Computers and Concrete, *Vol. 13, No. 5 (2014) 649-657*
DOI: http://dx.doi.org/10.12989/cac.2014.13.5.649

An investigation of water magnetization and its influence on some concrete specificities like fluidity and compressive strength

N. Khorshidi[1], M. Ansari[2] and M. Bayat*[3]

[1]*Department of Civil and Environmental Engineering*, *Sahand University*, *Tabriz*, *Iran*
[2]*Department of Civil and Environmental Engineering*, *Tarbiat Modares University of*, *Tehran*, *Iran*
[3]*Department of Civil Engineering*, *College of Engineering*, *Mashhad Branch*, *Islamic Azad University*, *Mashhad*, *Iran*

(*Received July 13, 2013, Revised March 3, 2014, Accepted March 7, 2014*)

Abstract. In this paper, effects of magnetic water on different properties of cement paste including fluidity, compressive strength, time of setting and etc, has been studied in concrete laboratory of Sahand University of Technology. For production of magnetic water, three devices including an AFM called device(made in UAE) ,a device marked AC(made in Germany) and finally a device was designed and made in Concrete Laboratory of Sahand University of Technology) have been used. The results show that, intensity and direction of magnetic field, velocity and time of water passing through magnetic device, and amount and type of Colloidal particles have direct effects on properties of magnetic water and using such a water in making cement paste, increases its fluidity and compressive strength up to 10%.

Keywords: concrete; cement paste; magnetic water; fluidity; compressive strength; time of setting

1. Introduction

The initial researches and scientific tests about application of magnetic field in manufacturing concrete and concrete blocks was commenced for military constructions such as airports and jetties at 1962 in Russia. Those researches were continued step by step in other institutes such as VNll Jelezonbeton Research & Scientific Institute in Russia, and some positive results were found in this regard. These results caused change in viewpoint of other countries researchers including USA scientists to benefit from magnetic technology in concrete. At present time, there are numbers of different devices for production of magnetic water and its application in concrete in western countries (Abdel-Raouf *et al*. 2009; Ma 2007; Al-qahtani 1996; Feraris *et al*. 2006; Gabrielli *et al*. 2001; Huchler *et al*. 2002; Kronberg 2009).

Magnetic devices include one or more permanent magnets, which induce changes and effects on ions passing through its magnetic field (Fig. 1).

Magnetic field has a considerable effect on clusters of water molecules and causes a decrease of such a mass from 13 molecules to 5 or 6 molecules. Such a decrease of molecules or in other

*Corresponding author, Researcher, E-mail: mbayat14@yahoo.com

http://www.techno-press.org/?journal=cac&subpage=8 ISSN: 1598-8198 (Print), 1598-818X (Online)

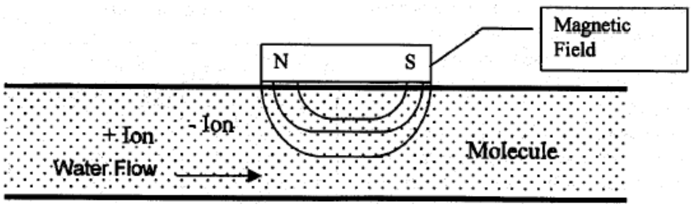

Fig. 1 Effect of a magnetic device with permanent magnet on ions passing through its magnetic field

words scattering of water molecules from each other causes for more participation of water molecules in cement hydration reaction. Generally, cement particles are scattered inside concrete mix in form of complex of molecules, and hydration reaction initially takes place in surface of cement particles and as a result, a soft layer of hydration reaction products forms on cement particles that prevents from penetration of water molecules to complex of particles and more hydration of cement particles and finally prevent from complete hydration of cement particles. If we use magnetic water instead of normal water, due to small cluster of water molecules, they have better opportunity to penetrate inside cement particles complex. As a result, complete hydration process in this procedure shall be obtained in comparison with use of normal water (Li *et al*. 2011; Macmahon 2009; Nan *et al*. 2000; Nan *et al*. 2003; Saddam *et al*. 2009)

The High Performance Concretes (HPC), have more advantages compared to normal concrete from viewpoints of slump, compressive strength and durability. Two most important methods to increase the mentioned parameters efficiency are using magnetic water and recycled aggregates in producing concrete.

