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A Survey on the Mechanical Properties of Magnetic Self-Compacting Concrete Containing Nanosilica

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ABSTRACT: Self-compacting concrete with less than 20 years of background has paved the way to solve plenty of problems concerning concrete structures; especially in sections with high density of rebar and places where it is not feasible to vibrate the concrete. High resistance against shearing, no need for vibration, low cost, effective use of workforce and acceleration of the construction operations are amongst the most important characteristics of this type of concrete. The laboratorial studies on normal concrete indicate the efficiency of magnetic technology and its impact on strength, workability and endurance of normal concrete. Yet, the magnetic effects on self-compacting concrete have not been surveyed; or very few researches have been conducted in this field. Therefore, in this research we have tried to survey tensile and compressive strength of self-compacting concrete prepared by means of nanotechnology and magnet in various ages. The laboratory results represent the enhancement of mechanical characteristics of concrete, which are shown in the form of graphs and charts in the article.
Keywords: Self-compacting Concrete, Mechanical Properties, Magnet, Nanosilica

INTRODUCTION

For many years, the engineers of different countries sought to compose a kind of self-compacting concrete without downfall in strength, workability, or shearing. In the early 20^{th} century, due to aridity of concrete mixtures, density of concrete was achieved merely by applying heavy impacts on extensive and accessible sections. In line with the development of armored concrete and divulgence of executive problems of dry mixtures application, the market tended to use wet mixtures. However, recognizing the impact of water-to-cement proportion in 1920s showed that enhancement of this proportion can result in the downfall of concrete strength (Okamura,1986).

In later years, taking into consideration the issue of concrete endurance revealed the destructive impact of increase in water-to-cement proportion on permeability and endurance of concrete. All of these cases drew the attentions toward workability and rheology properties of concrete, as well as compacting methods with the aim to optimize the resistance and endurance of concrete. The researches finally resulted in the development of self-compacting concrete (SCC) in late 1980s by Okamura in Japan (Okamura,1986). Self-compacting concrete is a highly fluid concrete, which can spread throughout the shutter and embrace the rebar, without shearing and needing for any mechanical compacting.

At the present time, magnet is used in various fields including prevention of sedimentation in cooling systems, improvement of blood circulation, diseases treatment, improvement of automobile engine efficiency, improvement of plants growth, processing of drinking water, tooth decay treatment, and even enhancement of concrete resistance. Some of these functions are proved via laboratorial documentations (Powell, 1998).
The initial researches and experiments on the application of magnetic fields in cement, ceramic and brick production were conducted in 1962 in former USSR. At the start, this technology was used in producing high-resistance concrete block for runways of military airports, coastal constructions and military equipments (Eshaghi, Gholizadeh, 2000). In this research, we have tried to study the efficiency of magnets in construction of self-compacting concrete via laboratorial studies.

Laboratorial Program

In order to evaluate the physical and mechanical properties, we conducted the tests related to fresh concrete including slump, slump T_{50}, J-ring, L-box, V-funnel, and V-funnel (after 5 minutes). Then, we made the required specimens in accordance with the related standards and tested them (Efnarc Method). To magnetize the concrete while making the specimens, the concrete passed through a 1.2 Tesla magnetic field (Figure 1). A summary of the type, dimensions, test methods and related programming are give in Table 1.

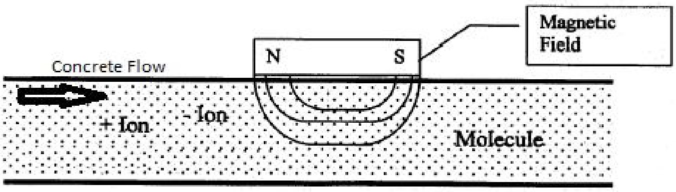


Figure 1. Schematic of Magnetizing Fresh Concrete

Table 1. Type and Method of Tests and Related Timing Plan

Type and Method of the Test	Specimens Dimension (Cm)	Test Age
Compressive strength 116: part: BS1881	10*10*10	3,7,28 Days
Tension strength (Brazilian) 116: Part: BS1881	Φ 15*30	7,28 Days

MATERIALS

Powder: The powder used in this research was Qom limestone powder with the diameter of 0.075-0.15 mm.

