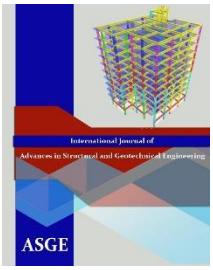

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EFFECT OF USING MAGNETIC WATER ON PROPERTIES OF PORTLAND CEMENT CONCRETE- A REVIEW

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ABSTRACT

This article review discusses the importance of magnetic water and its usage in Portland cement concrete. The role, mechanism and applications of magnetic water are presented in this article. Also, the effect of magnetic water on fresh properties, hardened properties, durability and microstructure of Portland cement concrete is reviewed and discussed as well. The results showed enhancements in all-desired characteristics. So, using magnetic water in the field of concrete industry seems to be promising.

Keywords: Magnetic Water, Magnets, Fresh Properties, Hardened Properties.

Contents

1. INTRODUCTION

Concrete is one of the most important materials in the construction industry at all, due to its characteristic properties and features that make it one of the first choices for designers [1,2]. These features are: suitable for use, easy maintenance, long life and cheap manufacturing costs compared to other construction materials. On the other hand concrete has some disadvantages including low tensile strength and different dimension changes [1,3]. Therefore, there is a need to improve properties, get rid of defects in concrete and to new special types of it [4,5].

In fact, There is a lot of research works dealing with the treatment of some disadvantages within the concrete and the improvement of properties as well [6,7]. By observing that most properties are affected by concrete compressive strength, it was necessary to pay attention to its increase as it significantly affects the other qualities [8]. Several methods have been used to do this; for example, to treat low tensile strength, fibers have been used. The fibers have clearly enhanced the concrete ductility [9]. Pozzolanic materials such as silica fume, slag and fly ash have also been used to increase concrete strength by up to 20% [10-12]. In addition, the chemical admixtures were used for this purpose due to ACI Manual of concrete practice [13,14]. These previous methods were not only expensive but also hostile to the environment. Therefore, scientists are looking for approaches that are economic, eco-friendly and of course achieving the same advantages (i.e. by looking at the basic components of concrete, particularly water) [15].

As mentioned above, water is one of the main ingredients of concrete because it is involved in the chemical reaction of cement [2,3]. The water governs the hydration, the workability, the microstructure, the durability of the concrete and its complete behavior (showed in Figure1) [3]. As water is used in the hydration process, it is also used in the curing [1-3]. In addition, the water used in the concrete industry should be clean and free of impurities, oils and salts that may harm concrete [1,3]. Therefore, the scientists pay attention to treat water in magnetic field to enhance its role in concrete either in mixing or curing [16-35].So, the influence of using magnetic water on properties of concrete is addressed in this review.

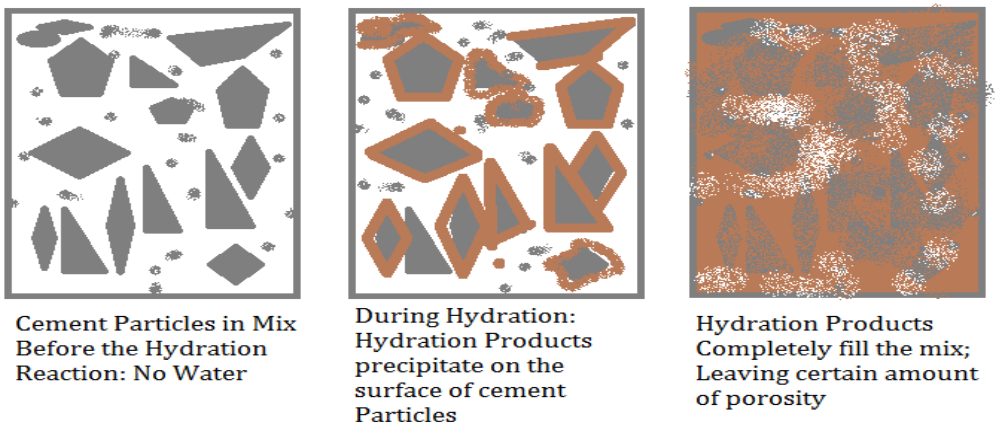


Fig. (1) Hydration process of cement particles in concrete[3]

2. MAGNETIC WATER

2.1. Definition of Magnetic Water

Magnetic water (MW) does not mean that it has a magnetic force that can attract things [18,19]. But can be considered as water that has been subjected to a magnetic field long enough (24 hours) and under certain circumstances changed its various properties [19,20]. In general, when water is subjected to magnetization, there is a decrease in surface tension [21,22]. Magnetized water can therefore be used to improve concrete properties. The reason why MW can improve the characteristics of concrete can be explained by the molecular structure of water (Figure2) [8,22].

