"Effect of Magnetic Water on Engineering Properties of Concrete"

Saddam M. Ahmed
Assistant Lecturer
College of Engineering / Water Resources Department
University of Mosul / Iraq
E-mail:saddamzxc@yahoo.com

Abstract

This research investigates the influence of magnetic water on compressive strength and workability (consistence) of concrete. Results show that the compressive strength of concrete samples prepared with magnetic water increases 10-20% more than that of the tap water samples. In the present study, increasing in compressive strength of concrete is achieved when the magnetic strength of water is 1.2 T, and velocity of water current that passes through magnetic field is of 0.71 m/s. It is also found that magnetic water improves the workability (consistency) of fresh concrete.

Key words: magnetic water, workability, compressive strength, concrete, Ampere's Role

"تأثير الماء الممغنط على الخواص الهندسية للخرسانة"

صدام محمد احمد
مدرس مساعد
كلية الهندسة/قسم هندسة الموارد المائية/ جامعة الموصل/ العراق

الخلاصة

في البحث تم دراسة مقاومة الانضغاط وقابلية التشغيل للخرسانة الممزوجة بالماء الممغنط ومقارنته مع تلك الممزوجة بالماء الاعتيادي (ماء الصنبور). نتائج البحث كشفت أن مقاومة الانضغاط للخرسانة الممزوجة بالماء الممغنط تزداد بنسبة تتراوح بين (10-20%) بالمقارنة مع النماذج المعمولة بالماء الاعتيادي, وبصورة خاصة وجد أن أفضل زيادة مقاومة انضغاط للخرسانة تحقق عندما تكون المقاومة المغناطيسية للماء بحدود (1.2T), وسرعة جريان تيار الماء خلال المجال المغناطيسي بحدود(0.71 m/s), ووجد أيضا أن الماء الممغنط يحسن قابلية التشغيل (القوام) للخرسانة الطرية.

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1. Introduction:

Much research in recent years has been devoted to establishing the fundamental and engineering properties of high-strength concretes, as well as the engineering characteristics of structural members made with the material [1,2].

Increasing the compressive strength of concrete is an aim which most researchers are looking for, using various methods to do so, as the use of fiber reinforcement in a concrete mixture [3] to increase concrete strength. Gopalan and Haque [4] found that the design methods influenced the strength development of fly ash concrete significantly for structural concrete, at prevalent replacement ratios, the variation of strength of 20% has been observed. Other researchers [5,6] used fly ash and combination of fly ash and silica. Vipulanandan and Dharmarajan [7] studied strength of both epoxy polymer and polymer concrete. When fiber comes from recycle fiber which is derived from recycling of waste paper (magazine) by dry mechanical processing, the improve stiffness (possible of filler action of fines in recycled fibers) are observed [8], the damage stiffness and all aspects of flexural performance are observed, to be enhanced through refinement of fiber. Certain admixtures including high-range water-reducing superplasticizers [9, 10, 11], also are used to produce high-strength concrete.

The cost of these methods is not comparable with their advantages, thus most researchers concentrate their attention on producing economical concrete with higher strength using new philosophies in design methods, through modern technique, like using magnetic water. Government of the Russian Federation adopted Federal Program "Application of magnetic fields in national economy"[12], based on which, State Construction Committee of Russia, created a range of documents, ordering their organizations to use magnetic technologies. This decision was made in order to economize on cementing and ferro-concrete reinforcement, increase cement product's strength, increase life of constructions and intensify various technological processes. Nan et al [13] show that the compressive strength of concrete containing fly ash and prepared with magnetic water increases by (15-25%) more than that prepared with normal water.

2. Magnetic Water:

2.1 Introduction

More than one hundred relevant articles and reports are available in the open literature, so clearly magnetic water treatment has received some attention from the scientific community. The reported effects of magnetic water treatment are varied and often contradictory. In many cases, researchers report finding no significant magnetic treatment effect. In other cases, reasonable evidence for an effect is provided. The Australian Fluid Energy [14] mentions that the molecule groups of magnetic water differ from molecule groups of ordinary water in having lower degree of consolidation, and the molecules volume is more uniform. Joshi et al [15] proposed magnetic field effect on hydrogen bonds between water molecules and found some exchange which happened in the properties of water such as light absorption, surface tension and pH.

