International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 05 Issue: 07 | July - 2021 ISSN: 2582-3930

A Review on the Influence of Magnetized Water on the Properties of Concrete

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Abstract - An important encounter for concrete technologists is to enhance the properties of concrete. In the past two decades, Russia and China used a new technology called magnetized water technology in the concrete industry. Magnetized water has been used in various fields like agriculture, medical care, construction, dairy production, and petroleum industries. In this technology, the water is passed through a magnetic field, and as a result, the number of molecules in the water cluster decreases. By the application of a magnetic field, the surface tension of water decreases, and its pH value increases. This study involves the procedure for the preparation of magnetized water, characteristics of magnetized water, and the influence of magnetized water on concrete properties.

Key Words: Magnetized water, Concrete, Concrete properties.

1. INTRODUCTION

Concrete is the most widely used building material because of its versatility and relatively low cost. Water content in conventional concrete has a significant impact on its engineering properties such as strength. When water flows through a magnetic field at a constant speed, it becomes magnetized and is known as magnetized water. Magnetization increases negative ionic hydration, thus escalating the detrimental effect on the water crystal structure. In the mixing of water and cement, a hydration reaction will first take place on the surface of the cement particles. A lean layer of hydration products is thus formed on the cement particles, which hinders further hydration and thus avoiding the development of strength of the concrete. But, if magnetic water is used instead, water molecules can easily penetrate the cement particles, allowing a more complete hydration process to occur and enhancing the strength of concrete. The important issue of optimizing water use in concrete structures is raised. The use of magnetized water can save the water consumption of concrete structures. Adding chemicals and admixtures while mixing alters its properties thus obtaining concrete with the desired property. Strength additives are not easily available in rural areas, and the cost of large-scale projects will be higher. Magnetized water treatment is a proposed method of reducing the effects of hard water and increase in strength. Magnetized water does not mean that the water has acquired magnetism, but that it has been exposed to a magnetic field. This field changes certain properties of concrete. These unique properties of water will cause many changes in its macroscopic properties.

2. TECHNIQUE FOR MAGNETIZED WATER

2.1. Magnetized Water

When water passes through a magnetic field, it is called magnetized water. The level of magnetization is determined by the method used and the purity of water. The structure of water arranges itself according to the intensity of magnetization in one direction, and the size of the molecules changes, and hence the hydration rate increases. Stronger hydrogen bonds will lead to higher viscosity, and this bond will break after magnetization. Fig. 1(a) demonstrates the water molecule's arrangement at ordinary temperature. Water molecules tend to form hydrogen bonding groups, which are destroyed when a magnetic field is applied, as shown in Fig. 1(b), which increases the activity of water. The true mechanism remains to be solved since many phenomena in liquid states have not been reasonably explained [1].

Fig -1: (a) Water molecules before magnetization; (b) Water Molecules after magnetization

The effect of the magnetic field on the water molecules is schematically shown in Figure 2.

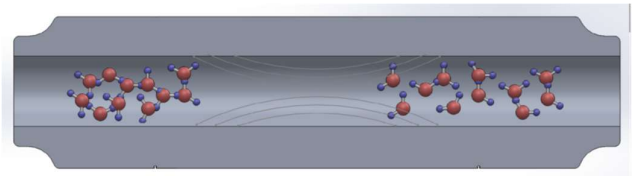

Fig -2: Effect of Magnetic Field in Water Molecule Clusters [1].

2.2. Magnetic Treatment of Water

The water is circulated for one hour to induce a magnetic field in the water by the applied magnetic field. This recirculated water is used to cast concrete. The arrangement to achieve the above-mentioned process includes Autotransformer, Permag

N406, and a 0.5 HP motor. The autotransformer is used to reduce the power supply voltage of the motor and regulate the water flow in the system. This process reduces the hardness of the water and improves the corrosion resistance of the steel bars [1].

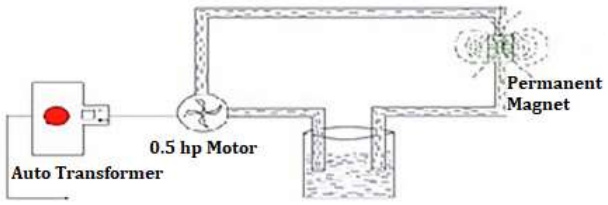

Fig -3: Schematic Design of Magnetic Treatment of Water [1].