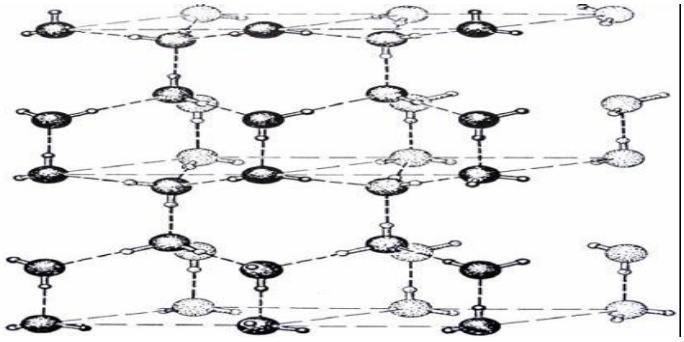


Fig. (2) Structural groups of water [8]

2.2. Mechanism of Magnetization

Water as a material varies greatly on Nano-scale as it is a polar substance. It tends to present in form of clusters of water molecules that are bound together by hydrogen bonds. Clusters are always in equilibrium. The cluster contains about 100 molecules at room temperature. If the water is affected by an external effect, for example the magnetic field, the hydrogen bonds are broken and the angle of the bond decreases [19].

It is believed that after applying a strong magnetic field, water will show diamagnetism. Diamagnetism refers to substances that are magnetized in a way opposite to the direction of magnetic field, having pair-up electrons which cancel each other's magnetic moment because the two electrons in a pair-up rotate opposite to each other. As a result, water molecules are 'directed' to have certain orientation as shown in Figure 3 [19].

Since water molecules are fixed in orientation, they are restricted to form water clusters due to chances of reducing matched orientation of water molecules in a cluster. Hydrogen bonds' association percentage will decrease. In other words, larger water clusters are cut and broken down by external magnetic field to form smaller water clusters or double water molecules [(H_2O) 2] or even single water molecule (H_2O). It's also stated that by light spectrum, the bond angle decreases from 104.5° to 103° because magnetic field deflects the bond pairs and squeezes the bond pairs to be closer together (Figure 4) [19].

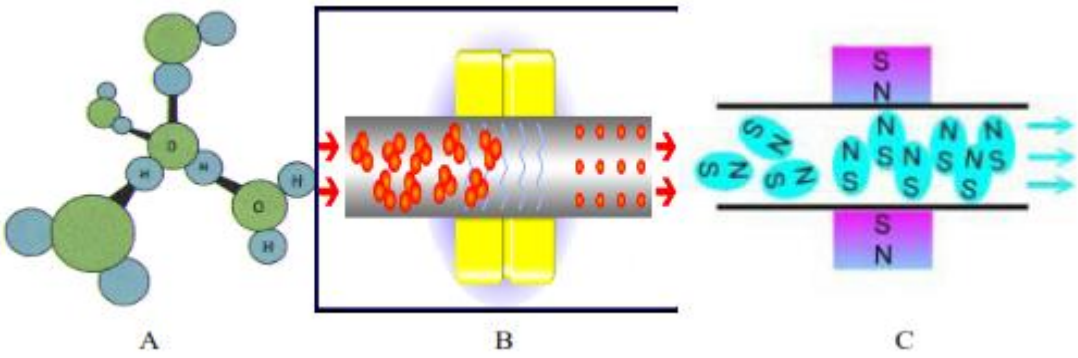


Fig. (3) Mechanism of magnetic water: A. water cluster; B. breakage of cluster; C. orientation[19]

