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RESEARCH ARTICLE

REVIEW ON THE STRENGTH OF CONCRETE USING MAGNETIZED WATER

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ABSTRACT

In this research paper, we will be studying about the effects of use of magnetic water in concrete. It is observed in various tests that, magnetic water has augmented the properties of concrete. Methods that were adopted by researchers around the world to magnetize water will be discussed. Our topic of interest is data obtained for compressive strength, split tensile strength, flexural strength, and workability of concrete for various combinations of cementitious materials with concrete using magnetized water. We shall discuss about these tests that were conducted and their practical implications.

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INTRODUCTION

It has been noticed that introduction of magnetic water in the concrete mix has enhanced the properties of concrete significantly. This study of the effects of magnetic field on concrete mix and the alterations caused in the hardened concrete is our topic of interest. We will be discussing about the changes in the properties of concrete due to use of magnetic water. Magnetic water is essentially water which is exposed to a magnetic field. This exposure of water to a magnetic field brings about changes in the physical properties of water. Hydrogen bonding is a key factor in understanding the fundamental difference between regular and magnetized water. The water molecules in regular water form a cluster due to hydrogen bonding. Water molecules are attracted towards each other and form groups or clusters of water molecules. However, when exposed to a magnetic field, these hydrogen bonds are broken and these clusters are reduced which in turn, increases the activity of water molecules. This effect of magnetic field on water was confirmed by Inaba *et al.* (2004) and Cai *et al* (2009). Magnetized water differs from pure water in optical properties, electromagnetic properties, thermodynamic properties and mechanical properties such as bond angle, dielectric constant, electric conductivity, pH, solubility, viscosity, surface tension, boiling point and freezing point (Pang, 2008; Siva Konda Reddy, 2014; Manjupriya, 2016; Sharma, 2020). These changes in the properties of water are retained for a long duration even after the removal of magnetic field (Colic, 1999). Application of magnetic field cause a great increase in ultraviolet absorption of water. Increase in the exposure duration of water to the magnetic field shows increase in absorption intensity of ultraviolet light. Additionally, there is a decrease in the surface tension as compared to that of pure water which suggests that there is also a decrease in hydrophobicity of water (Ahmed, 2017) Surface tension is an important property of water that affects the hydration and hardening process of concrete. During the hydration, the surface of the cement particle reacts with water and forms a thin layer around the cement particle that restricts further hydration. Due to partial reaction of cement, the true potential of the cement particle is not achieved in terms of its strength. In this process, the use of magnetized water promotes further hydration of the cement particle by impeding the formation of hydrate layer around the cement particle (Gholhaki, 2017) The water molecules penetrate more into the cement and eventually the strength of concrete is increased (Ahmed, 2017; Gholhaki, 2017; Wei, 2017; Faris, 2014; Reddy, 2014) This also reduces the pores present in the concrete structure. The microstructure of the concrete is significantly improved which also increases the density of the concrete (Ghorbani, 2018; Gholizadeh, 2011).

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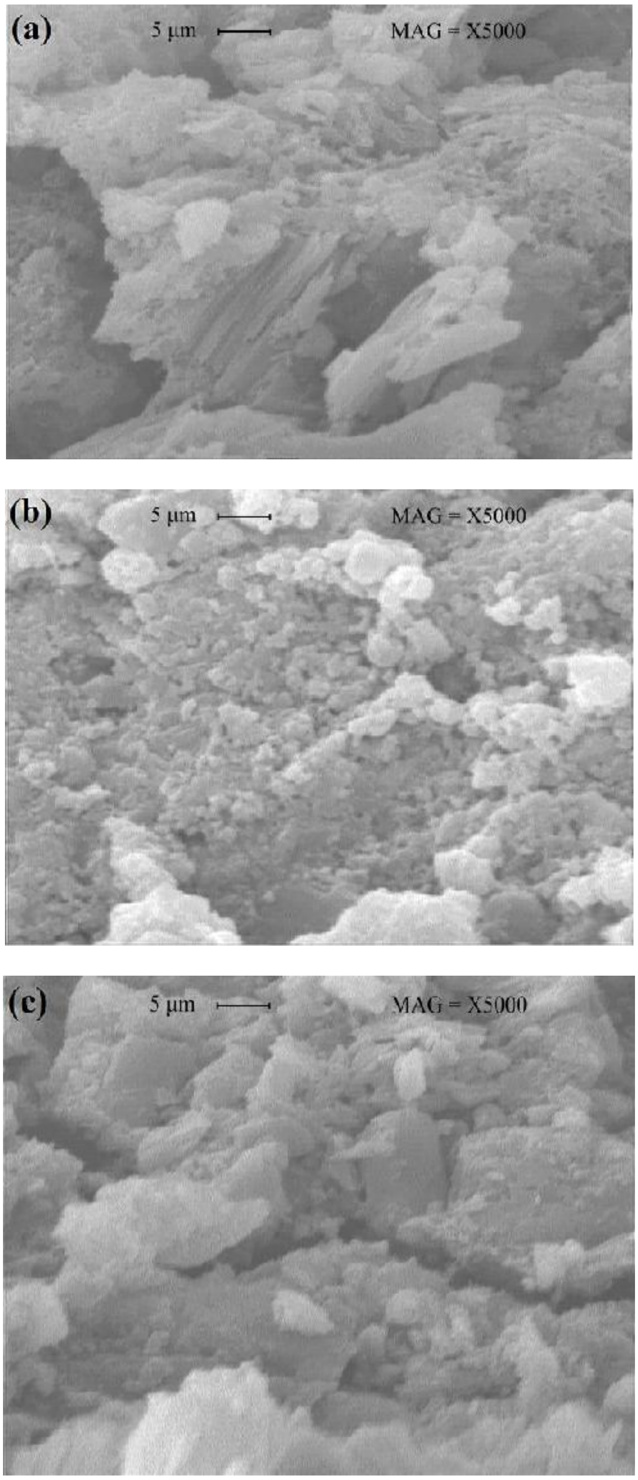


