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Effect of magnetized water on workability and compressive strength of concrete

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Abstract

In this research study, the effect of magnetized water on workability and compressive strength of concrete was studied, in order to obtain operative concrete with high resistance and at a lower cost. Data were collected from previous studies and researches. The magnetized water was prepared using the magnetic treatment system. Four concrete mixes were prepared, one without magnetized water and three with. Cement reduction of 12.5 % and 25 % was imposed on the last two mixes with magnetized water. Slump and compressive strength tests were carried out on all four mixes and it was found out that concrete produced by the magnetic technology is easy to operate without affecting the compressive resistance of concrete. It was also found that magnetized water increases the compressive resistance of concrete while cement is reduced up to 25 %.

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Keywords: Concrete mix; compressive strength; slump; cement reduction; magnetized water

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1. Introduction

Water consumption is rising as the population and human needs grow. Industrial sector comes in the second place with 20 % water consumption after the agricultural sector which accounts for 70 % of water use [1]. In concrete production practice there is more than one billion tonnes of water consumed each year [2]. Water used in concrete production plays a vital role in the concrete mix, starting from governing the hydration process of cement, along with proper curing in order to reach the desired strength, not to mention managing workability and durability of the concrete structure. Drinking water or tap water is usually used in concrete production to avoid the appearance of impurities. This constraint along with the limited availability of drinking water across the planet raised the important issue of optimizing the use of water in concrete constructions. Using magnetized water has promising potentials in saving water amount used in concrete construction [2,3].

1.1. Magnetized Water

When water passes through a magnetic flux it is known as magnetized water. The level of magnetization is controlled by the method used and water purity [2,4]. The structure of water is aligned in one direction after magnetization, and the molecule sizes change after the bond angle changes, therefore viscosity and surface area increases by magnetization, hence the hydration rate increases [3,5]. A study by Toledo et al. [6] examined the effect of a static magnetic field on liquid water, and suggested that stronger hydrogen bonds –which lead to a higher viscosity- was formed due to the broken hydrogen bonds after magnetization. Fig. 1(a) illustrates water molecules arrangement in normal temperature. Water molecules tend to form clusters with hydrogen bonds, while these clusters are broken due to the magnetic field when applied as shown in Fig. 1(b), hence increasing the water activity. Due to the smaller size of magnetized water molecules, the water layer surrounding the cement is thinner than normal water molecules, therefore less water demand which has positive effect of hardened concrete properties [5].

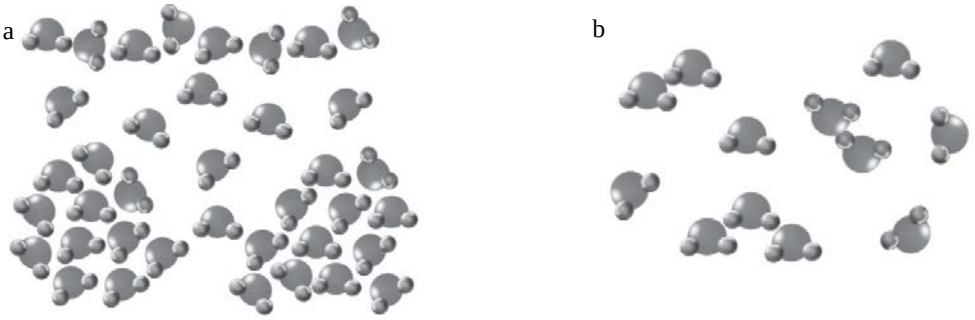

Fig. 1. (a) Water molecules before magnetic treatment; (b) Water Molecules after magnetic treatment [7].

1.2. Influence on Concrete Properties

Several studies had been done on the effect of magnetized water on cement paste and concrete properties. Magnetic treatment, using three different magnetic induction strengths, was carried out by Juan et al. [8] 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 [8]. The test also confirmed porosity reduction with magnetization treatment, but it had no effect after 7 days of complete hardening [8]. Another experiment suggested the application of the magnetic field on a pipe while pumping concrete in place. Tests conducted on real size pumping circuits of length 1000 m with a pipe diameter of 125 mm showed that this procedure improved 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 [7].

