

Effect of Magnetic Water on Strength Properties of Concrete

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Abstract - The research's main goal is to investigate the effects of using magnetic water in concrete mixes with regard to various mechanical properties such as compressive, flexural, and splitting tensile strength. The concrete mix investigated was designed to attain a specified cylinder compressive strength (30 MPa), with mix proportions of 1:1.8:2.68 cement to sand to crush aggregate. The cement content was about 380 kg/m³, with a w/c ratio equal to 0.54, sand content of about 685 kg/m³, and gravel content of about 1,020 kg/m³. Magnetic water was prepared via passing ordinary water throughout a magnetic field with a magnetic intensity of 9,000 Gauss. The strength test results showed an encouraging improvement in the fresh and hardened concrete properties. The percentage increases in compressive strength of 12.16, 10.16, and 8.62% at 7, 28, and 90 days, respectively, compared particularly well with the control mix containing tap water, with consistent flexural trends and splitting.

Key Words: flexural, magnetic water, splitting, tensile strengths.

1. INTRODUCTION

Magnetic water technology appeared in countries like Russia and China in military construction, airports, jetties, and concrete productions several years ago, and recently, the magnetic water technique has attracted considerable scientific interest, as concrete production using this technology appears to be better for the environment due to reducing pollution and costs based on reducing cement content [1]. Additionally, magnetic water technology has proven to overcome the problem of high sulfate contents in the sand [2] used in such concrete, as well as producing economical concrete with better strength without the need for additives like fly ash to improve the strength which uses by Ozyildirim and Haistead [3] and Ronne [4]. and also no complex concrete like epoxy concrete which was studied by Vipulanandan and Dharmarajan [5] and without using any chemical admixture like high range water reducing superplasticizer which was used by ACI [6] and Ramezaniapour et al. [7]. Water plays several essential role in producing concrete (mixing and curing), beginning with the hydration of cement and extending to the curing stage to enhance its strength. Tap water (drinkable water), which free from impurities, is the usual desired water in this technique. This can be converted to "magnetic water" by passing it through

a magnetic field. The structure of tap water molecules, which is usually oriented in random directions, is oriented in a one single direction after "magnetization"; in addition, molecule group sizes change when the bond angles change (decreasing from 13 to approximately 5 or 6 molecules), increasing viscosity and surface area and thus increasing hydration speed [8]. Water molecules consist of "1 oxygen atom and 2 hydrogen atoms" bonded with an isolated triangle angle of about (104.5°) by "light spectrum," which decreases to 103° when they are subjected to the magnetic field. This occurs as the magnetic field deflects the bond pairs and squeezes them to be closer together [9]. The water molecules thus appear to form "clusters" of hydrogen bonds, which break up when moving through a magnetic field and become more uniform, smaller in size, and lower in density; the thickness of the magnetic water layer around cement particles is also thinner than that of the tap water, this is the cause of decreasing water demand for mixing which leads to positive effects on mechanical properties of concrete "the strength" [1]. Magnetic water technology thus enhances compressive strength by 10 to 20% [10] and (10%) by AbdelMagid et al. [1]; they also found that this allowed a reduction in cement content of up to 75% without any effect on compressive strength. In addition to improving compressive strength, the treatment of concrete with magnetic water often has additional advantages; it increases durability properties by decreasing water absorption and porosity based on the magnetic intensity of the treated tap water (1 Tesla = 10000 Gauss) [11]. Compressive and tensile strength have been seen to increase by 9 and 6%, respectively, in normal conditions [12], while Shynier et al. [13] studied the effect of using magnetic water with different magnetic intensities (4,000, 6,000, and 9,250 Gauss) on concrete properties, finding an increase in compressive strength of about 10 to 22% as compared with the control tap water. Karam and Al-shamali [14] stated that the compressive strength of concrete increased by 10 to 15% when using magnetic water as compared to using tap water, and other mechanical properties like flexural and splitting tensile strength improved by 7 to 28% for concrete using magnetic water. Reddy et al. [15] used magnetic water at an intensity of 985 gauss to obtain compressive strength