Figure 12. SEM images (5000×) of concrete mixes with (a) regular tap water; (b) magnetized water after passing 10 times and (c) 80 times through a permanent magnetic field at a constant speed of 2.25 m/s

The main advantage of magnetization procedure of water is that, it is a simple method which does not require a lot of energy when a permanent magnet is used. Permanent magnets can be installed easily on a water-tube system, requiring no further energy for magnetization. There are other methods too, that are used to magnetize water. In general, these methods differ in the level of sophistication. Our aim is to determine the most efficient method that will serve to be economical too. There are 3 methods of magnetizing water that are widely adopted. Those methods are described below:

- Magnetization of stationary water: In this method, magnetic water is prepared by allowing water to retain in a glass beaker over a circular magnet of strength *m*. The beaker with pure water is placed above the magnets for a period *p*. The magnetic field lines penetrate through the glass and magnetizes water. The polarity of the magnet is noted.
- Magnetization of circulating water: In this method, a magnetic station is fixed at a spot of a water-tube system. The magnetic station consists of two permanent magnets of strength *m*. The water is circulated *n* number of times at a speed of *s* by using a simple pump.
- Magnetization is also done by using magnetic water machines that are widely available in the market; such as Aqua Correct. This applies a similar approach as the magnetization of circulating water.

Literature Review

The efficiency of these methods and the technology itself has been tested in various aspects around the world. We will be discussing the data of these tests and experiments to elicit the accurate implications of each datum in accordance with the other. The review is divided according to the grade of the concrete that was targeted.

Table 1. Compressive Strength (MPa)

M20:

Ref	Days	Magnetic	Non-Magnetic	% Increase	Method of magnetization
Reddy el at. [4]	7	30.01	18.86	59.1	(a) *m* = 985 Gauss *p* = 24hr
	28	44.06	28.29	55.7	
Gholisadeh et al. [14]	7	15.69	12.2	28.6	(c) *m* = 6500 Gauss
	28	22.065	18.14	21.63	

Table 2. Compressive Strength (MPa)

M25:

Ref	Days	Magnetic	Non-Magnetic	% Increase	Method of magnetization
Shine et al. [15]	7	30.52	24.14	26.4	(c) *m* = 1200 Gauss
	28	45.18	27.63	63.51	

Table 3. Compressive Strength (MPa)

M30:

Ref	Days	Magnetic Strength *m*			Non-Magnetic	% Increase	Method of magnetization
		0.8T	0.9T	1.0T			
Jain et al. [16]	7	20.1	22.0	22.2	18.67	19.06	(b)
	28	34.2	34.4	35.9	33.16	8.29	

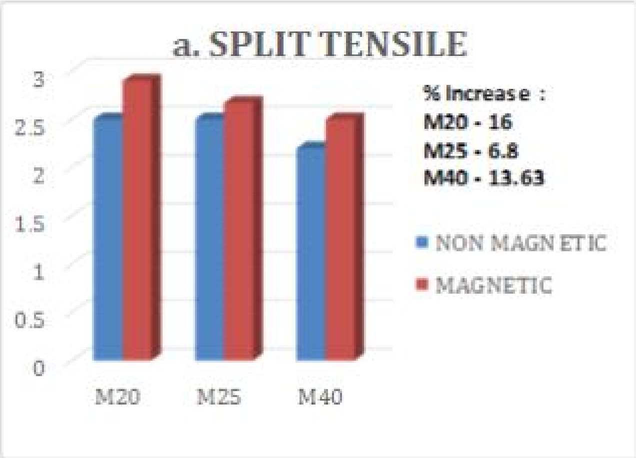
Table 4. Compressive Strength (MPa)

