IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 18, Issue 2 Ser. III (Mar. – Apr. 2021), PP 38-44
www.iosrjournals.org

Investigating the effect of magnetized water on engineering properties of concrete

Mohamed M yousry Elshikh[1], Mohamed Abd Elrahman[2], Ahmed M. Ghazy[3]
[1](Prof., Structural Engineering Dep. Faculty of Engineering, Mansoura University, Mansoura)
[2] (Associate Prof., Structural Engineering Dep. Faculty of Engineering, Mansoura University, Mansoura)
[3] (M. student, Structural Engineering Dep. Faculty of Engineering, Mansoura University, Mansoura)

Abstract: *Recently, magnetic field treated water (MFTW) is receiving special attention due to it is ability to enhance the performance of traditional concrete. In the part of this paper, we study the influence of magnetized water prepared at constant field strength (1.4)Tesla with a number of cycles equal to (50, 100, 150) cycles on the average compressive strength to find the optimum number of cycles. In the second part, we study the effect of magnetized water prepared at the optimum number of cycles on compressive strength, flexural strength and workability of fresh concrete through (6) mixes prepared with two types of water tap water and magnetized water with fly ash replacement percentage (0, 10, 20)% of cementitious materials and constant dosage of super-plasticizer (1)%. Results indicated that the use of magnetized water instead of ordinary water improves the fresh and mechanical properties of traditional concrete.*

Key Word*: Magnetized water; Optimum cycles number; Fly ash; Super plasticizer.*

Date of Submission: 10-04-2021 Date of Acceptance: 26-04-2021

I. Introduction

Water is the key ingredient in traditional concrete, which has a powerful influence on the behavior of fresh and hardened concrete according to its quality as well as quantity. However, there are comparatively scarce studies on the water as mixing water in concrete. According to Brower [1], the success of magnetized water date back to 1803. The magnetic field effect was first recorded when there was a notable difference in the texture of mineral accumulation on the sides and bottoms of laundry kettles, a soft substance was observed Instead of hard scale formation in kettles which lodestones (natural magnetic stones) were used. Since then, the technique of magnetized water has developed rapidly in many successful applications, such as increased concrete compressive strength [2], reduced precipitation rate of calcium carbonate (scale reduction) [3], improved plant productivity [4], wastewater treatment [5], animal science [6], etc.

Magnetized water or magnetic field treated water does not mean that water has a force or ability to attract other materials but it is exposed to a magnetic field strength which is found to change the structural composition and the physicochemical properties of ordinary water. At the nanoscale, polar substances like water is not homogeneous and exist as cluster depending on the temperature, pressure, hydrogen bond and vanderwaal's forces, each cluster contain about 100 water molecules at room temperature as shown in Fig.1 (a) [7]. Therefore, hydration reaction will first take place on the surface of cement particles and a thin layer of hydration products is formed, thus hinders further hydration of cement particles.

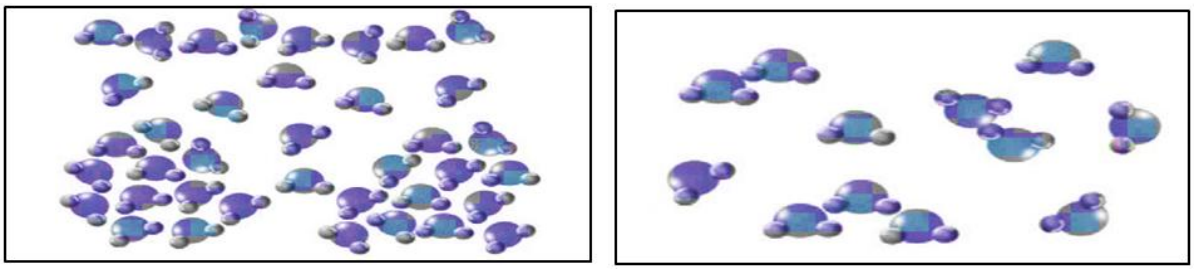

Fig.1. (a) water molecules before magnetic field (b) Water molecules after magnetic field [7]

However, when tap water passing through magnetic flux, magnetic force can break down these water clusters into a small cluster or single water molecules as shown in Fig.1 (b)[7], therefore the activity of water increased, solubility increased and more water is available for hydration (Bioavailability). Thus, magnetized

water can penetrate the core region of cement particles more easily during hydration reaction which will be more effective and complete and the result better quality and density for hydration products of cement.

