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Research Note

Improving Mechanical Properties of High Strength Concrete by Magnetic Water Technology

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Abstract. *The most important challenge for concrete technologists is to improve the properties of concrete. In the last two decades, in Russia and China, a new technology, called magnetic water technology, has been used in the concrete industry. In this technology, by passing water through a magnetic field, some of its physical properties change and, as a result of such changes, the number of molecules in the water cluster decrease from 13 to 5 or 6, which causes a decrease in the water surface tension. Using magnetized water in concrete mixtures causes an improvement in the workability and compressive strength of concrete. Also, this processed water causes a reduction in the cement content required for the specified compressive strength value. In this research, in the concrete laboratory of Sahand University of Technology, the effects of magnetic water on some mechanical properties of high strength concrete, such as workability and compressive strength, have been studied. For the production of magnetic water, a magnetic treatment device (made in Germany) has been used. This device mostly is used for the softening of water and, for the first time in this research, it has been used by the authors for the production of concrete. The results of tests showed that, in most cases, concrete made with magnetic water (magnetic concrete), has higher slump values than those of control concrete (up to 45%). Also in some cases, the compressive strength of the magnetic concrete samples was higher than that of the control concrete samples (up to 18%). Also, in some cases, with the same slump and compressive strength, cement content can be reduced by 28% in the case of magnetic concrete.*

Keywords: *High strength concrete; Magnetic water; Compressive strength; Slump; Clean concrete.*

INTRODUCTION

The initial research and scientific testing regarding the application of a magnetic field to concrete manufacturing were commenced in Russia in 1962 for military constructions such as airports and jetties. This research was continued step by step in other institutes, such as the VNLL Jelezobeton Research and Scientific Institute in Russia, and some positive results were found in this regard.

Magnetic devices include one or more permanent magnets, which induce changes and effects on ions and water molecule clusters passing through its magnetic field. A magnetic field has a considerable effect on clusters of water molecules and causes the decrease of such a mass from 13 molecules to 5 or 6 molecules (Figure 1).

Such a decrease of molecules causes more participation of water molecules in the cement hydration reaction [1-3]. Also, when water is mixed with cement, cement particles are surrounded by water molecule

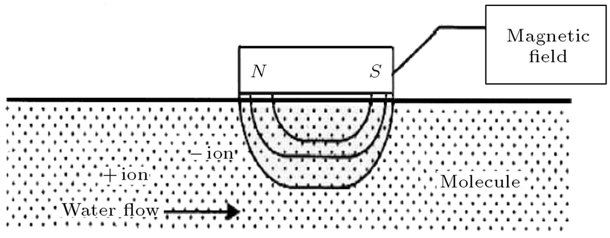

Figure 1. Effect of a magnetic device with permanent magnet on ions passing through its magnetic field.

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clusters. In the case of magnetic water in which the clusters have a smaller size and lower density, the thickness of the water layer around the cement particle is thinner than in the case of normal water. This fact results in a decrease in water demand for concrete mixing and, subsequently, in reducing the W/C ratio, which has positive effects on hardened concrete properties, such as strength, durability etc. [4-7].

EXPERIMENTAL DESIGN

Several tests on HPC samples, such as slump and compressive strength tests, were undertaken in the concrete laboratory of Sahand University [8].

Materials and Instruments

Materials such as aggregates, silicafume, superplasticizer, water and cement were used for tests. Aggregates were prepared from mines around Tabriz city (Table 1).

Table 1. Specifications of coarse and fine aggregates used for tests.

Aggregate Type	Maximum Diameter (mm)	Specific Gravity (kg/m^3)
Coarse	19	2805
Fine	4	2460

Cement type 2 (Table 2) was used and silicafume was prepared from the Azna mine of Lorestan state (Table 3). Melamine Lignosolphonate superplasticizer was also used.