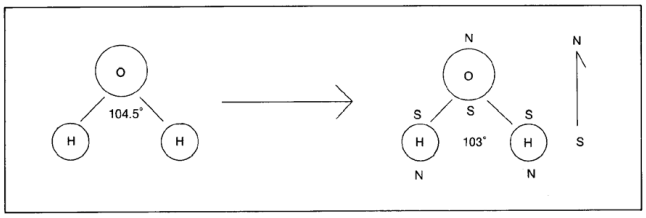
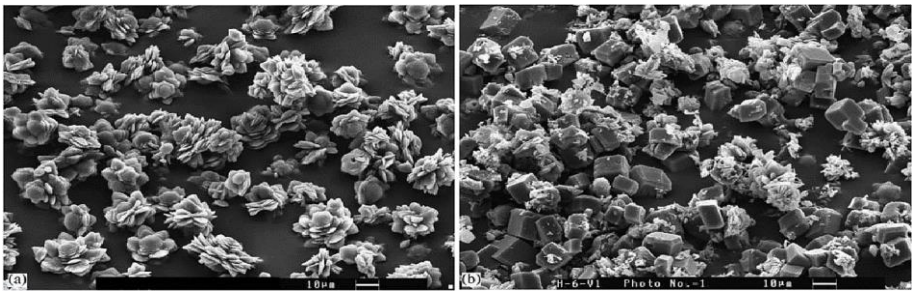


Fig. (4) The decrease in bond angle in water molecule exposed to magnetic field[19]

2.3. Effect of Magnetization

Recently, the aspect of magnetized water has been studied and a lot of researches have been carried out to determine its effect in various fields. Some scientists have reported that there is a direct effect on water properties such as light absorption and PH [21,22]. The extent of change in these properties depends on many factors such as magnetic field strength measured in Tesla, duration of water exposure to the magnetic field (velocity of water flow through the field) and amount of water exposed to the field [21,22].

The effect results from the interaction of the applied magnetic field with surface charges of suspended particles. It's found that the electrical charges on calcium carbonate particles were significantly affected by the application of a magnetic field as shown in Figure 5 [21,22].



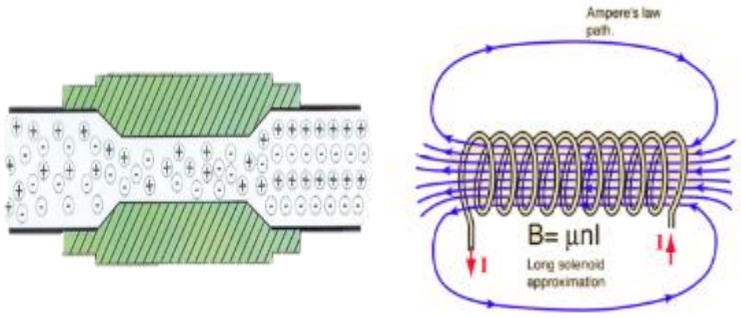
A B

Fig. (5) SEM images of calcium carbonate crystals obtained by homogeneous precipitation and filtration: A. non-MW, vaterite crystals; B. MW, calcite and vaterite transformed into aragonite [22]

2.4. Methods of Magnetization

As previously explained, magnetization of water is carried out by passing water through a magnetic field [23,24].
There are two basic ways to generate a magnetic field [25]:
(1) Using permanent magnets
(2) Using electro-magnets

The first is to use a permanent magnet, creating a permanent magnetic field that results from the mutual alignment of the very small magnetic fields produced by each of the atoms in the magnet [8,26]. These atomic-level magnetic fields result mostly from the spin and orbital movements of electrons [26]. This method reveals a steady stable magnetic field and no need for energy but it couldn't be intensity varied [26]. On the other hand, the second method is to use electromagnets [27]. Here, magnetic field is produced by the motion of charged particles [27]. It's constructed from many coils of wire wrapped around a central iron core. Of course, No electricity tends to magnetic field with intensity zero but It's a method provides various intensities using energy [27].Both permanent and electro-magnets are shown in Figure 6.