Andreu *et al*. (2014) considered three types of recycled concrete aggregates (RCA) in high performance concrete (HPC). They used HPC which were produced using 20%, 50% and 100% of RCA on substitution of natural coarse aggregates. They analyzed the physical, mechanical and durability properties of the recycled aggregates concretes and conventional concrete. Their results showed that considering mechanical properties, the 100% natural coarse aggregates' replacement would be possible when RCA were produced from original concrete with a minimum compressive strength of 60 MPa.

Nan *et al*. (2000) studied on compressive strength and workability of mortar and concrete mixed with magnetic water and contained granulated blast-furnace slag (GBFS). Their results have shown that the compressive strength of mortar samples mixed with magnetic water increased in comparison with tap water. Similarly, the compressive strength of concrete prepared with magnetic water increased in comparison with the tap water samples. It has also been found that magnetic water improves the fluidity of mortar, the slump, and the degree of hydration of concrete.

Also, when water is mixed with cement, cement particles are surrounded by water molecule clusters. In case of magnetic water in which the clusters have smaller size and lower density, the thickness of water layer around cement particle is thinner than in case of normal water. This fact results in a decrease in water demand for concrete mixing and subsequently reducing W/C ratio which has positive effects on hardened concrete properties like strength, durability, and etc (Song *et al*. 2011; Toledo *et al*. 2008; Zaidi *et al*. 2014; Damrongwiriyanupap *et al*. 2014; He *et al*. 2011; Van Mien *et al*. 2011; Wang *et al*. 2008).

In this paper, the details of the Test Programs are introduced. There are three main test groups. Some tables and figures are presented which are the results of our test programs and we discuss on them in details. Eventually, the test results demonstrated that the intensity and direction of magnetic field, velocity and time of water passing through magnetic device have direct effects on properties of magnetic water which should use for producing cement paste, improve its fluidity and compressive strength up to 10% .

2. Test program

Generally, performed tests can be classified in three groups:

Test group 1:

Those tests that study the effect of mineral materials available in magnetic water on cement paste properties. Here, we used three types of magnetic processing devices. One of those devices was made in Concrete Laboratory of Sahand university of Technology, and two further devices were made by foreign companies, which are engaged in magnetic processing affairs.

MFM Device: This device is made in UAE. Magnets are located in small space and water flows through the magnets.

AC device: This device is made in Germany. This device has powerful magnet that is source for generation of magnetic field. The power of device is 1300 Gauss and water flows through magnets. It should be mentioned that, device should be installed in path of water flow. Inside diameter of the device in water passing place was 0.45 cm.

NNN, SSS and 3NS Device: These devices were made in Sahand University of Technology, Concrete Laboratory and for manufacturing these devices, 6 permanent magnets made of Vanadium Bore Ferrous, which have power of 800 Gauss, were used. Two groups of magnets were installed in two opposite sides of plastic pipe with diameter of 0.75 cm in duplicate form. Some specifications of the devices such as diameter and outflow rates are given in Table 1.

Three types of waters were used in this group of tests: Normal, lime and cement water. Normal water was the tap water of Tabriz city and Lime and cement water were made by solving 3% of lime or cement by weight in water and after 24 hours sedimentation, the upper part of water in containers ,that have cement or lime materials, were used as lime or cement water to mix cement paste. Water to cement ratio in all cement paste samples was equal to 0.4. Then fluidity and compressive strength tests were performed in all samples. For fluidity Test, we used Flow Table device in such a way that, frustum of device filled with cement paste and with removing frustum container and measuring of opened diameter of cement paste, workability or flowability was obtained. In next stage, cement paste molded in 5x5x5 cm cubes and compressive strength test were performed on samples after 7 and 28 days. According to the results of first test group, the best device from standpoint of operation was selected and was used for 2nd test groups.