M40:

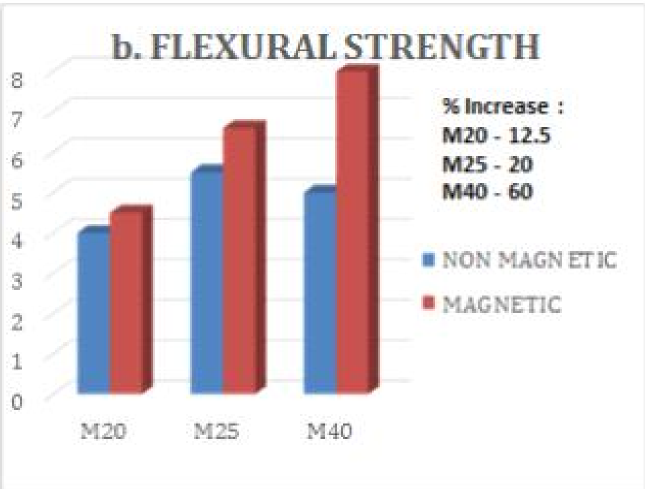
Ref	Days	Magnetic	Non-Magnetic	% Increase	Method of magnetization
Sharma et al. [6]	7	48	42.6	12.67	(b) *m* = 1.4T

The above tables numbering from 1 to 4 describe the compressive strength of concrete blocks by comparing two samples i.e. magnetic and non-magnetic samples. Different grades of concrete have been compared and their variations in percentage are mentioned above. We can observe that, when the concrete is prepared by magnetized water, we get higher compressive strength when compared to non-magnetic sample. The highest percentage increase in compressive strength has been observed under M25 grade

(28 days) and the least percentage increase in the compressive strength has been observed under M30 grade (28 days). It should also be noted that magnetization done by method show higher percentage increase for the same grade of concrete.



The above graph a. narrates about the split tensile strength test that has been performed on the concrete blocks for magnetic as well as non-magnetic water. Different grades of concrete blocks have been examined and by studying and comparing the samples, we see an increase in the split tensile strength by using magnetised water. We also observe that the highest percentage increase in the split tensile strength has been observed in M20 (7 days) grade and the least percent change in M25 (7 days) grade.



The above graph b. discusses about the flexural strength in the concrete. Different grades of concrete blocks have been studied and their flexural strength has been mentioned above.

The highest percentage increase in the flexural strength of the concrete block is 60% which have been observed for M40 grade. Whereas, the least percentage increase has been observed for M20 grade concrete. A trend can also be observed that the flexural strength of the concrete prepared by the magnetized water increases with the grade of the

The following table no. 5 discusses the results of using magnetic water with superplasticizer:

Table 5. Compressive Strength (MPa)

Mix Design	W=B	S:P=B	NMW	MW	% Variation
M113	0.45	1	65.93	61.09	-7.3
M114	0.5	1	58.25	604.5	1.8
M123	0.45	2	65.47	603.3	-9.6
M124	0.5	2	57.20	50.14	-12.3
M133	0.45	3	63.811	60.13	-5.5
M134	0.5	3	59.42	54.62	-8
M211	0.35	1	61.94	59.67	-3.6
M212	0.4	1	63.64	67.66	6.3
M213	0.45	1	60.96	58.93	-3.3
M221	0.35	2	64.55	72.14	11.8
M222	0.4	2	70.85	65.21	-8
M223	0.45	2	54.10	59.59	10.2
M231	0.35	3	69.30	77.08	11.2
M232	0.4	3	64.65	73.255	13.3
M233	0.45	3	57.59	65.85	14.3
M311	0.35	1	66.19	69.46	4.9
M312	0.4	1	55.82	72.96	31.4
M321	0.35	2	67.46	80.12	18.8
M322	0.4	2	56.48	75.80	34.2
M331	0.35	3	70.8	64.92	-8.3
M332	0.4	3	61.45	70.77	15.2

Variable	Mag.	Non-Mag.	Mag.	Non-Mag.	Mag.	Non-Mag.	Mag.	Non-Mag.
Mix Design	M124	N322	M114	N312	M133	N232	M114	N213
28 Days Compressive Strength	583	576	605	566	651	659	605	621
Slump (cm)	4.5	5	1.5	1.5	6	6	1.5	2
S.P./B (%)	2	2	1	1	3	3	1	1
W/B	0.5	0.4	0.5	0.4	0.45	0.4	0.5	0.45
Cement Content	450	350	350	450	350	400	350	400

The above table represents the data of the compressive strength of the concrete blocks when prepared by the magnetized as well as non-magnetized water. The data provides us compressive strength of both the samples after 28 days. The data suggests that the low-grade concrete when prepared with the magnetized water can provide us with high compressive strength which is comparable to the high-grade concrete prepared with the non-magnetized water. But the data also shows a lot of variation in the strengths at the range of 50Mpa to 65MPa where there is a decrease in the strength. (Afshin, 2010).

