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The Efficiency of using Magnetized Water in Concrete: A Review

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ABSTRACT

Concrete is globally considered the most utilized material in the world after water. Because of the increased demand for this critical material in the construction sector, researchers tend to enhance its properties by adding different additives, substituting with different pozzolanic materials (such as silica fume, glass powder, or any substance with pozzolanic activity), or changing curing methods to obtain concrete with better properties that could be employed in different applications. One of these methods is using magnetic water either by adding it to the concrete mix or by using it to cure concrete to produce concrete with improved mechanical properties. In this study, a group of articles related to the usage of magnetic water in concrete production are explained to explore the effects of magnetic water on concrete. The results showed increasing interest in this method, especially when the use of magnetic water tends to reduce the amount of cement used leading to a reduction of pollutants (indirect effect); hence, this method is considered sustainable. Also, using magnetic water could help reduce the curing time (accelerates hydration of cement). Hence, lowering both cost and time.

Keywords: Concrete, Magnetic water, Mechanical properties, Sustainable curing methods.

1. INTRODUCTION

Water usage in the creation of concrete is essential because it controls the cement's hydration process, ensures correct curing to achieve the required properties, and controls the workable property which refers to the ease with which fresh concrete can be mixed, placed, compacted, and finished. It is affected by factors like water content, mix proportions, aggregate size and shape, grading, and longevity of the concrete construction. To prevent the emergence of contaminants, drinking water or tap water is typically utilized in the manufacture of concrete. Saving water in concrete production by using magnetized water (MW) offers great potential **(Xiao-Feng et al., 2013)**. MW is water subjected to a magnetic field (MF) which contains uniform and smaller particles of water in one direction, **(Kronenberg, 1985).**

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MW has been used in various applications. In Agriculture, it is used in seed development **(Ali et al., 2014; Mahmoud et al., 2014; Martinez et al., 2000; Carbonell et al., 2000; Florez et al., 2004; Grewal and Maheshwari, 2011).** Also, MW is used to eliminate pollution from the environment and reduce contamination **(Atia et al., 2013; Atia et al., 2015).** Furthermore, MW utilization increases Fe^{+} ions in treated water **(Herzog et al., 1989)**.

Calcium Carbonate Precipitation and Magnetization: Research suggests that using magnetic water can increase the amount of calcium carbonate that precipitates (forms a solid) in solutions **(Alimate et al.,2009).** Additionally, it seems that exposure to magnetic fields can influence the way calcium carbonate forms **(Kney et al., 2006; Alimia et al., 2009; Vaskina et al., 2020).**

Lipid Metabolism: Studies on calves and sheep indicate that magnetic water might alter how these animals process fats (lipids). The exact nature of these changes is not specified, but it suggests potential effects on their metabolism **(Bergsrud and Lin, 1990)**. There is evidence that using magnetic water can positively impact growth and overall well-being. This could be relevant for animals or potentially even plants, though the text does not specify the exact subjects of these studies **(Al-Mufarrej et al., 2005)**. MW has beneficial impacts on plants **(Mossa, 2011; Gallego-Valero et al., 2021).**

The majority of rivers, wells, and lake waters are charged by magnetic fields naturally. However, the flow of magnetized water reduces, and as it passes through treatment plants and pipes, it becomes non-magnetized. Because the magnetic fluxes pass through the water, its energy is refreshed and leveled **(Ovchinnikova and Pollack, 2009).** The MW improved the quality of wheat (**Hozayn and Qados, 2010**). **(Maheshwari and Grewal, 2009)** showed that magnetic water treatment may have effects on snow peas' yields, and celery, and pea plants' water productivity. The magnetic field application could be used to enhance physical performance by coagulation of colloidal particles, which helps in the solid-liquid separation process. These applications are also crucial in shaping biological features throughout the advancement of bacterial activity assisted by **(Zaidi et al., 2014).**

This paper aims to review the latest studies that have utilized magnetic water in concrete production both as an admixture and as curing water to enhance the mechanical properties of concrete such as compressive, flexural, and splitting tensile strength and workability.