For magnetization of water, equipment made in Germany (generally used for treatment of water) was used for the first time in the production of concrete. Also, a pump was used for the circulation of water in the magnetizer. The water flow value was 2.26 liter/min and the water circulation time in the device was equal to 15 minutes.

Mixture: Proportioning of Samples

To study the effects of cement content, w/c ratio, superplasticizer percent and age of samples, 21 mix designs were performed. 350,400 and 450 kg of cement content; 0.35, 0.4, 0.45 and 0.5 w/c ratios; 1, 2 and 3% superplasticizer and 10% silicafume were used.

Two types of water, normal and magnetic, were used for the production of concrete samples.

Experimental Methods

Produced magnetic water was used for the concrete mixing. After mixing the concrete for two minutes, a slump test (according to ASTM C-143-90a) was undertaken on the concrete mixture. Then, the produced concrete was poured into $10 * 10 * 10$ cm^3 moulds and,

Table 2. Specifications of cement used for tests.

Cement Combinations	Percent in Cement	Cement Combinations	Percent in Cement
Na_2O	0.28%	SiO_2	21.97%
K_2O	0.95%	Al_2O_3	4.62%
C_3S	50.68%	Fe_2O_3	3.55 %
C_2S	24.76%	CaO	64.56%
C_3A	6.24%	MgO	2.33%
C_4AF	10.80%	SO_3	1.65%
L.O.I	≤ 1		

Table 3. Specifications of silicafume.

Name	Azna-Lorestan
Structure	Non-crystallized (amorphous)
Particle Shape	Conic
Approximate Diameter	Micron 1.0
Specific Surface Area	Approximate 20 m^2
Color	Bright gray turning to white