improvements of 50%, flexural strength increases of 25%, and splitting tensile strength enhancement of 18% when using magnetic water instead of tap water. A study by Ramachandran and Das [16] showed an improvement in compressive strength of about 50% at age 28 days when using magnetic water for both mixing and curing; in addition, the flexural strength increased to 8.5 MPa at 28 days when the concrete was mixed with magnetic water and cured in tap water, while the splitting tensile strength increased by 30% at 28 days when the concrete was both mixed and cured in magnetic water. Raouf et al. [17] observed percentage increases in compressive, flexural, and splitting tensile strength of up to 24, 18.9, and 19.44%, respectively, at 28 days when using magnetic water instead of tap water for different kinds of reactive powder concrete at all ages for the same non-magnetic mixtures. An investigation by Reddy et al. [18] was made to show the increase in mechanical characteristics by increasing magnetization intensity and duration time when using magnetic water with intensity of (0.6 teslas = 6000 Gauss) in mixing concrete (water subjected to magnetization for 24 hours); the percentage improvements in compressive, flexural and splitting tensile strength were 50.2, 34.5, and 31.5%, respectively, as compared to ordinary concrete. Figure 1 shows the mechanisms of this magnetic water technology. Hassan [19] studied the influence of magnetic water on cement mortar properties including compressive strength; initial and final setting time, and consistency at different water/cement ratios at 1 and 7 days. The results of this study showed compressive strengths ranging from 5.5 to 32.5 MPa, initial setting times ranging from 4 to 32 minutes, and final setting times ranging from 303 to 546 minutes, by using two types of mixing water (tap water and magnetic water). The results showed that magnetic water use led to an increase in compressive strength and decreases in both initial and final setting times as compared with tap water. Srinidhi et al. [20] proved that recirculation time increased when the pH value of magnetic water was increased from 6.68 to 7.87, by about 1 hour. The workability of concrete was increased when the slump value of magnetic water was 50 mm with a water/cement ratio 0.30, with an average increase in the compressive strength of 37.41% compared to tap water. Al-Maliki et al. [21] showed a slight increase in workability and compressive strength, also a reduction of about 7.5% in cement content obtained when using magnetic water instead of tap water, making the resulting concrete more sustainable. Nwofor and Azubuike [22] similarly conducted a study to investigate the effects of magnetic water on the workability and compressive strength of concrete and find the optimum time for exposing water to a magnetic field. Water was exposed to a magnetic field of (336 mT) per magnet for durations of 12, 18, 24, 36, and 96 hours, and used to create concrete which showed significant increases in compressive strength when compared to ordinary concrete of 6.5% at 7 days and 17% at 28 days at the 12 to 24 hours of magnetization level. Magnetic water concrete (MWC) also had a higher slump value than normal water concrete (NWC), making MWC more workable than

NWC. Divya [23] also noted advantages of magnetic water concrete over tap water concrete based on an increase in compressive strength of about 22% and reductions in cement content of up to 12%. Jouzdani and Reisi [24] investigated the effects of both water flow rates in different electromagnetic fields (Q) and different magnetic field intensities (MFI) with regard to the properties of self-compacting concrete (SCC). The results showed that using magnetic water instead of tap water increased concrete workability and improved SCC mechanical properties. The compressive, bending, and tensile strengths of the concrete increased by up to 34.1%, 52.4%, and 74.2%, respectively. The main objective of the current study was to study the effects of using magnetic water for improving the properties of fresh and hardened concrete.

2. MATERIAL AND METHODOLOGY

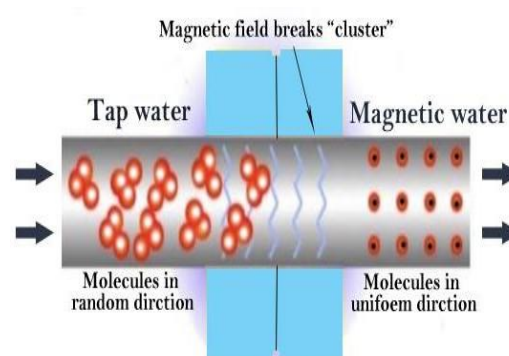


Fig: Mechanism of magnetic water technology

1. MATERIALS

A) CEMENT

Lafarge ordinary Portland cement was used in this work, and Tables 1 and 2 show the concrete physical properties and chemical composition, which are within limits set out in IQS No.5 (1984) [25]. All testswere established in the labs of the Building Research Centre (BRC)

| Oxi des | Contents ,% | IQS No.5 (1984) [25] |
|--------------------------------|-------------|----------------------|
| CaO | 60.60 | - |
| SiO ₂ | 19.80 | - |
| Al ₂ O ₃ | 4.80 | - |
| Fe ₂ O ₃ | 3.00 | - |
| Mgo | 3.50 | ≤ 5.00 % |
| LSF. | 0.90 | 0.66 - 1.02 |
| IR. | 0.70 | ≤ 1.5 % |
| LOI. | 3.10 | ≤ 4.00 % |