Test group 2:

In 2nd group of tests, the selected magnetic generating device and a fixed pump were used. The tests were performed in two series. In first series, outflow rate was constant 2.26 lit/min, but circulation times were 0, 15,30,60,90 and 120 minutes. Zero time of circulation means that the water has passed only one time through device. In second series the circulation time was fixed and water was passed through device only one time, but outflow rates were Q/4,Q/2,3Q/4 & Q (Q is equal to 2.26 liters/minute). Also, zero outflow means non-magnetic water. In this group of tests, fluidity and compressive strength of all cement paste samples were tested.

Table 1 Some specifications of magnetic devices such as diameter and outflow (with a permanent pump)

Device type	Diameter of device in output (cm)	Outflow lit/min	Passing velocity m/s
AC	0.75	2.26	0.85
MFM	0.7	4.02	1.74
NNN, SSS, 3NS	0.75	4.75	1.79

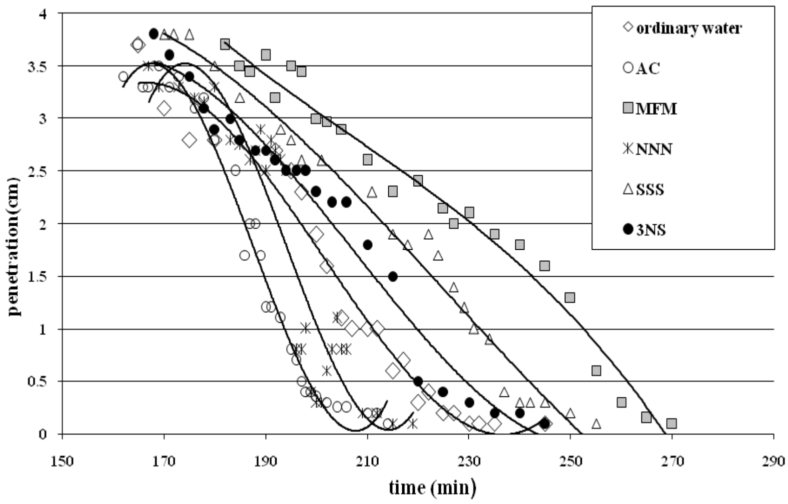

Fig. 2 Time-Vicat needle Penetration diagrams for cement paste samples made by different magnetic devices

<u>Test group 3</u>*:*

In third group of tests, setting time of cement pastes was measured. Three different magnetic devices, fixed pump, and tap water were used to study the effect of device type on hardening of cement paste. Water to cement ratio in third group tests was equal to 0.26 and water circulation time in device was equal to 15 minutes. Initial setting time and 1 mm penetration time for cement paste samples, were measured by Vicat needle.

Initial setting time is equal to the passed time from beginning of water and cement mixing to 2.5 cm penetration of Vicat needle in cement paste; and time of 1 mm penetration is equal to the passed time from beginning of paste mixing to maximum 1mm penetration of Vicat needle in cement paste.

3. Results and discussion

The results of first group of tests (studying the effect of available mineral materials in magnetic water) are presented in tables 2, 3 and 4. As shown in these tables, in case of AC device in all samples with different waters, an increase in fluidity and strength is observed. These increments in case of magnetized tap water were higher compared to tap water and were and 14.7% and 25% respectively. It shows that each magnetic device has a specific optimum outflow rate. 2.26 lit/min

Table 2 results of fluidity test on different samples of cement past

Device	Normal water		Limewater		Cement water	
	Fluidity (cm)	Change (%)	Fluidity (cm)	Change (%)	Fluidity (cm)	Change (%)
Non-magnetic water	18	0	18.58	0	20.9	0
AC	20.45	+14.7	20.93	+12.4	21.45	+2.4
MFM	12.55	-2.5	13.88	-25.3	21.05	+0.7
NNN	20.55	+14.2	14.33	-12.1	19.95	-4.5
SSS	14.75	-4.9	14.2	-23.5	21.3	+1.9
3NS	14.90	-4.1	13.38	-28	21.1	+1