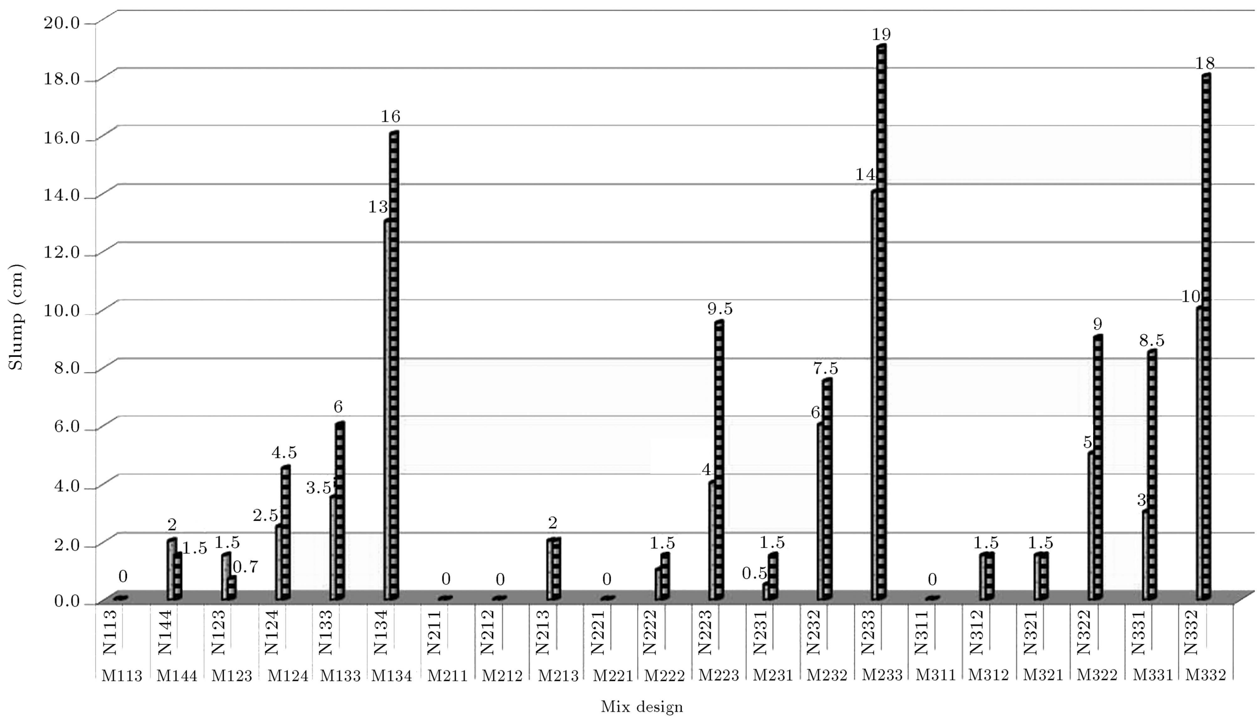

Figure 2. The slump values of magnetized and non-magnetized concrete samples.

after curing, compressive strength tests were done on the concrete cubes.

RESULTS AND DISCUSSION

Effect on Slump

Figure 2 shows the slump values of the magnetized and non-magnetized concrete samples. As shown, the slump values of the magnetized concrete were higher than those of non-magnetized concrete. Figures 3 to 5 show the slump variations in the concrete samples with various cement content. It can be concluded that the effect of the magnetic field will increase at higher cement content, w/c ratio and superplasticizer percent, and the slump of the samples will improve. The reason for this phenomenon can be explained as follows.

In mixtures with higher cement content, we also need more water for surrounding the cement participates and, faced with the low gathering of molecules in magnetic water and, in this regard, in the case of magnetic water, we need to lower the water volume for the surrounding cement particles and, as a result, a high rate of water shall be applicable for more efficiency.

Subject to more lubrication of the magnetic concrete mixtures with a rate of water higher than the amount of cement, it should be mentioned that an effective part of the magnetic field in the concrete mixture is changed to mixed water and, for as long as the higher rate of this water in the concrete mixture exists, its effect also shall be higher. It is observed that in mixtures with higher water to cement ratios, the effect of the magnetic field is higher to improve the mixture efficiency.

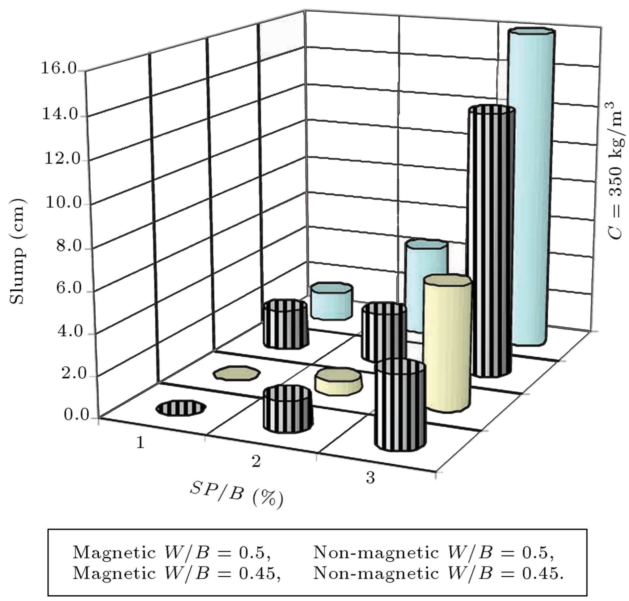

Figure 3. Slump variations in concrete samples with 350 kg cement content.

But, subject to the effect of the superplasticizer, due to the effect of magnetic water on the properties