Fine Aggregates: Small aggregates are of natural type excavated from Iranshahr region; the results of aggregation are shown in Table 2.

Large Aggregates: big aggregates used in this research are of smashed type with the maximum nominal diameter of 19mm, excavated from Iranshahr region; the results of aggregation are presented in Table 2.

Table 2. Aggregation of Stone Materials

	0.75mm	0.15mm	0.3mm	0.6mm	1.2mm	2.35mm	4.75mm	6.3mm	9.5mm	12.7mm	16mm	19mm	22.6mm
Sand	1.7	5.5	12.45	23.6	40.3	65.6	85.2	97.25	98.8	99.5	100	100	100
Gravel	0	0	0	0	0	0.34	1.9	15.1	61.6	87.68	95.65	98.65	100

Cement: In this research we used Portland cement type-2 (ASTM C150) processed in Khash plant. Chemical specifications of the cement are given in Table 3.

Table 3. Chemical Specifications of Cement

	Concentration								
Chemical Compounds	C_3A	C_2S	C_3S	SO_3	MgO	Fe_2O_3	Al_2O_3	CaO	SiO_2
Percent	2.6	19	53	‹2	3.4	4.6	4.2	61.9	21

Super Plasticizer: The super plasticizer used in this research was of polycarboxylic type with the specific weight of 1.37 g/Lit.

Nanosilica: The used Nanosilica is based on silicate particles with the diameter of 5-50 nanometers in the form of solid powder made by local factories.

Mixture Proportions

In this research we prepared 9 mixture plans and the specifications of plans components proportion are given in Table 4.(EFNARC METHOD)

Table 4. Mixture Plan Proportions

Contents of Self Contracting Concrete Mix for 1 Cubic Meter of Concrete									
P/B	W_f/B	SP ٪	W_f Kg	N.S Kg	G_d Kg	S_d Kg	P Kg	C Kg	Mix
0.37	0.48	1.1	192	40	695	886	148	360	SC40
0.37	0.48	1.1	204	42.5	656	823	157.25	382.5	SC42.5
0.37	0.48	1.1	216	45	620	792	166.5	405	SC45
0.37	0.48	1.1	228	47.5	605	765	175.75	427.5	SC47.5
0.37	0.48	1.1	240	50	589	720	185	450	SC50
0.37	0.48	1.1	252	52.5	569	690	194.25	472.5	SC52.5
0.37	0.48	1.1	264	55	552	664	203.5	495	SC55
0.37	0.48	1.1	276	57.5	539	643	212.75	517.5	SC57.5
0.37	0.48	1.1	288	60	521	626	222	540	SC60

Note: C: cement, P: limestone powder, S_d: dry sand, G_d: dry gravel, W_f: free water, SP: super plasticizer, NS: nanosilica, B=C+N.S

MIXING METHODS

To make the specimens we first put dry gravel and sand together with one third of the mixing water in the mixer and turned it on. Then we added cement, pozzolanic materials and the remaining mixing water as well as super plasticizers to the mix. To improve the efficiency of mixing process, we mixed some of the mixing water with chemical admixtures and added it to the mixture. We mixed the compound for three minutes after adding the last ingredient and then stopped mixing for three minutes. Finally we mixed the compound for more 2 minutes; and accordingly the concrete was prepared (Ghodusi, Abbasi, 2006).

Curing and Maintenance Conditions

All the specimens were taken out of the shutter to the curing room after one day. They were kept in standard conditions (temperature 25± 2℃ and saturated humidity) until the test time. It is necessary to mention that 3 specimens were made for each curing condition in each age.

TESTS RESULTS

The results of compressive and tensile tests for 9 plans of Table 4 for self-compacting and magnetic self-compacting concrete are shown respectively in Tables 5 and 6, and in the form of resistance growth percentage in Table 7, and in the form of graphs in Figures 2-7.