Su and Wu [8] concluded that the use of magnetized enhance the compressive strength of concrete and mortar, they found an increase in compressive strength about (15-20)% for mortar specimens when the magnetic field strength is 0.8 or 1.2 T. they also observed by using scanning electron microscope (SEM) small plates of calcium hydroxide (CH) formed separately when using magnetized water instead of large plates accumulated in one place when using tap water. In another investigation, Su et al [9] investigated the compressive strength and workability of concrete and mortar when prepared with magnetized water and contained granulated blast-furnance slag. Results showed that by using magnetized water, the compressive strength increased (9-19)% for mortar samples and (10-23)% for concrete samples. Moreover, the slump of concrete and fluidity of mortar were found to be improved.

Weilin et al [10] obtained results showing that there was a significant increase in cement compressive strength by (54)%, cement bending strength by (39)% and cement bonding strength by (20)% by magnetic treatment of slurry. The experimental results also show that the initial setting time and final setting time of slurry can be shortened by (39)% and (31)%, respectively, after the magnetization process.

Ghorbani et al [11] studied the effect of magnetized water that passing through a permanent magnetic field at constant velocity (2.25) m/s with 10, 20, 40 and 80 times on the mechanical properties and durability behavior of concrete block pavers. The results showed that there was an improvement in compressive strength by (12.5)%, in splitting tensile strength by (13)% and in flexural strength by (9)% relative to the control mix, due to using magnetized water instead of ordinary tap water. Furthermore, the images of SEM showed that using of magnetized water instead of tap water leading to a significant improvement of the microstructure of concrete mixes through forming a more unified denser structure with lower pores.

Saddam [12] investigated the effect of current velocity and water flow rate on compressive strength and consistency of concrete to find the optimum characteristics of water treatment. The result showed that the best increase in compressive and workability of concrete is achieved when velocity and discharge of water equal to (0.71) m/s and (0.22) liter/sec, respectively.

II. Materials

■ Cement: the cement used throughout this research work was ordinary Portland cement CEM I (42.5) complies with the American society of testing and materials ASTM C150 [13] produced by El Suez Portland cement with specific gravity (3.15). The chemical composition and physical properties of this cement are shown in Table 1 and 2 respectively.

Table no 1: Chemical analysis of used Cement.

Chemical analysis	Fe_2O_3	Al_2O_3	Na_2O	K_2O	SiO_2	SO_3	CaO	MgO	LOI
Mass (%)	3.58	4.6	0.36	0.22	21.3	2.82	63.1	2.41	2.15
ASTM C150 limit	----	----	----	----	----	≤3.5	----	≤6	----
Mineral Compounds	C_3S	C_2S	C_3A	C_4AF					
Mass (%)	46	26	6	11					

Table no 2: Physical specifications.

Blain fineness (cm^2/gr)	Setting Time (min)	
	Initial	Final
(3000)	(130)	(270)

■ Aggregate: fully complies with ASTM C33/C33M-13[14], the coarse aggregate used was natural gravel with maximum nominal size (16) mm and the fine aggregate used was natural silica sand. The physical properties of fine and coarse aggregate are shown in table 3.

Table no 3: Physical specifications of used aggregates.

Properties	Bulk density	Absorptivity	Fine modulus	Specific gravity
Fine aggregate	1560 kg/m^3	1.1 (%)	------	2.63
Coarse aggregate	1486 kg/m^3	0.9 (%)	2.67	2.63

■ Fly ash: the fly ash type (F) satisfy ASTM specification C618 [15] was used. It was supplied by SIKA EGYPT Company with specific gravity (2.25). Its chemical composition is shown in table 4.

Table no 4: Chemical analysis of used Fly ash.