2. THE MAGNETIC WATER TECHNOLOGY

Magnetized water (MW) results from water passing through a magnetic flux (MF). The quality of MF determines the amount of magnetism **(Reddy et al., 2023)**. The water structure will be magnetized and all the molecules will be aligned in one direction. The fluctuation in bond angles will also bring about changes in the molecular size resulting in making the water thicker with a higher surface area because of magnetism and the broken hydrogen bonds formed stronger bonds than the original bonds; hence, a raised viscosity as illustrated in **Fig. 1(a)**. The energy from the magnetic field provides a powerful tool to effectively introduce the disruption of existing water clusters as depicted in **Fig. 1(b),** raising the water activity. As the size of the electrically charged water molecules in the magnetized water is smaller than the ones in ordinary water, the cement surrounding the water layer will be thinner, leading to reduced water requirements and better concrete quality **(Afshin et al., 2010).**

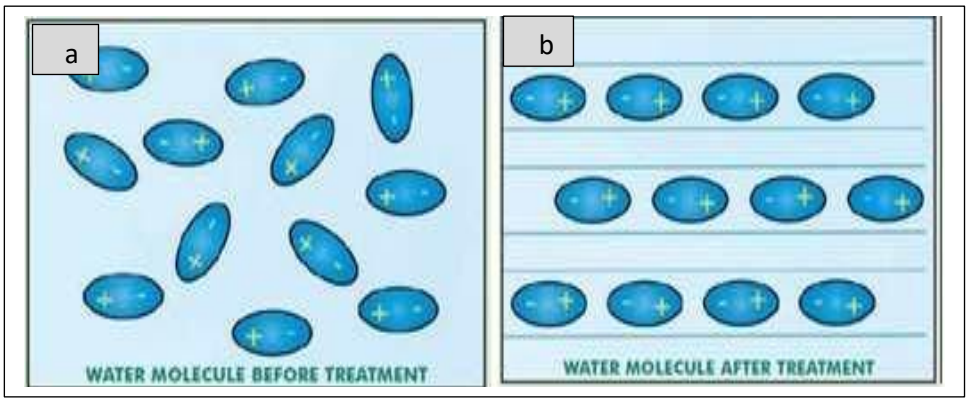

Figure 1. Illustration of water before and after subjecting to magnetization **(Abdel-Magid et al., 2020).**

The experimental investigations demonstrate that the mechanical characteristics of magnetized water (MW) have a considerably better influence on concrete than normal water (NW). According to **(Irzooki et al., 2018; Bogatin et al., 1999; and Amiri et al., 2006)**, treating water with MF changes the chemical and physical features of the water, where the pH is higher than that of regular water, and the surface tension, viscosity, and electrical conductivity were all reduced. Three factors should be taken into consideration when using MF to activate water treatment: 1. Volume of water subjected to the field; 2. Duration of water's exposure to the magnetized field; and 3. The magnetic flux density.

It is thought that by the time water molecules experience a very powerful magnetic field, they form a different spatial structure. It will be placed in one direction, as depicted in **Fig. 2**, and the angle of the bond will drop down to about 105° which means that the bond pairs now tend to be closer in the direction of each other. Through the restructuring of hydrogen bonds, a novel composite may arise, which could result in changes in some physical and chemical characteristics. Hence, "magnetized" is the term usually used to describe the water's exposure to a magnetic field that causes an alteration to its properties **(Ahmed et al., 2009; Verma, 2011).**

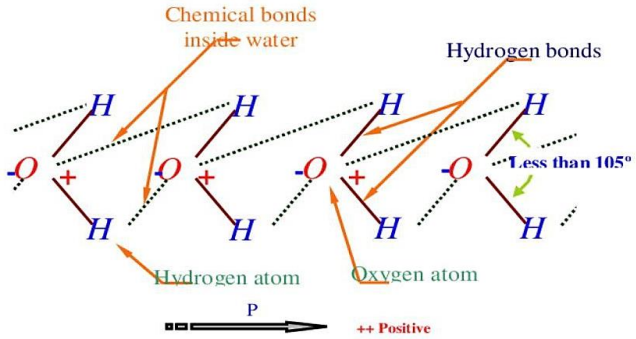

Figure 2. Directional arrangement of water molecules under the effect of magnetic field **(Lowe, 1996).**