Su and Wu (2003) had studied the effect of magnetic water on mortar and concrete with fly ash. It was observed that magnetized water can improve the compressive strength and the flow ability of mortar specimens with fly ash when compared to mortar specimens with pure water. Bharath *et al.* (2016) observed that the use of magnetized water augmented the workability of concrete mixes with 50% copper slag and cement. Similarly, Gholhaki *et al.* (2017) reported that the use of magnetized water can improve the flowability and viscosity of self-compacting concrete (SCC) when compared with pure water. Researchers have also reported that using magnetized water in concrete production leads to an increase in the workability and strength of the concrete which does not require addition of more water or materials such as plasticizers (Faris, 2014; Patil, 2016). Ahmed (2017) has studied the behavior of magnetic concrete with Egyptian nano alumina. It was concluded that a positive effect was see in the characteristics of concrete mix was obtained. Wei *et al.* (2017) observed that the use of magnetized water in concrete reduced the early-age shrinkage cracking in concrete when compared to the specimens with pure water. It has also been reported that the use of magnetic water can also decreases the amount of cement by about 5% and can also resist the concrete from freezing (Afshin, 2010).

Jalal *et al*. reported that it takes a long time for the stagnant water to get magnetized which is a practical hurdle (Jalal, 2013) It was also reported that the magnetic memory of water is short lasting from a practical point of view. It could last about 12hrs and therefore the water should be added to the mix as soon as possible after magnetization. Also, introduction of ferromagnetic substance interferes with the magnetization process (Bharath, 2016; Gonet, 1985; Ehsan).

RESULTS

It is observed that different methods of magnetization have yielded varying data regarding the improvements caused by the use of magnetized water. The proper derivation of each method is missing. But through a practical application point of view, the method using commercial magnetic water machine is much more pragmatic than other methods and can be easily adopted. Although the strength increase is lesser using this method but there are other factors such as increase in workability of the mix which contribute for its selection as a prospect for practical application.

The efficacy of this system also needs to be thoroughly tested. It is also observed that when magnetic water is used with super plasticizers shows a fluctuating data. The data for cement of grade around M50 are not positive. However, data for higher grade cement again are positive and pragmatic. Another problem that can be seen is the production of magnetic field for magnetization in remote areas. As suggested by Taman *et al*. (24), it was clear that the water-tube system with 0.8T did not show any significant magnetization whereas results shown by Jain *et al*. (16) that suggested magnetization was done at 0.8T as well. This discrepancy needs to be investigated. Another point to note would be that, 2 tests were conducted using different methods for the same grade of concrete i.e. M20. The magnetic fields that were applied were drastically different. Experiment performed by Reddy el at. used a magnetic field of 985Gauss whereas experiment performed by Gholisadeh *et al*. used a commercial Aqua Correct that produces 6500Gauss of magnetic field. The results obtained by Reddy *et al*. were much more significant than Gholisadeh *et al*. From this comparison, no result can be drawn about the relationship between the strength increase of the concrete and strength of exposed magnetic field. Two studies done with the same method; Magnetization of stagnant water on different grades of concrete show different % increase. Reddy el at. performed the experiment for M20 at 985Gauss magnetic field strength where as Sindhuja el at. performed the experiment for M40 at 1200Gauss magnetic field strength. The strength gains were observed to be around 55% and 20% respectively. Again, no correlation could be obtained from this data.

Conclusion

The above discussed papers and their results do suggest that the technology of magnetized water is promising but it lacks practical applications. The major problem lies in the fact that the magnetization of water cannot be carried out on a large scale. The most effective method in terms of strength increase is the method of magnetization of stagnant water. However, this method cannot be applied for kgs and tons of water that is required for large projects as it would require bigger electromagnets which is impractical. In the other methods adopted, the change is less and varying. There is a need of practical approach for application of magnetic water technology in the industry. Another problem with the method of magnetizing stagnant water is that, it is time requiring process. The water needs to be left stagnant for a considerable number of hours to ensure enough magnetization. The system also gets affected by ferromagnetic materials like steel, which is an essential building material. Magnetic memory of water is another impedance. The properties of magnetized water are seen to last only for a few hours (up to 12hrs). Therefore, transportation of water through longer distances to the areas where magnetization is not possible would not be such a good idea because the efficiency of this method will decrease significantly. These factors need to be overcome in order to make this technology pragmatic and apply in the field.

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