Table 5. Numeric Results of Tests on 9 SC Plans of Table 4

SC60	SC57.5	SC55	SC52.5	SC50	SC47.5	SC45	SC42.5	SC40	Plan	
20.64	21.1	22	22.35	21	20.5	20.3	19.8	19.45	3 Days	Compressive strength MPa
25.22	25.9	26.6	27.3	26.6	26.3	25.84	25.32	24.8	7 Days	
39.4	40.1	40.72	41.4	40.8	40.3	39.7	39	38.3	28 Days	
2.2	2.24	2.27	2.31	2.25	2.16	2.1	2	1.95	7 Days	Tension strength Mpa
2.77	2.81	2.85	2.9	2.87	2.75	2.68	2.57	2.5	28 Days	

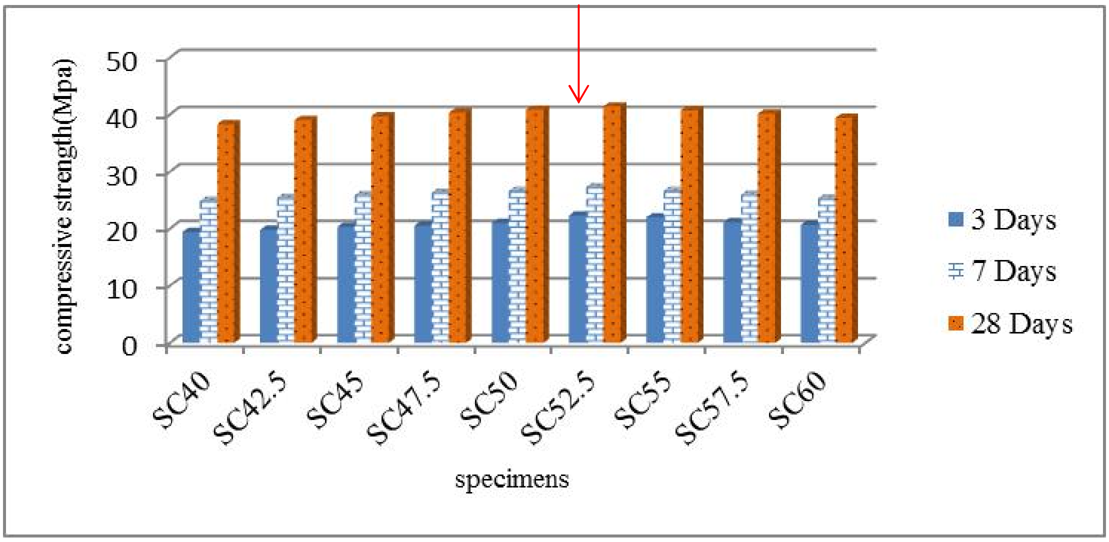
Table 6. Numeric Results of Tests on 9 Magnetic SC Plans of Table 4

MSC60	MSC57.5	MSC55	MSC52.5	MSC50	MSC47.5	MSC45	MSC42.5	MSC40	Plan	
22	22.47	23.45	23.53	22.13	21.58	21.35	2085	20.46	3 Days	Compressive strength Mpa
26.9	27.6	28.33	28.74	28	27.7	27.26	26.67	26.1	7 Days	
41.25	41.9	42.6	42.85	42.18	41.67	41.1	40.36	39.53	28 Days	
2.3	2.33	2.36	2.39	2.32	2.23	2.17	2.07	2	7 Days	Tension strength Mpa
2.84	2.88	2.92	2.96	2.92	2.8	2.73	2.62	2.55	28 Days	