Chemical analysis	Fe_2O_3	Al_2O_3	Na_2O	K_2O	SiO_2	SO_3	CaO	MgO	LOI
Mass (%)	3.58	4.6	0.36	0.22	21.3	2.82	63.1	2.41	2.15

■ Chemical admixture: the chemical admixture used was type (F) sikament-163 with specific gravity (1.2). This admixture conforms to ASTM C 494-92 according to product data sheet.
■ Water: the water used through this research was ordinary tap water; the water to cementitious materials ratio (W/CM) was constant for all concrete mixtures and equal to (0.5).
■ Magnetized water: in order to prepare magnetized water, ordinary water will be circulated through the permanent magnet with magnetic field strength (1.4) Tesla as shown in figure 3 with definite number of cycles (50, 100, 150).

Figure 2. Permanent Magnet used in this research work

This magnet, used during this research, was obtained from Delta Water Company, Alexandria Governorate, Egypt. The dimension, description and other specification for this magnetic device are given in table 5, according to manufacture data sheet.

Table no 5: Permanent Magnet dimension and specification

Description		**Specification**
Weight	(**6**) Kg	Eliminates the buildup of rust
Material	Stainless steel	Prevents corrosion and scaling
Connection	Thread connection	Reduces the effect of water hardness
Total length	30 inch	Minimizes water salts and chemicals
Outer diameter	3 inch	Improve water ability to absorb oxygen
Inner diameter	1 inch	Prevents formation of calcareous residues

III. Experimental program

The experimental program divided into two parts, in the first part through (9) mixes we investigate the effect of magnetized water prepared with cycles number (50, 100, 150) cycles on the average compressive strength of concrete cubes, to find the optimum number of cycles. In the second part, we evaluate the influence of magnetized water prepared at the optimum number of cycles on compressive strength and flexural strength of hardened concrete and workability of fresh concrete. To achieve this target a total of (6) mixes as shown in table 6 were prepared with two types of water tap water and magnetized water with fly ash replacement percentage (0, 10, 20)% of cementitious materials and with super plasticizer dosage (1)%.

Table no 6: Weights and Details of mixtures components (kg/m^3).

Mixture ID	Water Type	Cycles No	Cement (KG)	Gravel (KG)	Sand (KG)	Water (KG)	Fly ash (%)	Sp (%)
First Part : (9) Mixes								
M0	MW	50-100-150	375	1000	802.967	187.5	0	0
M10	MW	50-100-150	337.5	1000	790.595	187.5	10	0
M20	MW	50-100-150	300	1000	778.214	187.5	20	0
Second Part : (6) Mixes								
M1	TW - MW	150	375	1000	802.967	187.5	0	1
M2	TW - MW	150	337.5	1000	790.595	187.5	10	1
M3	TW - MW	150	300	1000	778.214	187.5	20	1

Note: (TW) Tap Water & (MW) Magnetized Water & (SP) Super Plasticizer

3.1 Mixing Procedure and Samples preparation

All concrete mixes were mixed by using a pan-type mixer with a total capacity (60) liter. After weighted all required quantities, the mixing process sequence consisted of mixing cement, fly ash if used, coarse and fine aggregates for two minutes then half amount of mixing water was added to the mixer for another two minutes. In the final, the remaining water was added and mixing was continued for three minutes. In case of magnetized water is used, directly after magnetization transferred to the laboratory for mixing process with the

exact steps mentioned before. After casting in wooden forms, all samples lasted for (24) hours for curing before they removed and cured in water path until they required for testing.

In the first part, from each mix six cubic specimens (150×150×150) mm were casted for compressive strength test according to BS 1881-116 [16] after 7 and 28 days. In the second part, from each mix the following specimens were prepared, six cubic specimens (150×150×150) mm for compressive strength test and six prismatic specimens (10×10×500) mm for flexural strength test according to ASTM C78 [17] after 7, 28 and 56 days. Moreover slump test was conducted according to ASTM C143 [18].