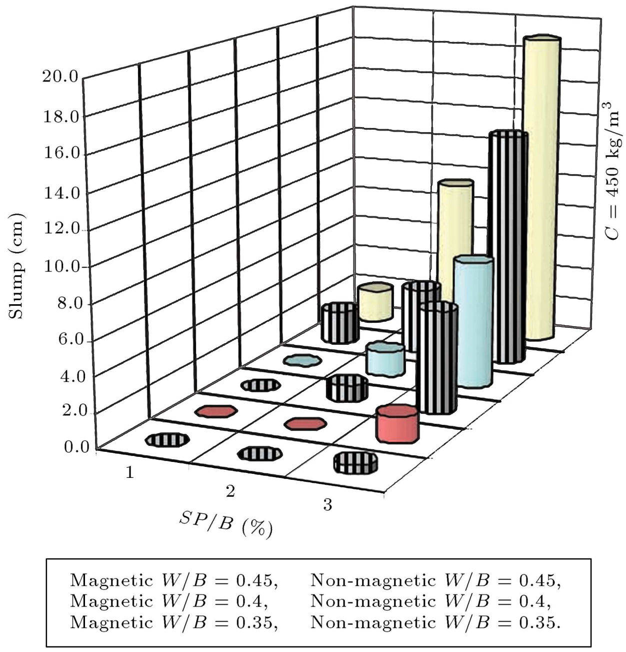

Figure 4. Slump variations in concrete samples with 400 kg cement content.

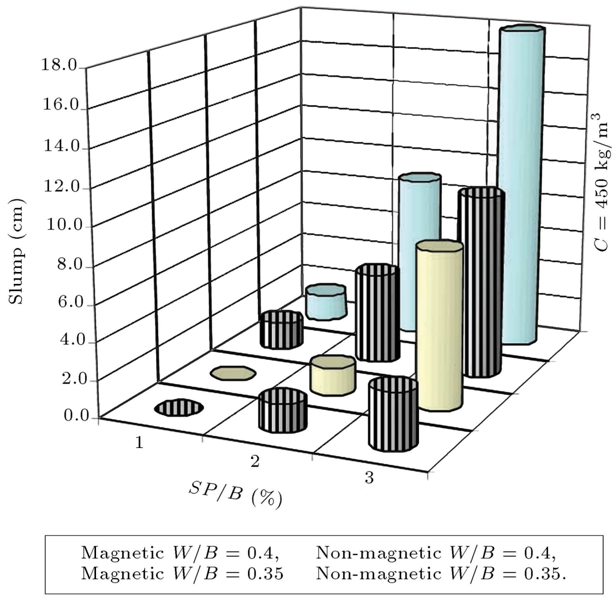

Figure 5. Slump variations in concrete samples with 450 kg cement content.

of concrete, we can say that the super lubricant has an effect on the electrical loan of the cement particles and is the cause for their separation from each other, facilitating its movement. Magnetic water particles also, due to loading, aid the work of the lubricator and, on the whole, we can say that magnetic water particles and a super lubricant have a special effect on cement particles, prevent its compressing and, due to separation, may cause better lubrication.

Effect on Compressive Strength

Values of the compressive strength at 28 days and the variation percentage of magnetic concrete strength in comparison with non-magnetic concrete, were presented in Table 4. In the 28-day sample, we observed an increase of compressive strength in the 400 and 450 cement content. At an age of 90 days, the strength values of magnetic concrete are higher than that of ordinary concrete (Table 4).

Effect of Magnetic Superplastizer

The operation of the superplasticizer is as follows. These molecules have two positive and negative parts. In the concrete combination, the positive part shall be loaded onto the cement particles and surround it. This changes the electrical charges on the surface of cement particles into negative and results in separation and dispersion of cement particles from each other; and finally causes a better lubricating of the concrete. When the superplasticizer and water pass from the magnetic processing unit, the magnetic field rates pass from the electron pair of oxygen atoms and cause a layer with 8 electrons to surround the superstructure molecules, i.e. free electron parts fill in the positive part of the superplasticizer by binding with the water molecules. Filling or neutralizing the positive part of the superplasticizer prevents the collection and absorption of these molecules and, as a result, causes lower operation, in comparison with concrete that has been prepared with a non-magnetic superplasticizer and magnetic water.

The result of lubricating and pressure strength of concrete samples with magnetic SP shows that concrete with magnetic SP has an application operation of non-magnetic SP concrete without SP and concrete without SP. The reason for this is a decrease of the magnetic field on the water due to the availability of a superplasticizer. In this case, the superplasticizer absorbs the solution of the magnetic field and, as a result, causes a decrease in the magnetic field of the water molecules.