The activation of water treatment using magnetic field depends on three conditions according to Huchler et al [16]:

- Magnetic flux density.
- Duration of exposing water to magnetized field (velocity of water current).
- The amount of exposing water to the field.

Starmer [17] found that the magnetic treatment of water increased the ion solubility in the water, and pH. Kronenberg [18] reported that magnetic treatment changed the mode of calcium carbonate precipitation such that circular disc-shaped particles are formed rather than

the dendritic (branching or tree-like) particles observed in nontreated water. Chechel and Annenkova [19]; Martynova et al [20], have found that magnetic treatment affects the structure of subsequently precipitated solids, because scale formation involves precipitation and crystallization. These studies imply that magnetic water treatment is likely to have an effect on the formation of scale. Some researchers hypothesize that magnetic treatment affects the nature of hydrogen bonds between water molecules. They report changes in water properties such as light absorbance, surface tension, and pH (e.g., Joshi and Kamat [15]; Bruns et al.; Klassen [21]). However, these effects have not always been found by later investigators (Mirumyants et al [22]). Further, the characteristic relaxation time of hydrogen bonds between water molecules is estimated to be too fast and the applied magnetic field strengths too small for any such lasting effects, so it is unlikely that magnetic water treatment affects water molecules (Lipus et al [23]). Among those who report some type of direct magnetic-water-treatment effect, a consensus seems to be emerging that the effect results from the interaction of the applied magnetic field with surface charges of suspended particles (Donaldson [24]; Lipus et al [23]). Krylov et al [25] found that the electrical charges on calcium carbonate particles were significantly affected by the application of a magnetic field. Further, the magnitude of the change in particle charge increased as the strength of the applied magnetic field increased.

2.2 Methodology of generation magnetic field and its effect on water molecules:

2.2.1 Magnetic device:

Magnetic fields are produced by the motion of charged particles. For example, electrons flowing in a wire will produce a magnetic field surrounding the wire. The magnetic fields generated by moving electrons are used in many household appliances, automobiles, and industrial machines. One basic example is the electromagnet, which is constructed from many coils of wire wrapped around a central iron core. The magnetic field is present only when electrical current is passed through the wire coils.

Permanent magnets do not use an applied electrical current. Instead, the magnetic field of a permanent magnet results from the mutual alignment of the very small magnetic fields produced by each of the atoms in the magnet. These atomic-level magnetic fields result mostly from the spin and orbital movements of electrons. While many substances undergo alignment of the atomic-level fields in response to an applied magnetic field, only ferromagnetic materials retain the atomic-level alignment when the applied field is removed. Thus, all permanent magnets are composed of ferromagnetic materials. The most commonly used ferromagnetic elements are iron, cobalt, and nickel.

Fig.(1), shows the line of magnetic fields which is generated from the coil. The line inside the coil is distributed uniformly and this refers to uniform field, thus each field between rolls of the coil ignores others and the field out of the coil is so weak and not uniform, the increase in the length of coil leads to much more uniform magnetic field inside the coil.

The identified coil is obtained when the rolls are closed with each others and the length of the coil is much more than its radius, in this case the outer magnetic field will be so weak compared with the magnetic field inside the coil. The Ampere's role [26, 27] used to find the magnetic field inside the coil is as follows:

$$\beta = \mu_{\circ} \frac{N \times I}{L} \qquad \ldots(1)$$

Where:

β : magnetic field, measured in teslas

μ_o :magnetic constant(known as the permeability of vacuum)has the exact value($4\pi*10^{-7}$ N/A^2, (Newton per ampere squared, or in henrys per meter) in SI units).

N : total number of rolls in coil (non dimensional).