2.3. Description of the setup

The recirculation configuration shown in the figure above consists of the motor (0.5 HP) that performs the action of lifting water from the container and then make the water pass through the magnetic field which is produced by a permanent magnet fixed around the tube as shown in Fig -3. The process of removing water from the container and passing the water through the magnetic flux is repeated over a while. The effect of flux induction will be more in water so that the hardness in water reduces more on continuous passage of water through the magnetic field. It is also demonstrated in the literature that the flow velocity should be in a range of 0.6 – 1.0 m/s. The autotransformer is used to keep the flow velocity within the range specified [1].

2.4. Magnetized water Mechanism

Water, as a diamagnetic material, has a mass magnetic susceptibility of approximately -7.20×10^{-3} JT^{-2}/kg. Pure water as a dipolar and associative liquid can modify its intermolecular bonds under the application of a magnetic field and transform to a metastable state. The magnetic field affects the physical and chemical processes of the crystallization and dissolution of water molecules. There are two main types of magnetic field effects. The direct field affects the biochemical reaction, and the indirect field affects the environment. In the first type of magnetic field, the concern might be the possible genetic effects on living organisms. However, the second magnetic field may produce secondary effects such as pressure, temperature, or mechanical stirring [18].

There are three proposed mechanisms of action of magnetic field on water. The first hypothesis assumes that the spontaneous formation and decay of colloidal complexes of metal cations occurs in magnetized water, which accelerates their successive sedimentation. The second hypothesis is the polarization of ions dissolved in water and the deformation of the hydrated layer under the influence of a magnetic field. According to the third hypothesis, the magnetic field influences the structure of water directly, due to the dipole polarization of water molecules. Water molecules are bound together via low-energy intermolecular Van der Waals forces, hydrogen bonding, and dipole-dipole interactions. The magnetic field might deform the hydrogen bonds and cause some partial separation[17].

Producing a weaker hydrogen bond in the magnetic field is also associated with the Lorentz force, which makes the positive and negative ions rotate oppositely, thus increasing the possibility of ion collision. The movement of molecules becomes stronger, its thermal motion upsurges and the hydrogen bonding becomes weaker. Therefore, as the magnetization time increases, weaker hydrogen bonds are obtained [19].

Based on the theory of magnetization of water, the variation of the magnetization effect of water increases with increasing exposure time (in fixed magnetic field strength at 3000 Gauss) and magnetic field strength. This can reach saturation at a higher magnetic field strength as shown in Fig -4 [17].

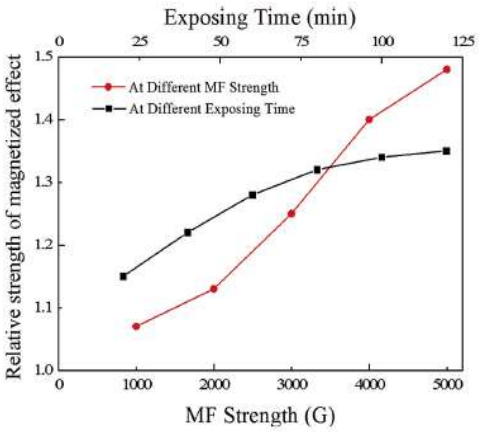

Fig -4: Magnetized effect of water with increasing exposure time and magnetic field strength [17].

In contrast to the third hypothesis, the hydrogen bond has greater stability in a magnetic field that can be increased. As the diamagnetism of a molecule relies on the level of the electron distribution, the electron delocalization of hydrogen-bonded molecules must rise its diamagnetism. Therefore, the hydrogen bond should become more stable under a magnetic field, which is the main reason for some fluctuations in the properties of water [17].

3. FEATURES OF MAGNETIZED WATER

3.1 Surface Tension

For preparing magnetized water, two fixed magnetic fields (3000 and 5000 G) were applied to distilled and tap water with various exposure time and measured their surface tension. The results discovered a sharp decrease until 5 min, after which they were almost saturated as shown in Fig -5. The general trend of a decrease in surface tension with the increasing magnetic field is due to the attractive force among water molecules due to the applied magnetic field. This is because of the improved polarized effect and the variations in the distribution of molecules in magnetized water. An increase in the intensity of the magnetic field causes a decrease in the surface tension of tested water samples, which reduces the capillary rise of water [17].

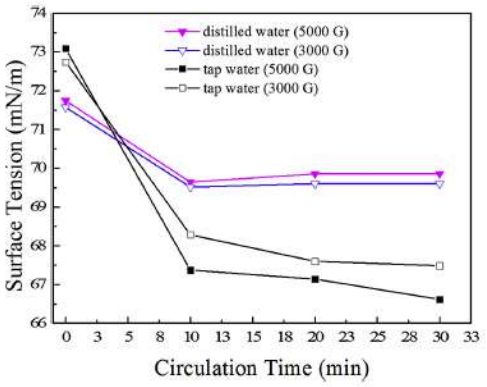

Fig -5: Surface tension of water at different magnetic field and different recirculation time for distilled water and tap water [17].