Table 3 results of 7 days compressive strength of cement paste samples

Device	Normal water		Limewater		Cement water	
	Compressive strength (kg/cm^2)	Change (%)	Compressive strength (kg/cm^2)	Change (%)	Compressive strength (kg/cm^2)	Change (%)
Non-magnetic water	321	0	232.6	0	324.4	0
AC	391.7	+22	280.1	+20.4	345.4	+5.8
MFM	301.9	-4	242.1	+4	353.4	+8.3
NNN	294.5	-7.4	214.9	-7.4	297.8	-8.7
SSS	249.3	-14.1	210.8	-9.3	319.4	-2.1
3NS	273.4	-14.8	236.6	+1.7	242.5	-19.4

Table 4 results of 28 days compressive strength of cement paste samples

Device	Normal water		Limewater		Cement water	
	Compressive strength (kg/cm^2)	Change (%)	Compressive strength (kg/cm^2)	Change (%)	Compressive strength (kg/cm^2)	Change (%)
Non-magnetic water	489.6	0	398.5	0	491	0
AC	612	+25	480.1	+20.5	538.6	+9.7
MFM	428.4	-12.5	414.8	+4	550.8	+12.2
NNN	508.6	+3.9	409.4	+2.7	467.8	-4.7
SSS	431.1	-11.9	397.1	0	495	+0.8
3NS	462.4	-5.5	402.6	+1	439.3	-10.5

Table 5 changes of fluidity and compressive strength of samples made with different non-magnetic and magnetic waters

Device	Normal water		Limewater		Cement water	
	Compressive strength (kg/cm^2)	Fluidity (cm)	Compressive strength (kg/cm^2)	Fluidity(cm)	Compressive strength (kg/cm^2)	Fluidity (cm)
Non-magnetic water	0	0	0	0	0	0
AC	+25	+14.7	+20.5	+12.6	+9.7	+2.6
MFM	-12.5	-2.5	+4	-25.3	+12.2	+0.7
NNN	+3.9	+14.2	+2.7	+12.1	-4.7	-4.5
SSS	-11.9	-4.9	0	-23.5	-0.8	+1.9
3NS	-5.5	-4.1	+1	-28	-10.5	+1

Table 6 Results of fluidity test on samples made with different circulation times (Q=2.26 lit/min)

Circulation time (min)	0	15	30	60	90	120
Fluidity (cm)	20.35	20.45	20.5	22.9	18.3	19.5
Change value in comparison with one time passed water	0	+1.5	+1	+12.5	-10.1	-4.2

Table 7 Results of fluidity tests on samples made with different outflow rates (water has passed through device only one time)

Outflow	0	Q/4	Q/2	3Q/4	Q=2.26 lit/min
Fluidity (cm)	18	16.45	16.45	18.2	20.35
Change value in comparison with non-magnetic water	0	-8.6	-8.6	+1	+13

Table 8 Results of compressive strength tests on samples made with different circulation times (Q=2.26 lit/min)

Circulation time (min)	0	15	30	60	90	120
Compressive strength at 7 days (kg/cm²)	250.2	391.7	242.1	244.8	229.8	239.4
Change value in comparison with one time passed water	0	+56.5	-3.2	-2.2	-8.2	-4.3
Compressive strength at 28 days (kg/cm²)	421.4	612	433.8	437.9	399.8	398.5
Change value in comparison with one time passed water	0	+45.2	+2.9	+3.9	-5.2	-5.4

Table 9 Results of compressive strength tests on samples at different outflow rates (water has passed through device only one time)