V. Result

4.1 The effect of number of cycles of magnetized water on average compressive strength

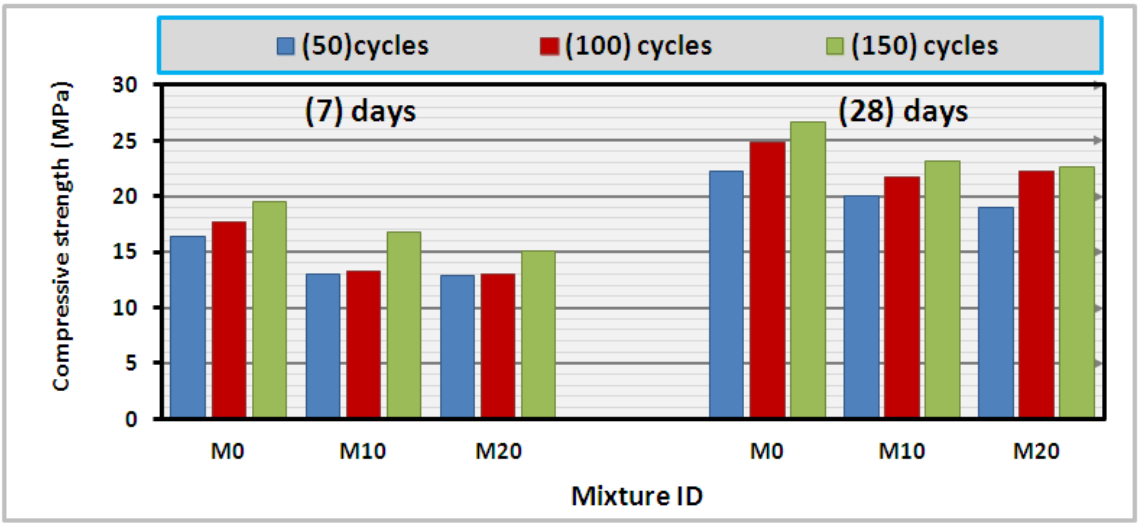

Figure 3. Average compression strength variation with number of cycles

As shown in figure 3, we can observe the variation in compressive strength with variation in the number of cycles for all mixes which contain different percentage of fly ash (0, 10, 20) %. Clearly, the concrete cubes prepared with number of cycles equal to (150) cycles had the maximum compressive strength values at all curing ages 7 and 28 days. Moreover, we can observe a reverse relationship between fly ash replacement percentage and compressive strength at all curing ages.

4.2 The effect of magnetized water prepared with cycles number (150) on workability

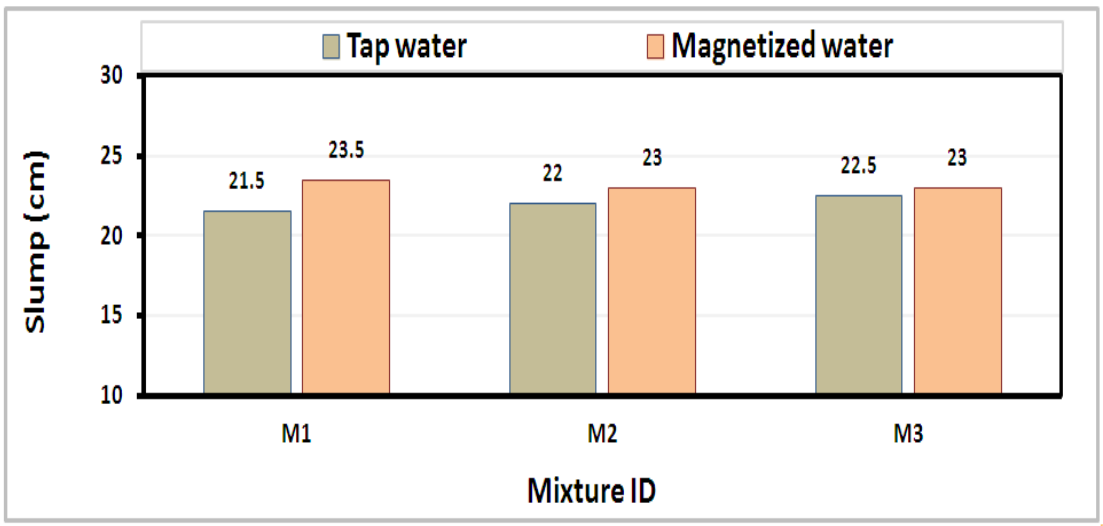

Figure 4. Results of slump test

As seen in figure 4, the effect of water type on slump values. Clearly, we can observe that all mixes prepared with magnetized water have higher slump values than mixes prepared with ordinary water. Moreover, we can observe a direct relationship between fly ash replacement percentage and slump values, this may be attributed to the repealing force between molecules of magnetized water and the spherical shape of fly ash particles [8, 19].