3.2 Electrical Conductivity

Electrical Conductivity [EC] is the capability of a material to conduct electricity. Fig -7 shows the change in electrical conductivity for different magnetic field intensities at a flow rate of 1000 l/h. The EC depends on the ion content. It is observed that decreasing of Ca ions with increasing intensity of magnetic field causes an increase in the EC [18].

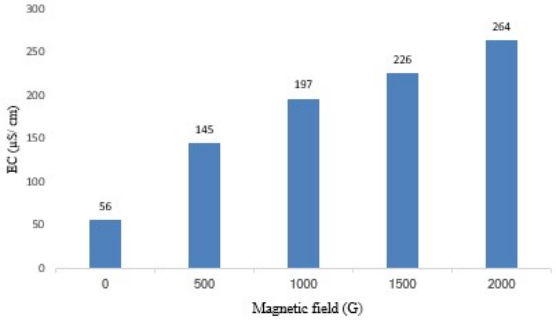

Fig -6: EC v/s Magnetic field intensity [18]

3.3 pH

The increase in pH with increasing magnet exposure time was due to the reduction in hydrogen ion concentration, while the increase in pH with increasing magnetic field strength for distilled water was attributed to the polarization of water molecules and because the water molecules will assemble in one direction with reducing hydrogen ion concentration [17].

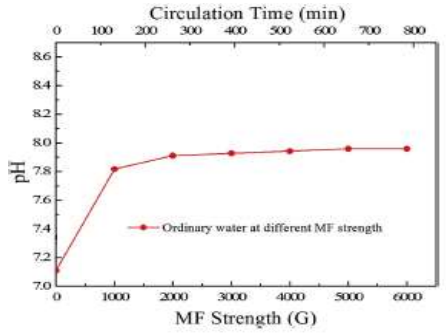

Fig -7: pH variation of ordinary water with increasing magnetic field strength and circulation time [17].

4. IMPACT ON THE PROPERTIES OF CONCRETE WITH MAGNETIZED WATER

There have been many studies on the effect of magnetized water on the properties of cement paste and concrete. After mixing and pouring in a controlled environment, the cement slurry is subjected to three different magnetic treatments. In this study, the samples were cured in a humid environment, and the results showed that the hydration rate and the and setting time were accelerated and the heat of hydration was increased concerning the samples not subjected to magnetic field [2]. Tests conducted on pumping circuits of length 1000 m and diameter of 125 mm showed that this procedure enhanced concrete pump ability due to the change in the lubricant layer properties between the interface of the concrete and the pipe wall. The thickness of this layer was measured using an ultrasonic velocity profiler [3].

The slump was observed increasing especially with higher cement contents up to 450 kg when mixing water was magnetized for 15 minutes with the water flowing with a rate of 2.26 litre/min [4]. This result is not affected by the addition of fly ash in the form of cement in different proportions up to 25%, while the water-cement ratio remains unchanged [5]. Since the magnetized water penetrates the cement particles more easily, the workability is improved due to the weakening of the bond between unipolar molecules (O_2 and H+) and water molecules [7]. A study conducted on concrete mixes with magnetized tap water and magnetized distilled water recommended that exposing the water to the north pole or south pole of a magnetic field for 24 hours gives a slightly diverse result of the slump with no difference between tap and distilled water. No segregation nor bleeding was observed in magnetized water fresh concrete [9].

It has been found that hardened concrete is affected by magnetized water. Compressive strength, split tensile strength and flexural strength were conducted and the result showed that the compressive strength was noticed to be positively affected by the magnetized water, this was spotted by several studies where different parameters were changed to prove magnetized water efficiency. Concrete cubes were treated in natural conditions and in wet conditions, compressive and tensile strength was observed to rise to 9 % and 6 % respectively [10]. The magnet field intensity was changed from 0.2 Tesla to 1.35 Tesla. Studies have shown that fields of 0.8 and 1.2 Tesla effectively increase the compressive strength [8]. Short and long-term compressive, split tensile, and flexural strengths were tested on samples mixed and cured in magnetized water and the result revealed that all these strengths were observed to rise in both long and short terms [9]. The increase in compressive strength is related to the speed of water flowing through the magnetization device [11]. This increase in compressive strength was proposed to be due to the large surface area of magnetized water concerning normal water [9]. The time at which the water was exposed to the magnetic field affects the compressive strength [9]. The effect of magnetized water on compressive strength, when used for curing rather than mixing the concrete, was studied and the resulted strength was found to be accelerating when magnetized water was used in both mixing and curing [9], [12]. The concrete density was found to increase, while Poisson's ratio was detected to decrease [10]. The toughness indices, load-carrying capacity, and the drying shrinkage of

concrete mixed with magnetized water were seen to be enhanced concerning normal water concrete [8].