3. METHODOLOGY OF WATER MAGNETIZATION

One or more permanent magnets are used to produce MW. In which it changes and affects ions and water molecule clusters passing through its magnetic field (MF) **(Kronenberg, 1985).** There are two effective ways to produce MW. **(Esmaeilnezhad et al., 2017)** Stated that the two methods can be summarized as MF treatment where the water is run through

an MF. The second process involves the use of static magnets that are placed in or near a certain amount of water. The magnitude of MF as well as the period in which MF is applied have a tremendous effect on the attributes of MW. Magneticities of permanent magnets are not influenced by applied electric current. Instead of the magnetic field being the case of two magnetic poles, it is merely the outcome of mutual alignment and aversion of the very small magnetic fields produced by each atom in the MF. These atomic-level magnetic fields are caused chiefly, by the electron's spin and orbital movements **(Esmaeilnezhad et al., 2017).** For water curing purposes, water is circulated via the magnetic field using a motor pump. Water is pumped through the pipe at a speed of 0.7 m/s using a 1 HP motor pump. The model's entrance and outlet are designed to accept and collect magnetized water in the curing tank throughout the curing process. Water is recirculated through the model for two hours every day **(Ramachandran and Das, 2018)**. **Table 1** shows a comparison between normal water and magnetic water as per the Bureau of India Standards.

Table 1. Water's chemical properties **(Malathy et al., 2017).**

Parameter(ppm)	Normal Water (NW)	Magnetic Water (MW)	Allowable limits of BIS Specifications
Calcium	340	145	300
Chlorides	1050	550	1000
Total dissolved solids	1800	1250	2000
Total Hardness	620	380	600
pH	8.9	8.3	6.5-8.5

4. USES OF MAGNETIC WATER IN the PRODUCTION OF CONCRETE

Many research articles have explored the utilization of magnetic water and its effects on concrete properties. The most significant improvements were witnessed in the fresh properties of concrete in addition to improved hardened properties such as compressive, flexural, and splitting strength. **Table 2** lists these articles and summarizes the effect of MW on the properties of concrete.

Table 2. Collected previous studies of using MW as an admixture.

Authors	Magnetic time	The effects of MW on samples
(Abbas et al., 2021)	-	Enhancement of fresh and hardened properties
(Gholizadeh et al., 2021)	-	Increase plasticity of concrete.
(Nadem et al., 2014)	-	Higher compressive strength and workability
(Khreef et al., 2020)	-	Enhance mechanical properties
(Venkatesh et al., 2020)	-	Raised workability and mechanical feature
(Esfahani et al., 2018)	-	Improvement compressive strength
(Afshin et al., 2010)	-	Higher slump and compressive strength
(Hassan, 2008)	4 to 32min.	Increased fresh and hardened properties of concrete
(Al-Maliki et al., 2020)		Increased workability and compressive strength
(Nwofor and Azubike et al., 2020)	12,18, 24,36 and 96hr.	Increased workability, compressive strength, and higher slump
(Divya, 2020)	-	Growth in compressive strength and decrease in cement content
(Elkerany et al., 2023)	-	Increased compressive strength