4.3 The effect of magnetized water prepared with cycles number (150) cycles on average compressive strength

The average compressive strength of concrete cubes prepared with two type of water after 7, 28 and 56 days of curing is shown in table 7 and figure 5, respectively. Obviously, we can observe that the compressive strength for all concrete cubes prepared with magnetized water is higher than those mixed with tap water at all curing ages, this result is in good agree with previous studies [8, 20]. This result may be attributed to the ability of magnetized water to penetrate the cement particles making hydration reaction more effective and complete. The result also showed that the mixture M1 had the highest compressive strength values at all curing ages and the mixture M2 mixed with magnetized water displayed the best increase in compressive strength relative to the identical mixture mixed with tap water; it recorded a relative strength 10% and 9% for curing age 7 and 28 days, respectively.

Table no 7: Results of average compressive strength of triplicate concrete specimens at 7, 28 and 56 days.

Mixture ID	Average Compressive Strength (Mpa)						Percent Increase (%)		
	Tap Water			Magnetic Water					
	(7)	(28)	(56)	(7)	(28)	(56)	(7)	(28)	(56)
M1	18.8	27.5	29.3	19.1	29.3	30.2	2 %	7 %	4 %
M2	17.3	26.6	28.6	18.9	28.8	29.2	10 %	9 %	3 %
M3	16.6	26.2	28	16.8	27.7	28.5	2 %	6 %	2 %

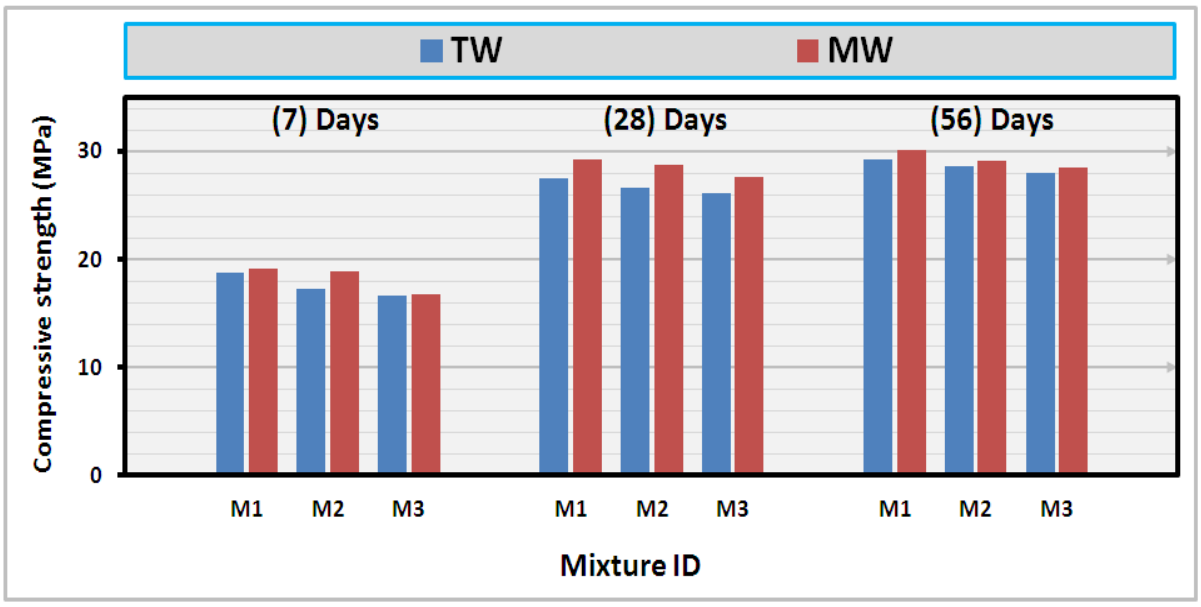

Figure 5. Compressive strength of concrete mixtures at different ages

4.4 The effect of magnetized water prepared with cycles number (150) cycles on average flexural strength

As can be seen from table 8 and figure 6, the average flexural strength of concrete samples prepared with tap water and magnetized water after 7, 28 and 56 days of curing. Similar to compressive strength test results, the flexural strength for all samples mixed with magnetized water is greater than those mixed with ordinary water at all curing ages. Coincident with previous studies [21, 11]. The result also showed that there was a reverse relationship for all mixtures at all curing ages between fly ash replacement percentage and flexural strength. The mixture M1 prepared with magnetized water had the highest flexural strength value (11) Mpa at curing age (56) days. Moreover, the mixture M3 had the highest increases in relative flexural strength at all curing ages.