Table 1. Chemical composition of cement.

| property | Re sul ts | IQS No.5 (1984) [25] |
|---|-----------------|-------------------------|
| Compressive strength, MPa | | |
| 3day | 19 | > 15 |
| 7day | 25 | ≥ 23 |
| Setting time | | |
| Initial time, min. | 90 | ≥ 45 min. |
| The final time, hr. | 5 | ≤ 10 hr. |
| Specific surface area,m ² /kg | 320 | ≥ 230 |
| Soundness,% | 0.4 | ≤ 0.8 |

Table 2. Physical properties of cement.

B) Fine aggregate (sand)

Natural grains of sand from the Al-Ekhadir area were used, in saturated and dry surface conditions, for the concrete mixes in this work, classified within zone (2), as shown in figure 2. The physical and chemical properties of the sand were within the limits set out in **IQS No.45 (1984)** [26], as shown in table 3. Tests were established in the civil engineering department of the University of Baghdad, in the Materials Lab

Table 3. Chemical and physical properties of fine aggregate.

| Property | R e s u l t | Limit of IQS No.45 (1984) [26] |
|--|----------------------------|--------------------------------------|
| Sulfate content,% | 0. 2 | ≤ 0.5 % |
| Specific gravity | 2. 5 8 | - |
| Fine material passing sieve (0.075)mm | 3.5 | ≤ 5 % |
| Fineness modulus | 2.8 | - |
| Absorption,% | 0.8 | - |



Figure 4. Magnetic water device for preparing magnetic water

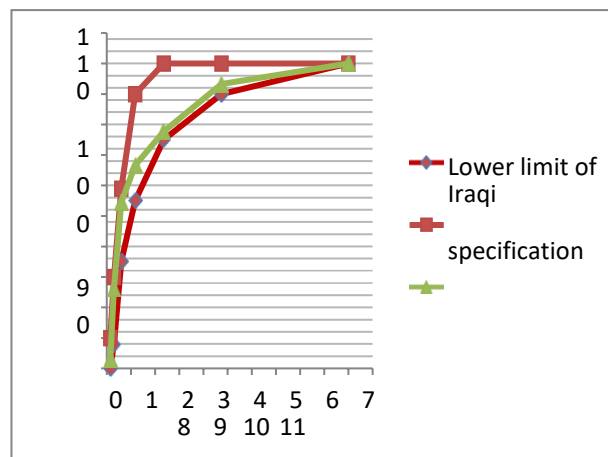


Fig: Fine aggregate grading

c) Crushed aggregate

A nominal 20 mm maximum size crushed aggregate, collected from the Al-Nibae region, and was used in this study in saturated and surface-dry conditions. Figure 3 indicates the grading of this, while table 4 displays the sample's chemical and physical properties, which were within the limits defined by **IQS No.45 (1984)** [26]. Tests were conducted in the civil engineering department of the University of Baghdad, in the Materials Lab.

Table 4. Chemical and physical properties of crushed

| Property | Result | Limit of IQS No.45 (1984) [26] |
|--|---------|-----------------------------------|
| Sulfate, SO ₃ % | 0.03 | ≤ 0.1 % |
| Specific gravity | 2.62 | - |
| Dry rodded density, kg/m ³ | 1560 | - |
| Absorption,% | 0. 6 | - |

aggregate.