I : current in wire, measured in amperes

L : length of the coil , measured in meter.

The strength of a magnet is given by its magnetic flux density, which is measured in unit of gauss, (1 gauss = 10^{-4} teslas = 100 microteslas (μT)), the strength of the magnet which is used in the present study was (1.2)Tesla, and in SI units of tesla, 1 T = 1 $kg \cdot s^{-2} \cdot A^{-1}$. An equivalent, but older, unit for 1 Tesla is Weber/m^2.

2.2.2 Chemical Molecule Figure of Magnetic Water:

A substance is said to be *magnetized* when its constituent molecules or structural elements can be aligned in a definite direction by the influence of an external magnetic field. In a liquid or in a gas, this can only happen to molecules that possess an odd number of electrons. Water, H_2O, contains 10 electrons, so it is not attracted to or oriented by a magnet. In fact, water, like most molecules, is *diamagnetic*; it is actually *repelled* by a magnet, although so weakly that sensitive instruments are needed to observe this effect. Fig.(2) shows structural group of water molecules. Fig.(3) shows water molecules which consiste of one oxygen molecule and two hydrogen molecules bonded as an isolated triangle with its upper angle is 105°. Generally,

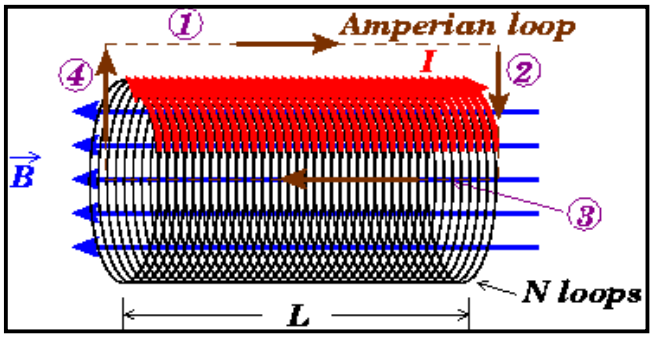

Fig.(1): Magnetic field generator [27]

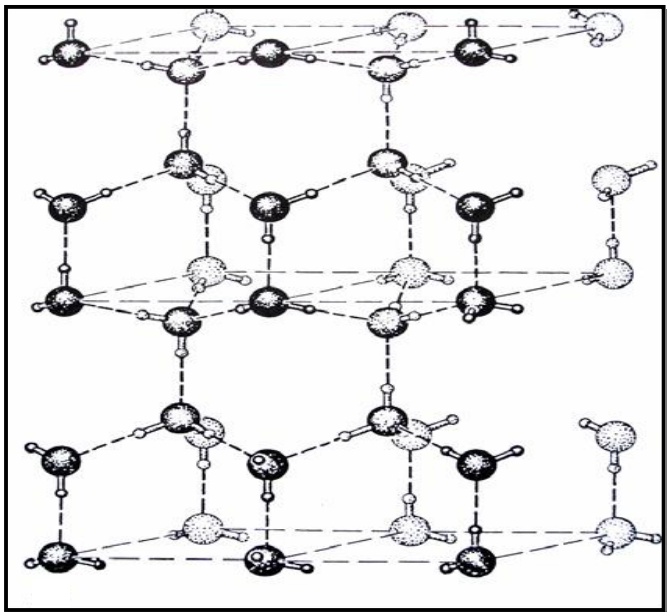

Fig.(2): Structural groups of water

when water is subjected to a magnetic field, the water molecules will arrange in one direction as shown in Fig.(4). This mode of arrangement is caused by relaxation bonds, then the bond angle decreases to less than 105º [14], leading to a decrease in the consolidation degree between water molecules, and increase in size of molecules. For these reasons, the viscosity of magnetic water is less than viscosity of normal water. This change in water molecules composite causes a change in permeability pressure, surface tension, pH and electric conduction.