Fresh concrete properties were tested and proved affected by the magnetization of water. 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 liter/min [5], this result is not affected with the addition of fly ash as cement substituent with different percentages up to 25 % while the water/cementitious material ratio remains constant [10]. Karam and Al-Shamali [11] justified this behavior with the homogenous matrix of hydrated cement, while Wang et al. [12] attributed the enhance in workability to the fact that magnetized water entrance to cement grains is much easier due to loose connection between single polar molecules (O^{-2} and H^{+}) and the water molecules. On the other hand an observation on the cement content suggested that it could be reduced by nearly 10 % to obtain a medium slump with magnetized water [9], in this particular study the Indian standard was used for designing and conducting tests while American and European standards were used in previously discussed studies. A study by Reddy et al. [13] conducted on concrete mixes with magnetized tap water and magnetized distilled water suggested that exposing the water to north pole or south pole of a magnetic field for 24 hours gives slightly different result of slump with no difference between tap and distilled water. No bleeding nor segregation were observed in magnetized water fresh concrete [4,13].

Hardened concrete was observed to be affected by the use of magnetized water as well. Concrete strengths, tensile, flexural, impact, and top of all, the compressive strengths were detected to be positively affected by the magnetized water, this was detected by several studies where different parameters were changed to prove magnetized water efficiency. Concrete cubes were treated in natural conditions and in water conditions, compressive and tensile strengths were observed to rise up to 9 % and 6 % respectively [2]. The intensity of the magnet field was changed from 0.2 Tesla throughout to 1.35 Tesla in a study by Nan and Chea-Fang [10] water was treated by flowing through the magnetic field and the compressive strength was observed to rise efficiently with the use of 0.8 and 1.2 Tesla fields. Short- and long-term compressive, tensile, flexural and impact strengths were tested on samples mixed and cured in magnetized water, all strengths were observed to rise in both long and short terms [14]. Increase in compressive strength was monitored when water was magnetized while flowing with different velocities as well [15]. Saddam [15] suggested that the increase in compressive strength is relative to velocity of the water passing through the magnetization device. This increase in compressive strength was suggested to be due to the large surface area of magnetized water with respect to normal water [14]. The time of which the water was exposed to the magnetic field affects the compressive strength as well [4]. Reddy et al. [14] studied the effect of magnetized water on compressive strength when used for curing rather than mixing the concrete, and the resulted strength was found to be accelerating, which were relatively the same results obtained by Ubale et al. [3] when magnetized water was used in both mixing and curing. The concrete density was found to increase, while Poission's ratio was observed to decrease [2]. The load carrying capacity, toughness indices and the drying shrinkage of concrete mixed with magnetized water was witnessed to be enhanced with respect to normal water concrete [9].

2. Experimental Study

2.1. Materials

For the purpose of this research, mixes with characteristic strength of 30 N/mm^2 were studied Ordinary Portland Cement (OPC) was used in all mixes. Coarse aggregate had a maximum nominal size of 20 mm and dry density of 1600 kg/m. water/cement (w/c) ratio was modified for different mixes studied.

Experimental study was carried out on six concrete mixes to study fresh concrete workability. Water/cement ratios of 0.45, 0.5 and 0.55 were used on the six mixes with altering the mixing water into magnetized water in three mixes as shown in Table 1. For the purpose of studying hardened concrete compressive strength, four mixes were prepared; Mix *A* was mixed using normal water with w/c ratio of 0.47 to represent the reference mix. Mixes *B*, *C* and *D* were mixed with magnetized water and with cement reduction of 0%, 12.5 % and 25 % respectively as tabulated in Table 2. Constant coarse and fine aggregate contents were used in all mixes as 1155 kg/m^3 and 633 kg/m^3 respectively. Table 3 shows the quantities of mixing materials used in 0.01 m^3 for reference mix A.