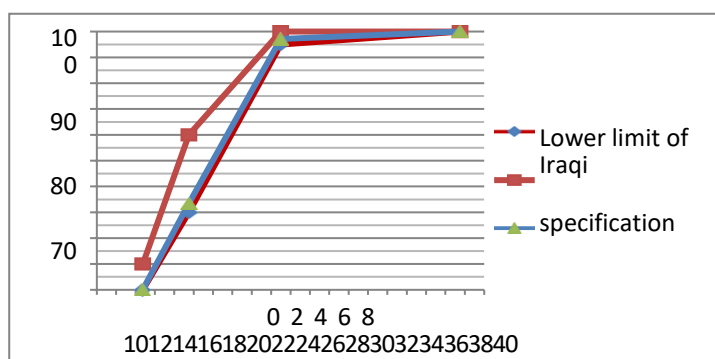


Fig: Crushed aggregate grading

D) Mixing water

Tap water from the water supply system for Baghdad City, which conforms to **IQS 1703/1992** [27], was used for mixing and curing, for both tap and magnetic water cases. The magnetic water device used was from the building research centre of the Ministry of Construction and Iraq Housing. The

procedure for using this was to open the tap water valve and thus allow the tap water to pass through the magnetic unit (intensity of 9000 Gauss) for the magnetization process. Magnetic water was then collected in an empty container and used as soon as possible for not to lose its properties, as shown in figure 4

ACI 211.1-91 [28] was adopted to achieve a reference mix of specified cylinder compressive strength (30 MPa) giving a 37.5 MPa cube compressive strength at the age of 28 days. Slump range for all mixes was 75 to 100 mm, and the content of cement, fine aggregate, crushed aggregate, and water were 380, 685, 1,020, and 205 kg/m³, respectively, with w/c=0.54 and mixing ratios of 1:1.8:2.68 for cement: sand: crushed aggregate, respectively.

E) Mixing and curing of concrete

Using a rotary mixer, cubic moulds (100 mm), cylinder moulds (150 x 300 mm), and prism moulds (100x 100 x 400 mm), were arranged, cleaned and oiled as necessary. A vibrating table was used for compaction. According to BS 1881: part 108:1983 [29], cube compaction was done in two layers for (10-12 sec). According to ASTM C192-11 [30], cylinders and prisms were emplaced and cured. Cylinders were compacted in three layers and prisms had two layers. The specimen surfaces were smoothed with trowels and coated with a nylon sheet for just 24 hrs. After that, the moulds were opened and the samples cured in a tap water tank until the ages of 7, 28, and 90 days.

Testing

Testing for hardened concrete was adopted to study the magnetic water technique at an intensity of 9000 Gauss.

1.1.1. Compressive strength test. Cubes of 100 mm side length were tested at 7, 28, and 90 days per BS 1881: part 116:1989 [31], as shown in figure 5.

1.1.2. Flexural strength test. A prism of 100 x 100 x 400 mm was tested at 7, 28, and 90 days per ASTM C78/C78M-18 [32], as shown in figure 6.

1.1.3. Splitting tensile strength test. A cylinder of 150 x 300 mm was tested at 7, 28, and 90 days per ASTM C496-17 [33], as shown in figure 7.



Figure 5. Compressive strength test machine.

Figure 6. Flexural strength test machine.

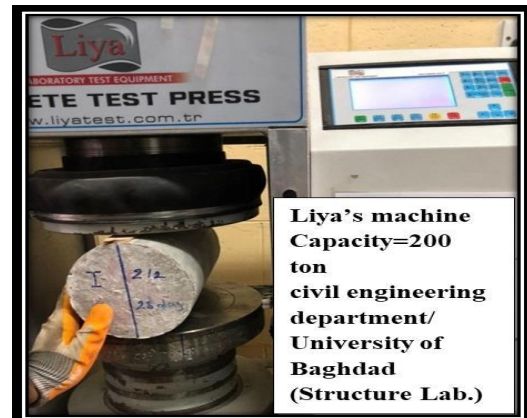
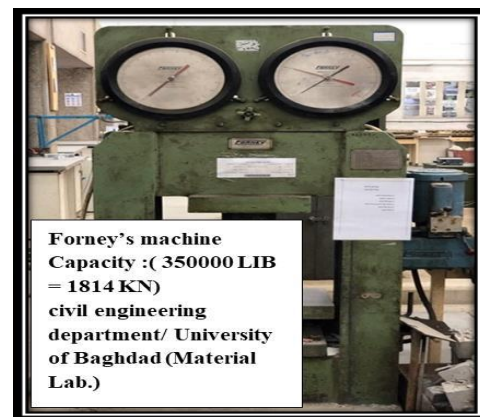


Figure 7. Splitting tensile strength test machine.