A B

Fig. (6) Effect of: A. permanent; B. electro magnets[27]

3. EFFECT OF USING MAGNETIC WATER ON PROPERTIES OF PORTLAND CEMENT CONCRETE

While hydration of cement particles is in progress, the MW can penetrate the core region of cement particles more easily [28]. Hence, hydration can be done more efficiently which in turn improves concrete strength [28]. When cement particles are surrounded by MW of same electrical charges, these particles will repel each other and thus disperse cement clusters which facilitates the flow of entrapped mixing water [29]. In addition, when hydration takes place, it forms hydration layer on the cement exterior [29]. As magnetized water molecules are rather dispersed or of small clusters, they can penetrate through the hydration layer more easily and therefore, hydration is more complete [28,29].

The magnetized water can be kept in a reservoir for 0–12 h, over this range, its advantage may be lost [17,28]. So it should be used during that period to make the following effects on the fresh concrete properties and hardened ones as well [28,29].

3.1. Effect on Fresh Concrete Properties

Concrete is checked for workability (the most important fresh property) by slump test [1,2]. According to Bharath et al., 2016 [20] the use of magnetized water improves the workability (slump) of concrete containing copper slag up to 50% over control mix due to low water absorption of copper slag and dispersion effect of magnetized .water Hence, 10-12% of water

content could be reduced without compromising the workability of the concrete [30]. Research papers revealed a slight change in workability for slump test it was about 10% and for compacting factor test it was almost the same [30]. Magnetic strength has a positive effect on fluidity. the fluidity of fresh mortar prepared with magnetic water is higher than that mixed with tap water that was investigated by Nan Su et al.,2000 [29]. he observed that the increase in fluidity was about 10%.

Gholhaki et al.,2018 [12] reported that the use of magnetized water instead of regular tap water can improve the flow ability and viscosity of self-compacting concrete (SCC). A study was carried out by Esfahani et al.,2018 [31] on cement pastes after mixing and casting in a controlled environment. For this particular study, samples were cured in wet conditions and revealed that the rate of hydration as well as setting time were accelerated and the heat of hydration was increased with respect to the samples not subjected to magnetic field [31]. In addition, Gholizadeh and Arabshahi .,2011 [32] found a great change in slump values as shown in Figure 7.

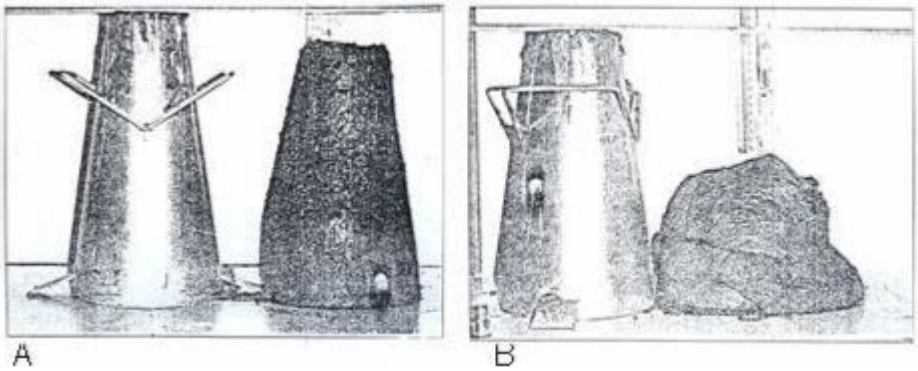


Fig. (7) Subsidence rate of samples in slump experiment, A. made by ordinary water; B. made by magnetic water [32]

3.2. Effect on The Hardened Concrete Properties

3.2.1. Mechanical properties

The test was carried on three different grades of concrete which were M25, M30, and M35. It was found that magnetized water increased the compressive strength of concrete up to 14% according to Sagar and Jawalkar.,2018 [25]. Self-compacting concrete mixture containing magnetic water and 20% of silica fume can be considered as an optimum mix design at the age of 28 days where compressive strength and splitting tensile strength increased by 49% and 41%, respectively(Gholhaki et al.,2018) [12]. Results showed that the compressive strength of mortar samples mixed with magnetic water of 0.8-1.35 Tesla increased by 9-19% more than those mixed with tap water. Similarly, the compressive strength of concrete prepared with magnetic water increased by 10-23% more than that of the tap water samples (Nan Su. et al.,2000) [29].