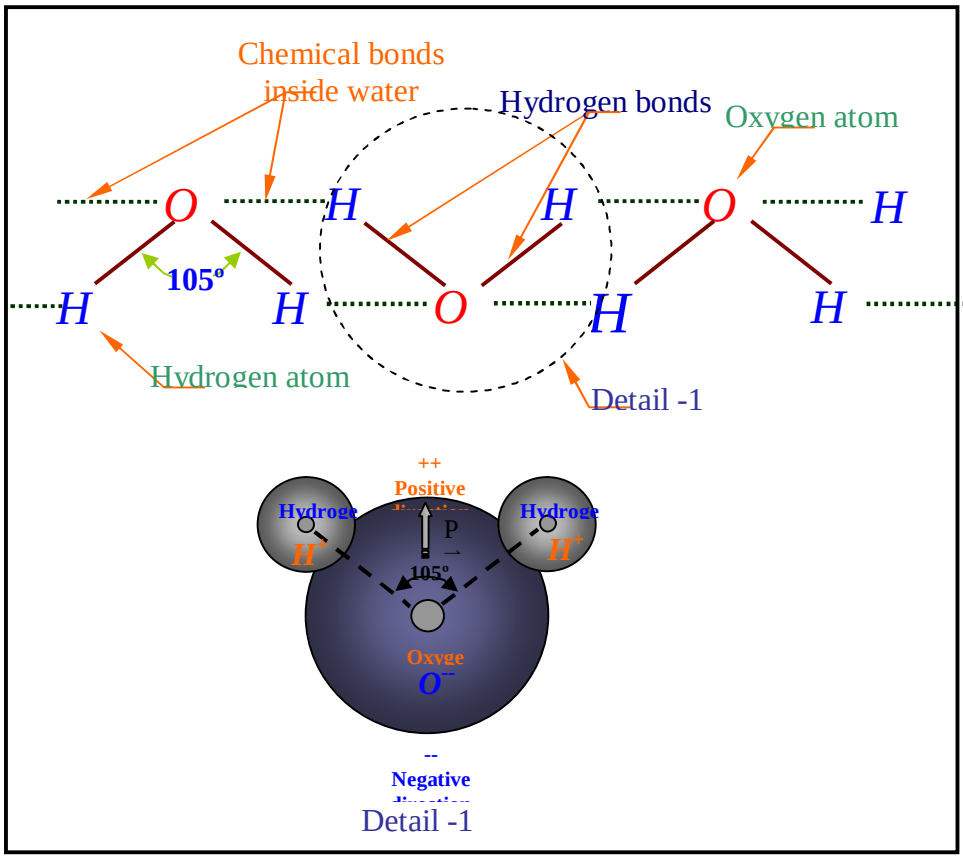

Fig.(3): Water Molecule [14]

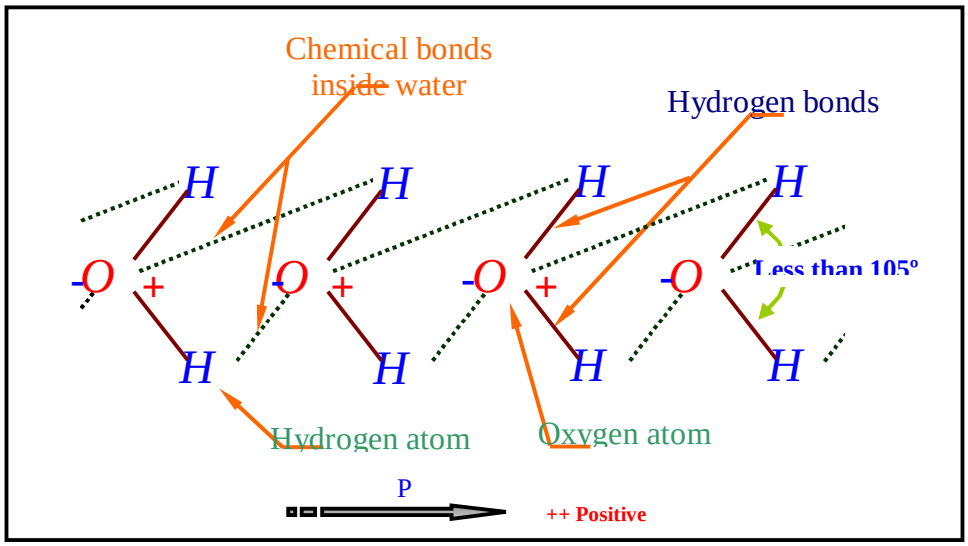

Fig.(4): Directional arrangement of water Molecule under effect of

3. Experimental work:

3.1: Materials:

Cement: the cement used throughout this work was ordinary Portland cement (O.P.C) produced by ***Adana Cement Factory***, the physical test results of the used cement are given in Table (1). It conforms to the Iraqi Specifications No.5, (1984) [28].

Fine aggregate (sand): sand was river sand from ***Kanhash*** region, which had black appearance, its grading was within ASTM specification C33 [29], and measured bulk specific gravity was 2.65 and fineness modulus of 2.75. The weights of the fine aggregate are based on material in the saturated surface dry condition, in which, as the description implies, the fine aggregate is fully saturated but has no water on the exterior of the particles.

Coarse aggregate (gravel): Natural uncrushed gravel (local river gravel from Mosul region) was used and its grading was within ASTM specification C33 [29]. The bulk specific gravity based on material in the saturated surface dry condition was 2.70, and fineness modulus of 3.20.

Water: water is needed for the chemical process (hydration) in which the cement powder sets and hardens into one solid mass. For normal concretes, the water-cement ratio is generally in the range of about (0.4-0.6) [30], drinking water from Mosul water supply is used throughout the research for both magnetic and normal water case.

3.2: Mixing procedure:

It is customary to define the proportions of a concrete mix in terms of the total weight of each component needed to make up 1 m^3 of wet concrete, such as 400kg of cement, 170kg of water, 700kg of sand, and 1200kg of coarse aggregate, plus the total volume of air, in percent. A trial- batch method [31] used to obtain mixes of the desired properties from the cements and aggregates at hand, produced from several small trial batches with varying amounts of aggregate to obtain the required strength.

Table (1): Physical properties of cement.

Physical Properties of cement		Test result	Limit of I.S.,No.5
Setting time Vicat's method	Initial setting (hour)	3.0 hour	≥ 1.0 hour
	Final setting (hour)	4.5 hour	≤10.0 hour
Soundness (%)		0.8	≤0.8
Compressive strength of mortar(MPa)	3-days	27.5 MPa	≥15.0 MPa
	7-days	37.2 MPa	≥23.0 MPa

3.3: Testing:

Concrete consistency (workability): Concrete consistency is most frequently measured by the slump test. The slump is a good measure of the total water content in the mix. The slump of each groups of concrete mixes was carried out according to **BS** 1881: part 2 (1970). Results of the tested mixes are summarized in Tables (3), and (4).

Compressive strength: All the samples were standard cubic specimens (150*150*150mm) in accordance with **BS**, and tested immediately after removing from water, compressive strength of each group of concrete was carried out according to **BS** 1881[32]. The compressive strength was taken as the average value of three specimens. Results of the tested specimens are summarized in Tables (3), and (4).

3.4: Mix proportions:

- In the present study, to find the effect of current velocity and time treatment of water on the compressive strength and consistency of concrete, then to find the optimum characteristic of water treatment, 7-type of mixes were prepared, these mixes are (N, M1, M2, M3, M4, M5, and M6), mix-N is the normal concrete which is prepared with normal water, (M1, M2, M3, M4, M5, and M6) are the normal concrete prepared with magnetic water which is prepared by exposing water to magnetic field strength about (12,000 gauss) with velocities equal to 1.27, 0.71, 0.42, 0.32, 0.25, and 0.20 m/s respectively, the time of treatment is shown in Table (3). All the mixes had mix proportions of about (400 kg) of cement, (180 kg) of water, (700 kg) of fine aggregate, and (1110 kg) of coarse aggregate (1:1.75:2.775/0.45 –by weight), the samples are tested at the age of 7-days, the tested specimens are summarized in Table (3).