Table 1. Mixes' details for slump test.

Mix No.	Water type	w/c ratio
1	Normal	0.45
2	Normal	0.5
3	Normal	0.55
4	Magnetized	0.45
5	Magnetized	0.5
6	Magnetized	0.55

Table 2. Mixes' details for compressive strength test.

Mix Identity # (Mix ID)	Water type	Cement reduction %	w/c ratio
A	Normal	0%	0.45
B	Magnetized	0%	0.45
C	Magnetized	12.5%	0.5
D	Magnetized	25%	0.55

Table 3. Material quantities for Mix A (per 0.01 m^3).

Mix Identity # (Mix ID)	Cement (*kg*)	w/c ratio
A	3.85	0.47
B	3.85	0.47
C	3.37	0.53
D	2.89	0.62

2.2. Sample Preparation and Testing Procedures

All materials required to the experimental study were prepared, weighted and tested to assure quality. Fineness as well as initial and final setting times were checked to meet the standards [16,17]. For fine and coarse aggregate, the specific weight and absorption were checked to meet the standards [18], and a sieve analysis test was conducted to assure both aggregate types are well graded. Water used for mixing and curing was drinking water in accordance with the WHO guidelines [19]. Water was magnetized using a hand magnetic device while water was poured manually due to unavailability of velocity measuring device. Slump test was conducted on the six mixes in accordance with BS EN 12350 [20-21] and was measured immediately after mixing. Compressive strength test was conducted on four mixes in accordance to BS EN 1390 series [22-24] and were recorded after 7 and 28 days.

3. Results and Discussion

3.1. Slump

Fig. 2 illustrates the effect of magnetized water on concrete slump. Slump was recorded to increase (about +550 %) as expected with the increase in w/c ratio for concrete mixed with normal water. Increase in slump was recorded for the same w/c ratio when magnetized water was used. As can be seen from Fig. 2, slump amplified by approximately 400 % and 300 % for w/c ratios 0.45 and 0.5 respectively when magnetized water was used with respect to normal water mixes. While slump only improved 25 % for w/c ratio 0.55 in magnetized water mix compared with normal water mix. This result complies with test results from literature which states that viscosity and surface area of water molecules increase by magnetization [5], hence concrete slump rises.

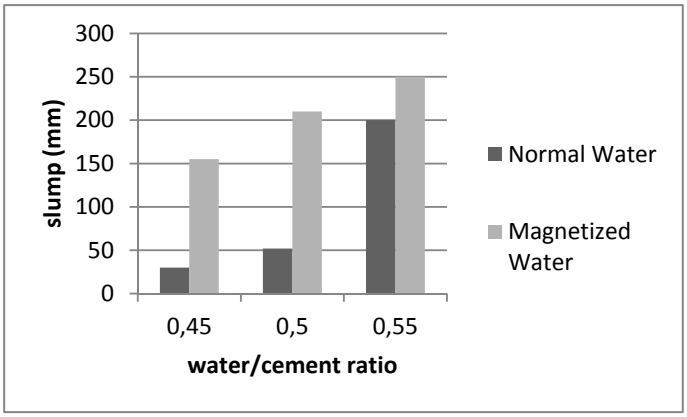

Fig. 2. Slump variation with w/c ratio and type of water.

3.2. Weight of Cubes

Six standard test cubes (150 mm × 150 mm × 150 mm) for each mix: *A*, *B*, *C* and *D* (see Table 2) were molded and cured as per specifications, then three cubes were weighted after 7 days and the other three after 28 days and the average weight was recorded. Fig. 3 demonstrates the effect of magnetized water on concrete weight. Concrete increase in weight as it ages as expected due to the formation of the solid paste. Mix B (mixed with magnetized water and 0.47 w/c ratio) had the lowest weight in both test ages. This can be due to the fact that water molecules when magnetized they break into smaller particles and hence lower volume. Concrete weight decreased as cement content dropped with different mixes, naturally. In Mix D cement content was lowered by 25 % and concrete weight stood the same in early age as Mix A where normal water was used and cement content was used 100 % as designed mix. This could be reasoned by the concept that certain amount of water react with the cement to form the paste, while some other part stays neutral due to the reduction in cement content.