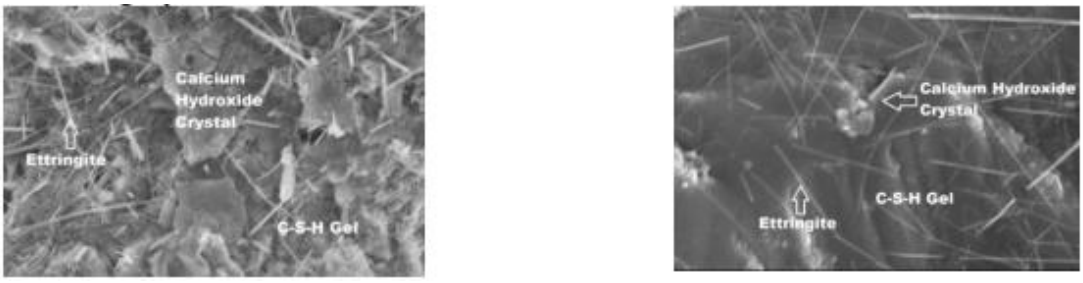
The mechanical performance of concrete showed an improvement due to using magnetized water instead of regular tap water: relative to the control mix, an average improvement of 12.5%, 13%,and 9% after 28 days of water curing was registered for the compressive, splitting tensile, and flexural strengths respectively (Ghorbani and Gholzadeh.,2018) [34]. Compressive strength has increased by 10% with the use of magnetized water (Taghried et al.,2017) [33]. Afshin et al.,2010 [35] determined that, with the compressive strength, cement content could be reduced by 28% in the case of magnetic concrete. These improved properties of concrete can be obtained without the use of any chemical admixtures which avoids environmental pollution.

3.2.2. Durability

When sulfuric acid reacts with the hydration products, dissolution of the hydrated composites and hydrogen ions occurs. The higher resistance of specimens with magnetized water to acid attack may be attributed to the reduction of pores in the structure of the specimens with magnetized water, as a result of their greater density and higher degree of hydration. These differences explain why the magnetized water can increase the durability properties of concrete mixes (Ghorbani and Gholzadeh.,2018) [34].

3.2.3. Microstructure

The engineering properties of concrete with (85Cement+15Copper Slag) was the higher. Therefore, That mix was observed under scanning electron microscope after 28 days of curing. Figure 8 (a) and (b) show the Scanning Electron Microscope (SEM) image of concrete prepared with tap water and magnetized water, respectively. It was observed that large amount of C-S-H was found in magnetized water in comparison with tap water. It was also observed that larger calcium hydroxide Ca(OH)2 crystals were present in concrete prepared with tap water. However, Ca(OH)2 crystals were smaller and separated in the concrete prepared with magnetized water as cement reacts with the smaller molecules of magnetized water more easily resulting in faster and complete formation of C-S-H. This could be the reason for the increase in strength parameters of Magnetic Water Concrete.(Bharath et al.,2016)[20].



A B

Fig. (8) A. Microstructure of Tap water concrete at 5000X; B. Microstructure of Magnetic water concrete at 5000X

4. Conclusions

Based on the above discussions, the following conclusions could be drawn:

- Magnetized water is the water that has been subjected to a magnetic field for an appropriate period until changes have occurred in some of its properties such as low surface tension, increased viscosity and PH.
- Treating water in magnetic field results in reduction in the surface tension of water provides the breakage of large water clusters into smaller water clusters. This leads to the change in the trajectory of water particles providing much better bonding between the other materials added to the water.
- Permanent Magnets are better in magnetic field stability while the electromagnets are better in various intensities .
- There is an enhancement of workability and fluid ability
- The compressive, splitting tensile, and flexural strengths of all portland cement mixes increased, as expected. However, the rate of increase varies for different mixes.
- The mass loss showed that magnetized water had a positive effect on the resistance to sulfuric attack.
- The SEM images showed that using magnetized water instead of regular tap water led to a significant improvement of the microstructure of the corresponding concrete mixes and resulted in denser microstructure.

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