- Trial mixes are prepared to find the effect of magnetic water on the compressive strength and consistency of concrete with mixes proportions (1:1.75:2.775/0.45, mix-NA), (1:1.60:2.0/0.56, mix-NB), and (1:1.75:3.0/0.425, mix-NC), by weights, prepared first of all with normal water. The same mixes are also prepared with magnetic water at optimum discharge, velocity, and magnetization time of water (magnetic strength about 1.2 Tesla and treatment time is of 4.5 sec./liter) to produce mix-MA, mix-MB, and MC. Table (2) summarizes the details of these mixes and the samples are tested at the age of 7- and 28-days. Results of the tested specimens are summarized in Table (4).

Table (2): Details and Properties of the Tested Specimens

Specimen	Weight in kg/m^3				w/c by weight	Type of water
	cement	sand	gravel	water		
NA	400	700	1110	180	0.45	tap water
MA	400	700	1110	180	0.45	Magnetic
NB	405	720	900	225	0.56	tap water
MB	405	720	900	225	0.56	Magnetic
NC	400	700	1200	170	0.425	tap water
MC	400	700	1200	170	0.425	Magnetic

4. Results and discussion

4.1: Effect of water flow ,velocity, and time treatment on compressive strength and consistency of concrete:

The results show that the concrete prepared with magnetic water (M1, M2, M3, M4, M5, and M6) has a compressive strength higher than that of the mix with normal water (mix-N), although the same mix proportions are used for all mixes, the increase in compressive strength depends on velocity of water current that passes through magnetic field, as shown in Fig.(5), Fig.(6) and Table (3). The best performance increase of sample is achieved when the velocity of current is of (0.71 m/s) and discharge of water that passes through the field about

(0.22 liter/sec.). Fig.(7) shows that the compressive strength depends also on the time of treatment of water that is used in the mixture, and the best time of water treatment in magnetic field is (4.5 sec./liter),

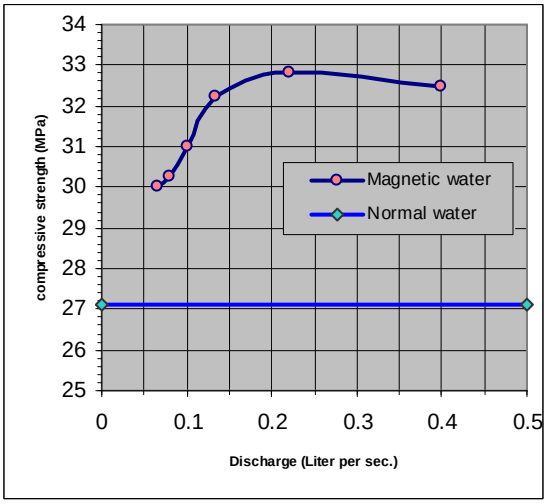

Fig.(5): Relationship between compressive strength and discharge of water.

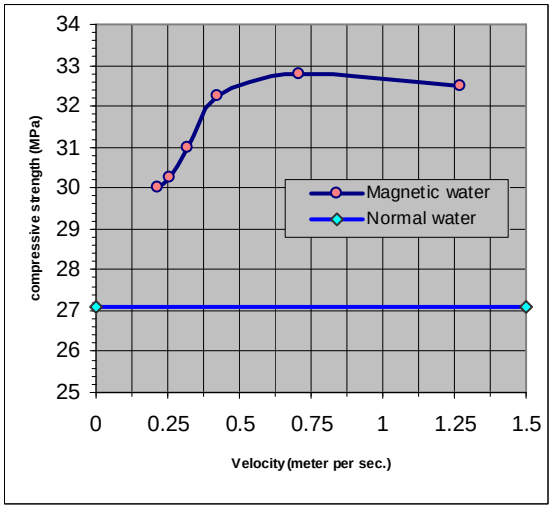

Fig.(6): Relationship between compressive strength and velocity of water.