Table no 8: Results of average flexural strength of triplicate concrete specimens at 7, 28 and 56 days.

Mixture ID	Average Compressive Strength (Mpa)						Percent Increase (%)		
	Tap Water			Magnetic Water					
	(7)	(28)	(56)	(7)	(28)	(56)	(7)	(28)	(56)
M1	7	8.7	10.7	7.8	9	11	12 %	4 %	3 %
M2	6.3	8.1	9.2	7.3	8.5	10.6	16 %	5 %	16 %
M3	5.4	7	7.6	6.7	7.8	10	24 %	12 %	32 %

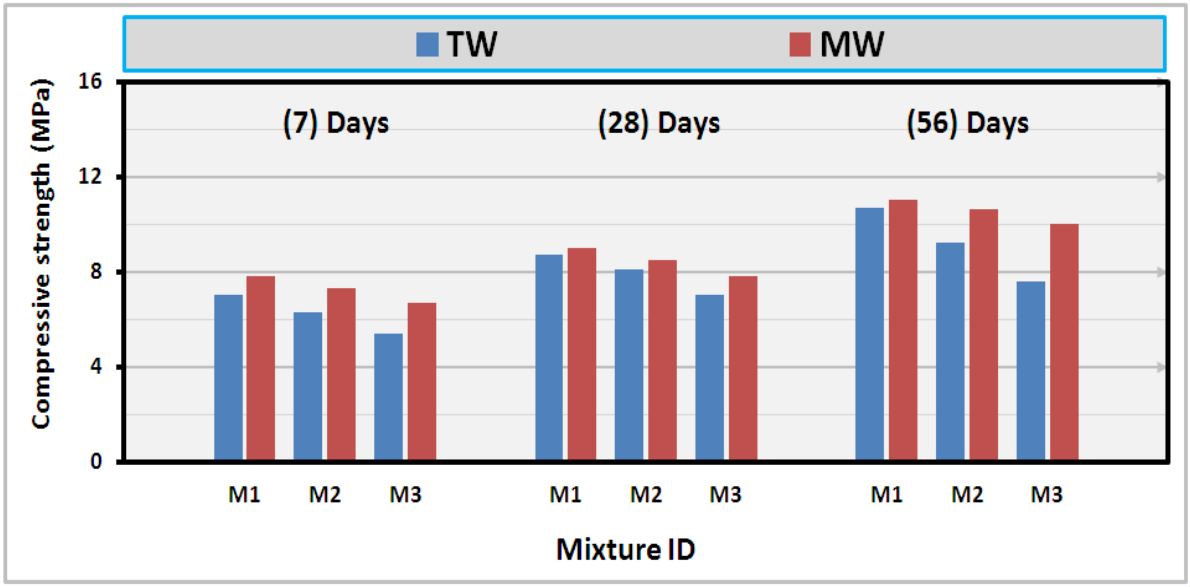

Figure 6. Flexural strength of concrete mixtures at different ages

IV. Conclusion

In this research, we study the effect of number of cycles of magnetized water on the average compressive strength of concrete cubes to find the optimum number of cycles then to find the influence of magnetized water prepared at optimum number of cycles on the fresh and hardened properties of traditional concrete containing different replacement percentage of fly ash, from this research the following conclusion could be drawn:

- The best increase in compressive for concrete cubes is achieved with number of cycles (150) cycles.
- The use of magnetized water at optimum magnetizing condition instead of ordinary water enhance the workability of fresh concrete and improve the compressive and flexural strength of hardened concrete.
- The best increase in workability was (10)% for mixture M1, in compressive strength (10)% for mixture M2 at curing age 7 days and in flexural strength (32)% for mixture M3 at curing age 56 days.
- There was an inverse relationship between fly ash replacement percentage and hardened properties of traditional concrete.

