “Fresh and mechanical behavior of a self-compacting concrete with additions of nano-silica, silica fume and ternary mixtures”, *Construction and Building Materials* 160 (2018) 196–210.

[18] Mostafa Jalala, Ehsan Teimortashlu, Zachary Grasley, “Performance-based design and optimization of rheological and strength properties of self-compacting cement composite incorporating micro/ nano admixtures”, *Composites Part B* 163 (2019) 497–510.

[19] Erhan Güneyisi, Mehmet Gesoglu, Asraa Al-Goody, SüleymanIpek, “Fresh and rheological behavior of nano-silica and fly ash blended self-compacting concrete”, *Construction and Building Materials* 95 (2015) 29–44.

[20] Mostafa Jalal, Alireza Pouladkhan, Omid Fasihi Harandi, Davoud Jafari, “Comparative study on effects of Class F fly ash, nano silica and silica fume on properties of high performance self-compacting concrete”, *Construction and Building Materials* 94 (2015) 90–104.

[21] Rezaniaa, M. Panahandeh, S.M.J. Razavic, F. Bertoc, “Experimental study of the simultaneous effect of nano-silica and nano carbon black on permeability and mechanical properties of the concrete”, *Theoretical and Applied Fracture Mechanics* 104 (2019) 102391.

[22] Baoguo Ma, Jie Wang, Hongbo Tan, Xiangguo Li, Lixiong Cai, Yang Zhou, Zhugen Chu, “Utilization of waste marble powder in cement-based materials by incorporating nano silica”, *Construction and Building Materials* 211 (2019) 139–149.

[23] L.G. Li, J.Y. Zheng, J. Zhu, A.K.H. Kwan, “Combined usage of micro-silica and nano-silica in concrete: SP demand, cementing efficiencies and synergistic effect”, *Construction and Building Materials* 168 (2018) 622–632.

[24] Erhan Güneyisi, Mehmet Gesoglu, Oday Ali Azez, Haticeoznuroz, “Effect of nano silica on the workability of self-compacting concretes having untreated and surface treated lightweight aggregates”, *Construction and Building Materials* 115 (2016) 371–380.

[25] Mayank Gupta, Maneek Kumar, “Effect of nano silica and coir fiber on compressive strength and abrasion resistance of Concrete”, *Construction and Building Materials* 226 (2019) 44–50.

[26] Sakshi Gupta, “Application of nano-silica in cement mortar and concrete”, *Smart Nano concretes and Cement-Based Materials* (2018) 601-617.

[27] S. Rao, P. Silva, J. de Brito, “Experimental study of the mechanical properties and durability of self-compacting mortars with nano materials (SiO2 and TiO2)”, *Construction and Building Materials* 96 (2015) 508–517.

[28] Rakesh Choudhary, Rajesh Gupta Ravindra Nagar, “Impact on fresh, mechanical, and microstructural properties of high strength self- compacting concrete by marble cutting slurry waste, fly ash, and silica fume”, *Construction and Building Materials* 239 (2020) 117888.

[29] Mohammed BS, Achara BE, Nuruddin MF, Y M, Zulkefli MZ, “Properties of nano-silica-modified self-compacting engineered cementitious composites”, *Journal ofCleaner Production* (2017).

[30] Oveys Afzali Naniz and Moosa Mazloom, "Effects of colloidal nano-silica on fresh and hardened properties of self-compacting lightweight concrete”, *Journal of Building Engineering* (2018)