Table (3): Result of the Tested Specimens

Specimen	Treatment time Sec./Liter	Velocity of current Meter/Sec.	Slump mm	Average compressive strength (MPa), at 7-day	Percent increase %
N	Tap water	-	20	27.10	
M1	2.5	1.27	55	32.50	20%
M2	4.5	0.71	65	32.80	21%
M3	7.5	0.42	50	32.50	20%
M4	10.0	0.32	45	31.00	14.4%
M5	12.5	0.25	40	30.25	11.6%
M6	15.0	0.20	40	30.00	10.7%

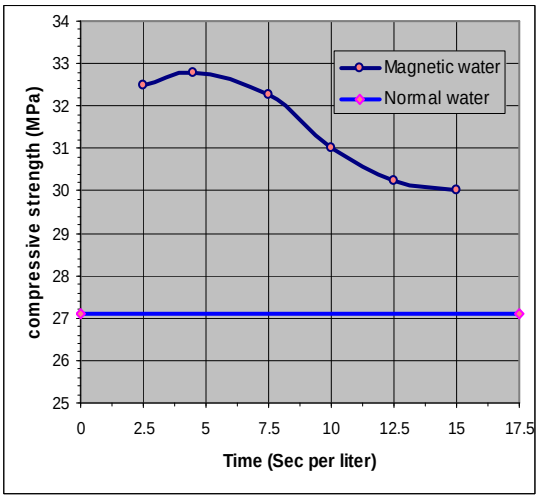

Fig.(7): Relationship between compressive strength and magnetization time.

although the increase in compressive strength is observed, the workability (consistency) of fresh concrete also increases significantly for all magnetic mixes specially in mix-M2 from the mix-N that is prepared with normal water and same condition, which means that the consistency of fresh concrete is enhanced also when using magnetic water.

4.2: Effect of magnetic water on both compressive strength and consistency:

The three trial mixes MA, MB, and MC, that were prepared using magnetic water which came from treatment water at velocity (0.71 m/s), and water treatment time about (4.5 sec/litter).Table (4) shows that the compressive strength increased (10-20%) when using magnetic water as compared to those prepared by ordinary water.

Table (4): Result of the Tested Specimens

Specimen	Slump mm	Average compressive strength (MPa) at 7-day / 28-day	Percent increase at 7-day/28-day
NA	20	27.10 / 47.3	21% / 13%
MA	65	32.80 / 53.4	
NB	75	21.10 /36.1	13% / 10%
MB	115	23.90/39.7	
NC	10	28.7/48.6	16% / 14%
MC	35	33.4/55.5	

It can be explained by the fact that a more homogeneous lattice of new formations of hydrated cement minerals is developed when mixed with magnetized water.

Increased compressive strength of concrete by this process leads to an extra effect of saving cement, additives and thermal energy when magnetized water is used in concrete, for which compressive strength is vital. Even when compressive strength is the main factor for concrete, statistically relevant confirmation of increasing cement's plasticity when it is prepared using magnetic water. Plasticity levels depend on the qualities of cement glue and since magnetic treatment influences glue's qualities, then the level of concrete's plasticity changes, as shown in Fig.(8), when using magnetic water for kneading of cement.

-A-
Concrete prepared using normal water (mix-NA)

-B-
Concrete prepared using magnetized water (mix-MA)

Fig. (8): Change in the plasticity level in fresh concrete.

4. Conclusions:

- The strength of concrete prepared with magnetized water increased by 10 to 20 percent, when the magnetic flux density was (1.2 Tesla).
- The use of magnetic water increased workability and strength, it's a good phenomenon, since conventional increase in workability by adding water leads to a decrease in strength of concrete.
- The velocity of water current about (0.71m/s) and time treatment of (4.5 sec./liter) are the best characteristic treatment of water which is more suitable for preparing fresh concrete.

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