References

[1]. Brower, D, 2005, Magnetic Water Treatment, *Pollution Engineering*

[2]. Reddy, B. S. K., Ghorpade, V. G., & Rao, H. S. (2014). Influence of magnetic water on strength properties of concrete. *Indian journal of science and technology*, *7*(1), 14-18.

[3]. Simonič, M., & Urbancl, D. (2017). Alternating magnetic field influence on scaling in pump diffusers. *Journal of Cleaner Production*, *156*, 445-450.

[4]. Lin, I. J., & Yotvat, J. (1990). Exposure of irrigation and drinking water to a magnetic field with controlled power and direction. *Journal of magnetism and magnetic materials*, *83*(1-3), 525-526. *North-Holland*

[5]. Zaidi, N. S., Sohaili, J., Muda, K., & Sillanpää, M. (2014). Magnetic field application and its potential in water and wastewater treatment systems. *Separation & Purification Reviews*, *43*(3), 206-240.

[6]. Gilani, A., Kermanshahi, H., Golian, A., Gholizadeh, M., & Mohammadpour, A. A. (2014). Assessment of magnetized drinking water on excreta quality, nutrients digestibility, serum components and histomorphology of digestive tract in broiler chickens. *Research Opinions in Animal and Veterinary Sciences*, *4*(3), 120-127.

[7]. Abdel-Magid, T. I. M., Hamdan, R. M., Abdelgader, A. A. B., & Omer, M. E. A. (2017). Effect of magnetized water on workability and compressive strength of concrete. *Procedia engineering*, *193*, 494-500.

[8]. Su, N., & Wu, C. F. (2003). Effect of magnetic field treated water on mortar and concrete containing fly ash. *Cement and concrete composites*, *25*(7), 681-688.

[9]. Su, N., Wu, Y. H., & Mar, C. Y. (2000). Effect of magnetic water on the engineering properties of concrete containing granulated blast-furnace slag. Cement and Concrete Research, 30(4), 599-605.
[10]. Weilin, S., Yun, L., Hanzhao, H., & Quingwang, L. (1992). Effects of magnetic treatment on properties of cement slurry. Society of Petroleum Engineers of AIME,(Paper) SPE, 8.
[11]. Ghorbani, S., Gholizadeh, M., & De Brito, J. (2018). Effect of magnetized water on the mechanical and durability properties of concrete block pavers. Materials, 11(9), 1647.
[12]. M Ahmed, S. (2009). Effect of magnetic water on engineering properties of concrete. Al-Rafidain Engineering Journal (AREJ), 17(1), 71-82.
[13]. ASTM, C. (2012). 150: Standard Specification for Portland Cement.[book auth.]. ASTM International. Annual Book of ASTM Standards. West Conshohocken: ASTM International.
[14]. ASTM (American Society for Testing and Materials). ASTM C33/C33M-13, Standard Specification for Concrete Aggregates; ASTM:West Conshohocken, PA, USA, 2013.
[15]. ASTM. (2005). C 618-19: Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete. ASTM.
[16]. Standard, B. (1881). Method for determination of compressive strength of concrete cubes. British Standards Institution.Principal results from EUROASPIRE II. Eur Heart J 2001,22:554-572.
[17]. ASTM C78/78M, Standard test method for flexural strength of concrete (using simple beam with third-point loading), 2018.
[18]. ASTM C143 / C143M-15: Standard Test Method for Slump of Hydraulic-Cement Concrete, West Conshohocken, PA, 2015
[19]. Atiş, C. D., & Karahan, O. (2009). Properties of steel fiber reinforced fly ash concrete. Construction and Building Materials, 23(1), 392-399.
[20]. Yousry, O. M., Abdallah, M. A., Ghazy, M. F., Taman, M. H., & Kaloo p, M. R. (2020). A Study for Improving Compressive Strength of Cementitious Mortar Utilizing Magnetic Water. Materials, 13(8), 1971.
[21]. Ghorbani, S., Ghorbani, S., Tao, Z., De Brito, J., & Tavakkolizadeh, M. (2019). Effect of magnetized water on foam stability and compressive strength of foam concrete. Construction and Building Materials, 197, 280-290.

Mohamed M yousry Elshikh, et. al. "Investigating the effect of magnetized water on engineering properties of concrete." *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 18(2), 2021, pp. 38-44.