Outflow	0	Q/4	Q/2	3Q/4	Q = 2.26 lit/min
Compressive strength at 7 days (kg/cm²)	277.4	225.8	250.2	223	250.2
Change value in comparison with non-magnetic water	0	-18.6	-9.8	-19.6	-9.8
Compressive strength at 28 days (kg/cm²)	489.6	384.9	436.4	345.4	421.6
Change value in comparison with non-magnetic water	0	-21.4	-10.8	-29.4	-13.9

Table 10 results of setting times (initially and 1 mm penetration) of cement paste samples

Device	Normal water	AC	MFM	NNN	SSS	3NS
Initial time of setting	188	182	216	188	204	194
Time of 1mm penetration	234	207	268	214	253	243
Difference of times	46	25	52	26	49	49

Table 11 results of setting times (initially and 1 mm penetration) of cement paste samples

Device	Normal water	AC	MFM	NNN	SSS	3NS
Initial time of setting	188	182	216	188	204	194
Time of 1mm penetration	234	207	268	214	253	243
Difference of times	46	25	52	26	49	49

was an appropriate rate for AC device, but 4.02 and 4.75 lit/min were not the optimum rates for MFM and NNN, SSS, 3NS devices. Results of table 2 show that samples made with cement water have more fluidity in comparison with tap water and limewater. This is due to less surface tension of cement water which results in easier and better movement of cement particles on each other in paste. Also, samples which are prepared with cement water have higher compressive strength in comparison with normal and limewater. This is due to some reason mentioned above. Easier and better movement of cement particles result in more condensed paste and more reaction between cement particles and water molecules. In case of limewater, due to higher volume of calcium hydroxide gel in paste, the strength of samples is less than other cases. Change percentages of table 2 shows rate of fluidity change in comparison with non-magnetic case.

From results shown in table 5, it can be concluded that AC device has better efficiency than other two types. So, AC was used to produce magnetic water in next test group.

Results of 2nd test group (studying the effect of circulation time of water and outflow rates) are presented in tables 6, 7, 8 and 9.

Above mentioned results show that time of circulation and outflow rate are effective parameters on operation of magnetic water generation devices. For AC device, at 60 minutes circulation time and 2.26 lit/min outflow rate, we have maximum fluidity. Also, results show that compressive strength at 15 minutes circulation time and 2.26 liter/min outflow has maximum values. Increasing fluidity and compressive strength simultaneously in cement paste samples are impossible, because there is an optimum rate for water demand and fluidity of cement paste. When magnetic water is used for mixing cement paste and fluidity increases from its optimum value, some water will be unused in cement paste. This unused water will decrease the compressive strength of hardened cement paste.

Results related to third group of tests were presented in figure 1 and table 10. Figure 1 shows the rate of Vicat needle penetration in cement paste. As shown in figure 1, the less setting time is related to AC device while the most setting time is related to MFM device. The difference between initial setting time and time of maximum 1 mm penetration shows hardening rate of cement paste that decreases considerably when NNN and AC devices are used (minimum 20 minutes). The reason of this phenomenon is due to aid of AC device to reduce the number of molecules in the cluster of water molecules and then to simplify its penetration into cement particles that causes better and faster forming of crystals and hardening of cement paste.

4. Conclusion

It can be concluded:

1- In case of limewater, the compressive strength of samples is less than other cases due to higher volume of calcium hydroxide gel in paste.

2- Cement paste samples made with cement water show more fluidity and compressive strength.

3- AC magnetic device has more efficiency in producing magnetic water.

4- Increasing time of circulation of water in magnetic device from its optimum value, produced magnetic water has negative effect on fluidity and compressive strength of concrete samples; and optimum time of circulation must be specified for waters containing different colloidal materials and for devices with different specifications.

5- Results of setting time show that applying AC device for producing water for concrete mixtures can accelerate forming of crystals in cement paste and shortening its hardening time.

References

Abdel-Raouf, M. and Abou-Zeid, M.N. (2009), “Properties of concrete incorporating magnetized water”, *J. Transport. Res. Board*, 2113, 62-71.