Saving of Cement Consumption

Suppose that we wish to produce concrete with a fixed amount of plasticizer and pressure strength and, in this regard, offer a mixture (combination) plan. Because of the higher rate of lubrication and pressure strength of magnetic concrete in comparison with non-magnetic concrete, we use this plan to increase the lubricating and high pressure operation and we can present another plan that has a lower fineness of cement and different characteristics from figures presented in the initial plan.

Table 5 is a comparison between magnetic and

Table 4. Values of compressive strength at 28 days and variation percentage.

No.	Mix Design		B (kg)	W/B	$S.P/B$ (%)	Non-Magnetic (kg/cm^2)	Magnetic (kg/cm^2)	Variation Percentage (%)
1	N113	M113	350	0.45	1	672.3	623	-7.3
2	N114	M114	350	0.5	1	594	604.5	1.8
3	N123	M123	350	0.45	2	667.7	603.3	-9.6
4	N124	M124	350	0.5	2	583.3	511.3	-12.3
5	N133	M133	350	0.45	3	650.7	615	-5.5
6	N134	M134	350	0.5	3	606	557	-8
7	N211	M211	400	0.35	1	631.7	608.5	-3.6
8	N212	M212	400	0.4	1	649	690	6.3
9	N213	M213	400	0.45	1	621.7	601	-3.3
10	N221	M221	400	0.35	2	658.3	735.7	11.8
11	N222	M222	400	0.4	2	722.5	665	-8
12	N223	M223	400	0.45	2	551.7	607.7	10.2
13	N231	M231	400	0.35	3	706.7	786	11.2
14	N232	M232	400	0.4	3	659.3	747	13.3
15	N233	M233	400	0.45	3	587.3	671.5	14.3
16	N311	M311	450	0.35	1	675	708.3	4.9
17	N312	M312	450	0.4	1	566.3	744	31.4
18	N321	M321	450	0.35	2	688	817	18.8
19	N322	M322	450	0.4	2	576	773	34.2
20	N331	M331	450	0.35	3	722	662	-8.3
21	N332	M332	450	0.4	3	626.7	721.7	15.2

Table 5. Comparison between specifications of magnetic and non-magnetic concretes.

Concrete Type / Variable	Mag.	Non-Mag.	Mag.	Non-Mag.	Mag.	Non-Mag.	Mag.	Non-Mag.
Mix Design	M124	N322	M114	N312	M133	N232	M114	N213
28 Days Compressive Strength	583	576	605	566	651	659	605	621
Slump (cm)	4.5	5	1.5	1.5	6	6	1.5	2
$S.P./B$ (%)	2	2	1	1	3	3	1	1
W/B	0.5	0.4	0.5	0.4	0.45	0.4	0.5	0.45
Cement Content	450	350	350	450	350	400	350	400

non-magnetic concrete and it is understood that, in a number of cases, we can save approximately 50 kg of cement in each cubic meter of concrete. In some cases, such a saving will attain 100 kg per cubic meter.

CONCLUSION

1. It can be said that, approximately, in all the plans, the rate of lubrication of magnetic concrete in comparison with ordinary concrete is higher.
2. With an increased fineness of cement, its lubricating is also increased. Also, magnetic water, in the presence of a plasticizer, shows better operation.
3. The pressure strength of the magnetic concrete samples at finenesses of 400 and 450 is higher than that of ordinary concrete.
4. In the case of adding a superplasticizer to water, passing the solution through the magnetic unit and benefiting from the final solution to produce concrete, the plasticizer of the produced samples is lower than that of non-magnetic concrete.
5. The pressure strength of concrete produced with

a superplasticizer is higher than that of ordinary concrete and lower than that of magnetic concrete.

6. In the case of using magnetic water instead of ordinary water to produce concrete, a considerable amount of saving will occur in the rate of consumed cement.

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