Table 7. Growth Rate of Pressure and Tension strength

MSC60	MSC57.5	MSC55	MSC52.5	MSC50	MSC47.5	MSC45	MSC42.5	MSC40	Plan	
6.6	6.5	6.6	5.3	5.4	5.3	5.5	5.3	5.2	3 Days	Compressive strength MPa
6.6	6.5	6.5	5.3	5.4	5.3	5.5	5.3	5.2	7 Days	
4.7	4.7	4.6	3.5	3.4	3.4	3.5	3.5	3.4	28 Days	
4.2	4.1	4.1	3.4	3.3	3.3	3.3	3.4	3.3	7 Days	Tension strength MPA
2.5	2.5	2.5	1.9	1.8	1.8	1.8	1.9	1.8	28 Days	

Figure 1. Comparing Compressive strength of SC Concrete



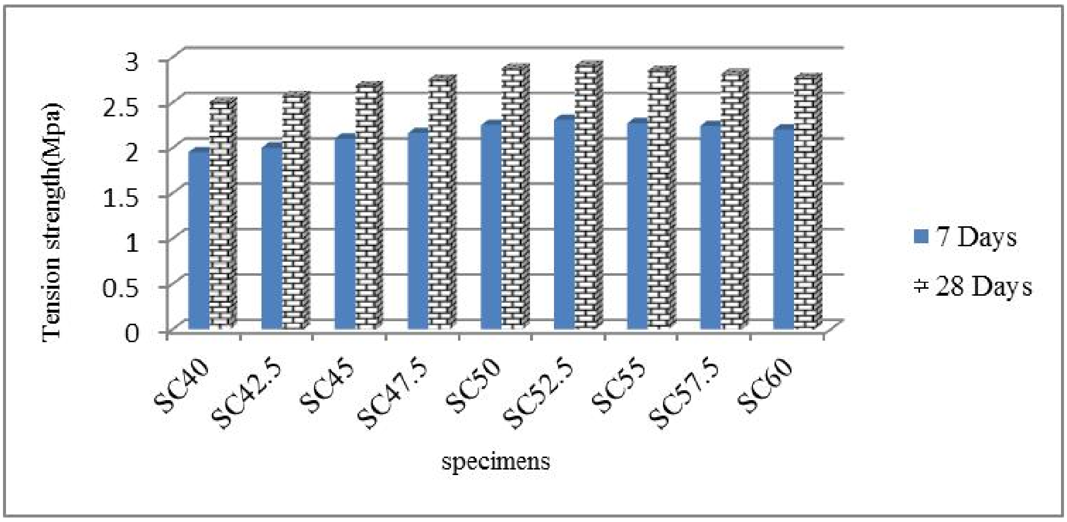


Figure 2. Comparing Tensile Pressure of SC Concrete

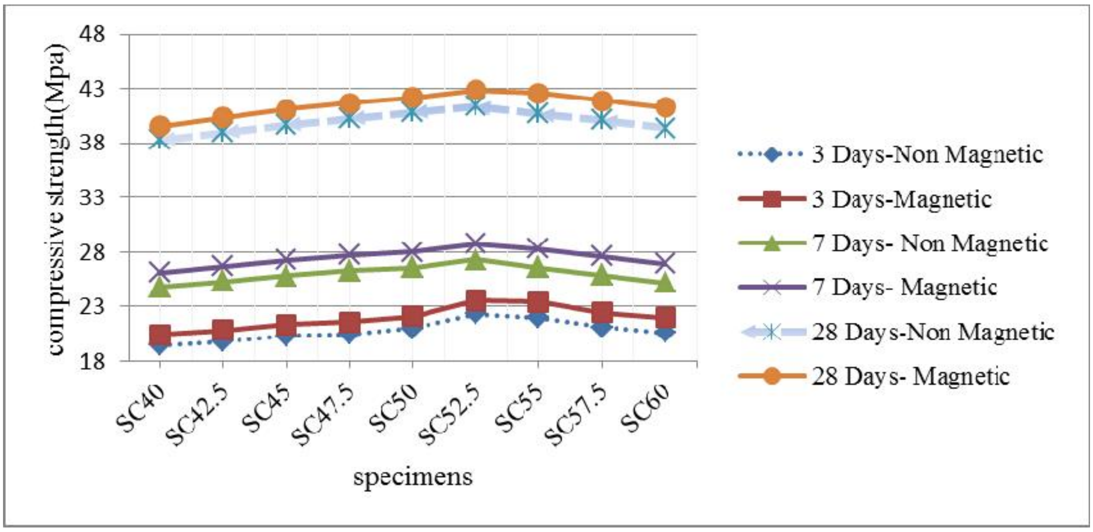


Figure 3. Comparing Compressive strength of SC Concrete and Magnetic SC Concrete

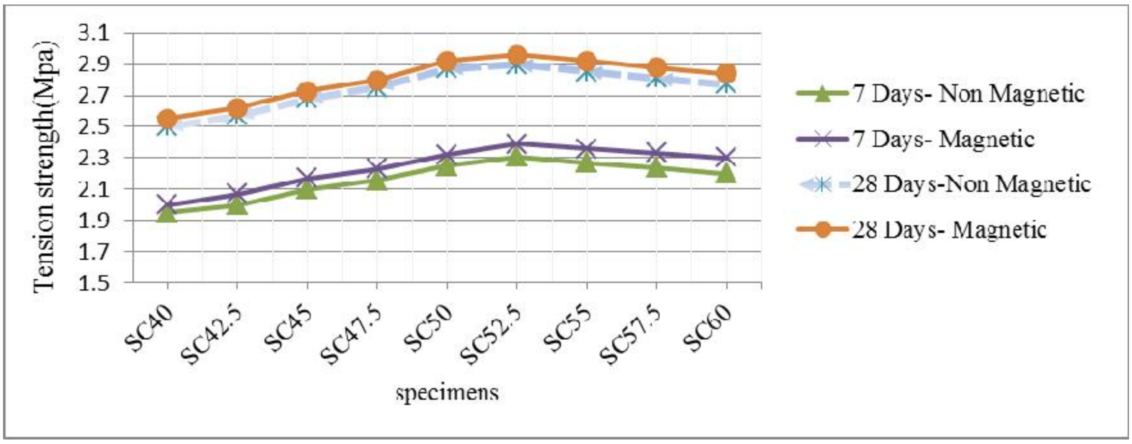


Figure 4. Comparing Tension strength of SC Concrete and Magnetic SC Concrete

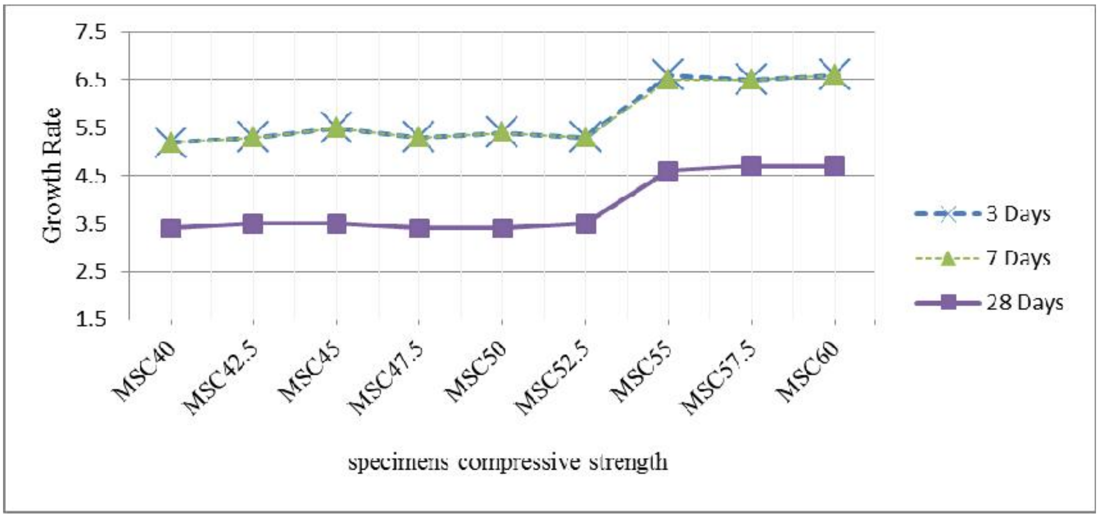


Figure 5. Comparing Growth Rate of Compressive strength in SC Concrete and Magnetic SC Concrete