Al-Qahtani, H. (1996), “Effect of magnetic treatment on gulf seawater”, *Desalination*, **107**(1), 75-81.

Andreu, G. and Miren, E. (2014), “Experimental analysis of properties of high performance recycled aggregate concrete”, *Constr. Build. Mater.* , **52**(2), 227-235 .

Damrongwiriyanupap, N., Li, L., Limkatanyu, S. and Xi, Y. (2014), “Temperature effect on multi-ionic species diffusion in saturated concrete”, *Comput. Concrete*, **13**(2), 149-171.

Feraris, C., Kartik H.O. and Russel H. (2006), “The influence of mineral admixture on rheology of cement paste and concrete”, Yang, Y., Dong, F., Feng, J., Study on healthcare magnetic concrete, *Rare Metals*, **25**(6) , 562–567.

Gabrielli, C., Jaouhari, R., Maurin, G. and Keddam, M. (2001), “Magnetic water treatment for scale prevention”, *Wat. Res.*, **35**(13), 3248-3259.

He, H., Stroeven, P., Stroeven, M. and Sluys, L.J. (2011), “Influence of particle packing on fracture properties of concrete”, *Comput. Concrete*, **8**(6), 677-692.

Huchler L.A. and Mar P.E. (2002), “Non-chemical water treatment system: Histories, Principles and Literature Review”, International Water Conference, IWC-02-45, Pittsburgh, PA.

Kronenberg, K.J. (1985) “Experimental evidence for effects of magnetic fields on moving water”, *Transact. Magnetics*, **21**(5), 2059-2061.

Li, G., Huang, Y. and Chen, C. (2011), “Study on test about the impermeability of magnetic water concrete”, *Adv. Mater. Res.*, 250-253, 601-604.

Ma, A.T. (2007), “Effect of magnetic water on engineering properties of self-compacting concrete with waste catalyst”, A thesis submitted to Institute of Construction Engineering, National Yunlin University of Science & Technology in Partial Fulfillment of the Requirements for Degree of Master of Design in Construction Engineering, Taiwan, Republic of China.

McMahon, C.A. (2009), “Investigation of the quality of water treated by magnetic fields”, In fulfillment of the requirements of Courses ENG4111 and 4112 Research Project Towards the degree of Bachelor of Engineering (Environmental), University of Southern Queensland, Faculty of Engineering and Surveying, Australia.

Su, N. and Wu, C.F. (2003), “Effect of magnetic field treated water on mortar and concrete containing fly ash”, *J. Cement Concrete Compos.*, **25**(7), 681-688.

Su, N., Wu, Y.H. and Mar, C.Y. (2000), “Effect of magnetic water on the engineering properties of concrete containing granulated blast-furnace slag”, *J. Cement Concrete Res.*, **30**(4),599 -605.

Saddam, M.A. (2009), “Effect of magnetic water on engineering properties of concrete”, *Al-Rafidain Eng.*, **17**(1), 71-82.

Song, H.W. and Zhao, S.Y. (2011), “Effect of admixtures treated by magnetic field on concrete”, *Adv. Mater. Res.*, **287**-**290**, 934-938.

Toledo, E., Ramalho, T.C. and Magriotis, Z.M. (2008), “Influence of magnetic field on physical–chemical properties of the liquid water: Insights from experimental and theoretical models”, *J. Mole. Struct.*, **888**(1-3), 409-415.

Van Mien, T., Stitmannaithum, B. and Nawa, T. (2011), “Prediction of chloride diffusion coefficient of

concrete under flexural cyclic load", *Comput*. *Concrete*, **8**(3), 343-355.
Wang, L. and Zhao, S. (2008), "Laboratory studies on the properties of cement-based materials with magnetic water", *Indian Concrete J*., **82**(9), 17-27.
Zaidi, N., Sohaili, J., Muda, K. and Sillanpaa, M. (2014), "Magnetic field application and its potential in water and wastewater treatment systems", *Separation Purification Reviews*, **43**(3), 206-240.

CC