(Jouzadani and Resi., 2020)	-	Developed compressive strength, bending, and tensile strength
(Raouf et al., 2016)	-	Increased compressive, flexural, and tensile strength
(Shynier et al., 2014)	-	Enhancement of the compressive strength
(Karam et al., 2013)	45min.	Improved compressive, flexural, and tensile strength
(Abdul- Raheem et al., 2021)	-	Increased compressive strength
(Su and Wu et al., 2000)	-	Enhancement of workability and compressive strength
(Wang and Zhao et al., 2008)	-	Favorable effects on compressive strength and pore formation abilities of concrete
(Alkrissat et al., 2023)	-	Enhancement of workability, compressive, flexural, and tensile strength
(Pang, 2008)	-	Increased compressive strength
(Ahmed et al., 2023)	-	Improved compressive strength of concrete
(Holakoei et al., 2022)	-	Increased compressive, flexural, and tensile strength and elastic stresses
(Al Hubboubi et al., 2018)	**-**	Improvement in compressive, flexural, and tensile strength

5. CONCLUSIONS

1- The advantages of using MW in concrete, are as follows: There is no need for a chemical or additive in the concrete mix; magnetic equipment is simple to install and requires little upkeep; concrete preparations utilizing MW will be economical and environmentally friendly; using magnetic water made concrete easier to work, Compared to conventional compacting concrete, concrete with magnetic water mix exhibits greater compressive, split tensile, and elastic strengths; the use of concrete at a young age is aided by magnetic water**.**

2- The use of MW in concrete mixture leads to increased mechanical properties of concrete such as (compressive, flexural, and tensile strength) and workability (because the mixture is homogeneous) compared to normal mixing water concrete

3- It makes the mixture maintain its plasticity, i.e. flexibility in handling and workability, for up to several hours because the effect of the magnetization continues for up to 6 hours before it gradually disappears.

4- It reduces the curing time of concrete due to its rapid hardening resulting from the complete interaction of water molecules with cement.

5- As a result of the cohesion of the coarse and fine aggregate in the mixture, it is more compact and less porous.

6- The magnetic water has uniform molecules in one direction while the molecules of normal water are in different directions.

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Credit Authorship Contribution Statement

Dhuha Hussain: Writing – reviewing & editing. Zena K. Abbas: Supervision, reviewing, evaluation & editing

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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كفاءة استخدام الماء الممغنط في الخرسانة: مراجعة

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الخلاصة

تعتبر الخرسانة عالمياً من اكثر المواد استخداما حول العالم بعد الماء ونتيجة للطلب المتزايد عليها يلجأ الباحثون الى تحسين خواص الخرسانة باضافة مواد مضافة او عملية استبدال مواد بوزولانية مثل غبار السيليكا، مسحوق الزجاج او اي مادة ذات فعالية بوزولانية، او تغيير في طرق الانضاج وغيرها من الطرق لزيادة الخواص الميكانيكية للخرسانة للاستفادة منها في مجالات عدة. احدى هذه الطرق هي استخدام الماء الممغنط لانتاج خرسانة بمواصفات ميكانيكية عالية. لقد درس الباحثون العديد من الطرق لاستخدام الماء الممغنط منها اضافة الماء الممغنط الى الخلطة الخرسانية بدلا من الماء الاعتيادي وهناك طريقة اخرى وهي عملية انضاج الخرسانة باستخدام الماء الممغنط. سيتم في هذا البحث استعراض مجموعة من البحوث التي لها علاقة باستخدام الماء الممغنط في انتاج خرسانة ذات خواص متميزة لمعرفة مدى فعالية اضافة الماء الممغنط للخرسانة وتأثيرها على الخواص الناتجة. النتائج اظهرت ان البحوث في هذا المجال في ازدياد مستمر حيث ان الماء الممغنط يقلل من الملوثات المنبعثة في الجو من خلال تقليل كمية الاسمنت المستخدمة في الخرسانة وبذلك تعتبر طرق مستدامة في انتاج الخرسانة وكذلك اظهرت النتائج ان الماء الممغنط يعمل على تسريع عملية الانضاج وبذلك تقليل الوقت والكلف و كذلك اظهرت زيادة ملحوظة في الخواص الميكانيكية للخرسانة الناتجة.

الكلمات المفتاحية: الخرسانة، الماء الممغنط، الخواص الميكانيكية، الاستدامة، عملية الانضاج.