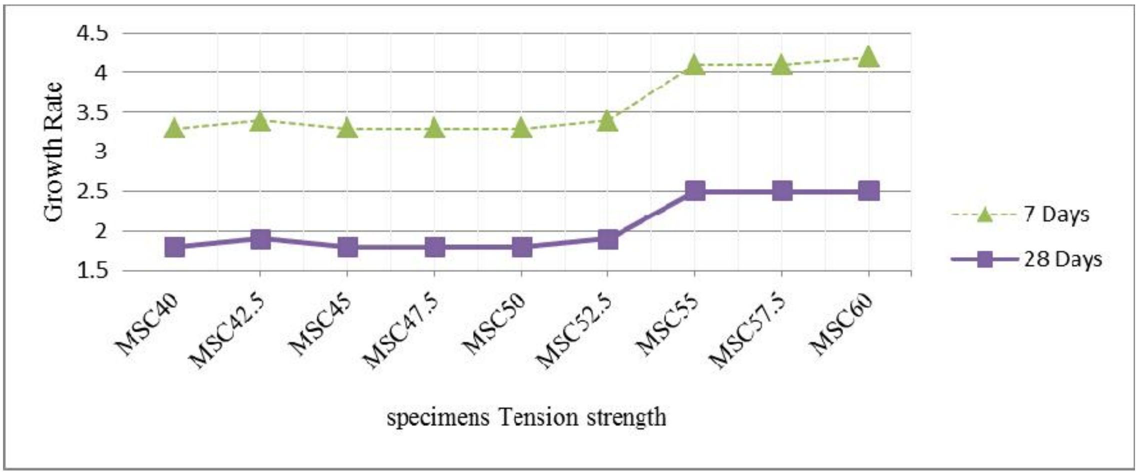


Figure 6. Comparing Growth Rate of Tension Strength in SC Concrete and Magnetic SC Concrete

RESULT ANALYSIS

Since the water-cement particle ratio is a fixed value (Table 4), the mix plan SC52.5 exhibit the maximum compressive and tension strength amongst the 9 presented mix plans (Figures 2 & 3); and this represents the optimum and desired ratio of cement materials, fine aggregates, and large aggregates. The results of Tables 5 and 6 as well as Figures 4 and 5 show that almost in all of the plans the magnetic field has a considerable effect on compressive and tension strength of the concrete.

Along with the start of cement compaction in the magnetic concrete, the thinner hydrated layers begin to form between cement particles. This layer quickly reacts to surface layers of cement particles; but, after completion of this layer of water around the particles, hydration of cements becomes slower, and water hardly penetrates into cement particles to continue the hydration process. Therefore, magnetic concrete hydrates rather quickly in initial stages, but this pace gradually gets lower (Table 7 & Figures 6-7). As a result of this action, the porosity of concrete decreases considerably, which results in the increase of compressive and tension strength (Figures 6 & 7). In this case, plasticity and workability of cement would also increase due to lower pace of hydration (Grashko, Belova,Lishanski, 1982). It is also shown in Figures 6 & 7 that specimens MSC55, MSC57.5, and MSC60 exhibit a higher compressive strength growth rate compared with the other specimens. Considering the fact that water-to-cement proportion is fixed and more small aggregates are used in these specimens, the above mentioned facet could be an outcome of magnetic impact on small aggregates and their density (Grashko, Belova,Lishanski, 1982).

CONCLUSION

Considering the effects of magnets on water and small aggregates, we may realize the impact of magnets on SC concrete.

Application of magnets has a positive impact on improving the strength of concrete during the initial days.

Application of magnets would reduce the use of super plasticizers, which are used in order to improve workability of concrete and reduce water consumption, and therefore decreases the costs related to such materials.

The distance for the transmission of concrete made of magnetic water would increase due to the increase of plasticity and decrease of compaction.

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