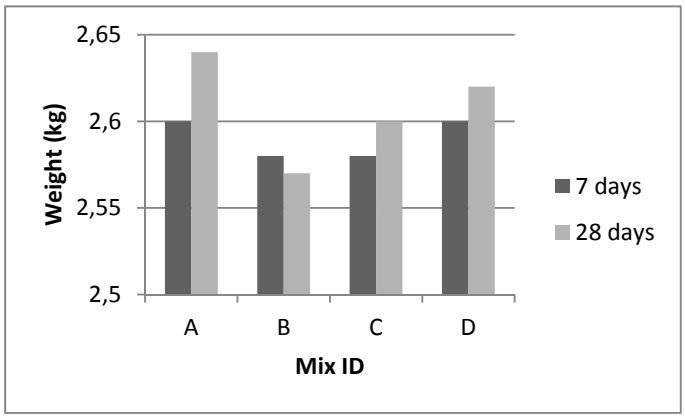

Fig. 3. Concrete weight variation with different concrete mixes.

3.3. Compressive Strength

Six standard test cubes (150 mm × 150 mm × 150 mm) for each mix: *A*, *B*, *C* and *D* (see Table 2) were molded and cured as per specifications, then cubes were tested after 7 days and 28 days and the average strength was recorded. Fig. 4 demonstrates the effect of magnetized water on concrete compressive strength. The positive effect of the magnetized water is observed when comparing mixes B, C and D with mix A. The early strength was observed to stay approximately constant although the cement content was reduced up to 25 %. This implies that magnetized water can be used to preserve the strength. Magnetization results in higher spreading of water particles – observed by the increase of slump- hence, as the cement content decreases the same water content can react with the entire cement content, therefore maintain the strength. The strength gain rate was hardly affected by cement reduction and use of magnetized water in all four mixes (ranging between 35 % in mix C to 54 % in mix B). The highest late-age compressive strength recorded in mix B (mixed with magnetized water and cement content was not reduced).

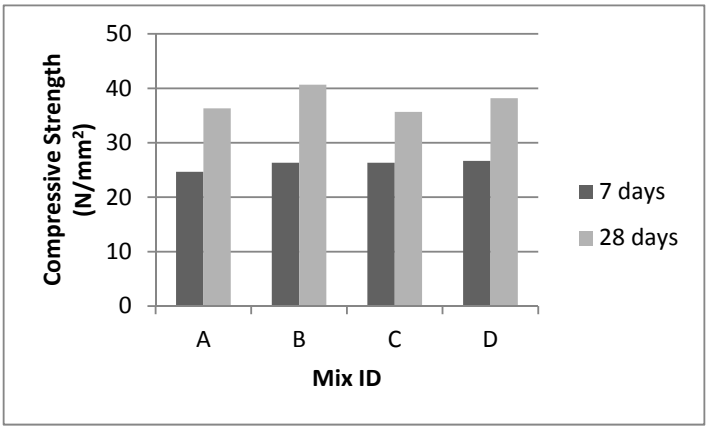

Fig. 4. Concrete compressive strength variation with different concrete mixes.

4. Conclusions

Based on this research study, the following conclusions emerged:

- Magnetized water effectively enhances concrete workability (up to +400%)
- Concrete cube's weight can be reduced approximately 3 % with the use of magnetized water
- Compressive strength is increased up to 10 % with the use of magnetized water.
- Cement content can be reduced up to 75 % without affecting compressive strength when combined with the use of magnetized water.

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