The water after passing through a magnetic field of certain strength will yield magnetized water. In 1962, Wulachoufuski and Albanina in Russia began to study the use of magnetized water for mixing concrete [13]. Parallel researches were also conducted in Japan, China, and Europe guarantee that magnetized water could improve concrete strength by as much as 10% [14].

The use of magnetic water has the advantage that it has less scale deposition produced in pipes after extended use. The magnetic field effects of water increase with increasing magnetizing time. The concrete prepared by using magnetized water will be environmentally accepted, cost-effective, and required low maintenance for the devices [15].

In a magnetic field, magnetic force can break apart water clusters into smaller ones. Consequently, the activity of water is improved. When the cement particles are hydrated, the magnetized water is more likely to penetrate into the central area of the cement particles. Hence, hydration will be more efficient which in turn improves the strength of concrete. When cement particles are bounded by magnetized water of the same electrical charges, these particles will repel each other and thus scatter cement clusters which facilitate the flow of water. In addition, when hydration takes place, it forms a hydration layer on the cement peripheral, which prevents further penetration of other water molecules. As magnetized water molecules are rather spread or of small clusters, they can penetrate through the hydration layer more easily, and so, hydration will be more complete [16].

The morphology of hydration products such as C–S–H gel, ettringite, and monosulphate hydrate of pastes mixed with magnetized water is similar to those mixed with tap water. However, larger CH crystals with distinctive hexagonal plates were detected for pastes mixed with tap water. Tap water molecules tend to clump together and form clumps. The larger CH plates are crowded in the transition zone, could be produced after the reaction of cement with these clustered water molecules. The molecules of tap water tend to agglomerate with each other and form clusters. The CH crystals in hydrated paste tend to be smaller and formed separately because smaller water molecules of magnetized water reacted with cement. This difference explicates why the compressive strength of cementitious materials with magnetized water is higher than those with tap water [5].

The two main types of devices for magnetizing water are based on either a permanent magnet or an alternating current solenoid electromagnet generating an alternating magnetic field. The magnetic field strength and the magnetization time have a great impact on the properties of magnetized water [17].

A Japanese patent states that when concrete hardens in magnetized water, its hydration substance would tend to align itself along the magnetic field, resulting in higher compressive strength. To find out how the magnetic field affects water, Raichukin discovered that it affects hydrogen bonding and Pekercarki said it fetched about structural and charge changes of ions in water [13].

Magnetizing water augments the resistance against early shrinkage cracking [20]. The workability of self-compacting concrete (SCC) improved when the same procedures were applied to the water used in concrete production [21].

The use of magnetized water leads to a higher slump flow and a lower viscosity of the SCC mixes. Magnetized water significantly improved the properties of the SCC mixes. The enhancement depends on the number of times that water passes through the permanent magnetic field [22].

The mortar samples mixed with magnetic water of 0.8 to 1.35 Tesla (T) showed an increase in compressive strength of about 9-19% more than those mixed with ordinary water. Likewise, the compressive strength of concrete prepared with magnetic water increased 10–23% more than that of the tap water samples [14].

With the same mix proportions, foam concrete specimens with magnetized water will have higher stability, strength, and lower water absorption than the control specimens due to a complex degree of hydration. For specimens with magnetized water, as the times that water passes through the permanent magnetic field increase, the foam concrete specimen becomes denser and the pores of the foam concrete structure decrease. Bigger and more frequent crystals can be seen in the foam concrete specimens with magnetized water compared to the specimens with ordinary water. For specimens with magnetized water, as the times that water passes through the permanent magnetic field increase, larger and more frequent crystals can be seen in foam concrete specimens [23].

5. CONCLUSIONS

1. Although some opposing results may be due to the differences in magnetizing devices, magnetizing process (treatment time), or variable conditions, the surface tension of water is decreased by the application of magnetic field, while it increases the pH of water.
2. The magnetic field effects of water increase with increasing magnetizing time after which the properties of magnetized water were constantly increased.
3. The concrete prepared by using magnetized water will be cost-effective, environmentally accepted, and required low maintenance for the devices.
4. The main advantage of using magnetized water in the concrete is that increment in the strength properties and also saving in the cement content.
5. The workability of magnetic water concrete is more than that of normal water concrete.
6. The Compressive strength of Magnetized water concrete is more than that of normal water concrete.
7. The Spilt tensile strength of Magnetized water concrete is more than that of normal water concrete.

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