3. RESULTS AND DISCUSSION

Table 5 and figures 8, 9, and 10 show the mechanical characteristic results for compressive, flexural, and splitting tensile strength at 7, 28, and 90 days for two mixes: MT (Tap water) and MM (Magnetic water). The second mix (MM), which was prepared with magnetic water at 9000 Gauss showed higher compressive, flexural, and splitting tensile strengths than MT, the reference mix made with tap water. The mixing ratios were constant in both mixtures. Table 6 and figure 11 showcase the percentage increases in compressive strength (12.16, 10.16, and 8.62%); flexural strength (11.92, 10.48, and 9.66%)

and splitting tensile strength (10.88, 9.83, and 8.52%) at the 7, 28, and 90 days, respectively simply by using magnetic water in mixing ordinary concrete instead of tap water; these are in general agreement with Ziyad et al. [34], who used magnetic water in concrete mixing to develop increases in compressive, flexural, and splitting tensile strength of about 23.3, 22, and 13.2%, respectively, at 28 days and also with Karam and Al-shamali [14], who identified a percentage increase in compressive strength of 10 to 15% on using magnetic water, with flexural and splitting tensile strength increases of 7 and 28%, respectively. Similarly, reasonable agreement was found with Sumathi and Sindhuja [35], who noted an increase in compressive strength at 28 days of about

19.72% when using magnetic water as compared to using tap water, with an enhancement in flexural strength of approximately 31.5% and an improvement in splitting tensile strength of up to 12.7% at 28 days.

| Mi x ID | Descripti on | Test (MPa) | Age at testing (days) | | |
|---------------|-------------------|----------------------------------|---------------------------|------|----|
| | | | 7 | 28 | 90 |
| MT | | Compre ssive strength | 29 | 40.6 | 47 |
| | | Flexural strength | 7 | 2 | 7 |
| | | Splitting tensile strength | 5 | 5 | 5 |
| | Tap water | Compre ssive strength | 30 | 3.5 | 38 |
| | | Flexural strength | 2 | 3.0 | 3 |
| | | Splitting tensile strength | 48 | 54 | 0 |
| MM | Magnetic water | Compre ssive strength | 33 | 44.7 | 51 |
| | | Flexural strength | 37 | 58 | 7 |
| | | Splitting tensile strength | 38 | 39 | 42 |
| | | Compre ssive strength | 27 | 33 | 3 |
| | | Flexural strength | 7 | 5 | 6 |
| | | Splitting tensile strength | 5 | 9 | 9 |

Table 5. Mechanical properties of concrete (MPa).

Table 6. Effect of magnetic water on mechanical properties (MM percentage increase as compared toMT)

| Test | Age of test (days) | | |
|-----------------------------|---------------------|----|----|
| | 7 | 28 | 90 |
| Compressi ve strength | 12.16 | 1 | 8 |
| | 11.92 | 0 | . |
| | 10.88 | . | 6 |
| Flexural strength | | 1 | 2 |
| | | 6 | 9 |
| | | 1 | . |
| Splitting strength | | 0 | 6 |
| | | . | 6 |
| | | 4 | 8 |
| | | 8 | . |
| | | 9 | 5 |
| | | . | 2 |
| | | 8 | |
| | | 3 | |

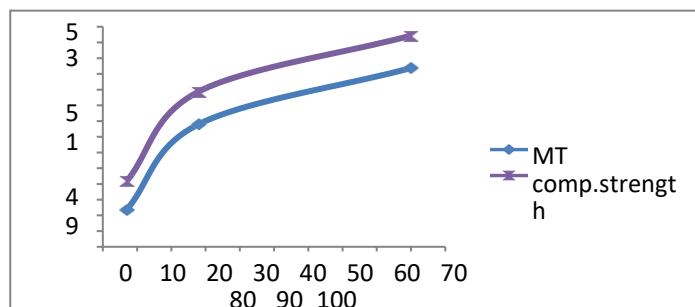


Figure 8. Compressive strength results: MT compared to MM mixes in MPa

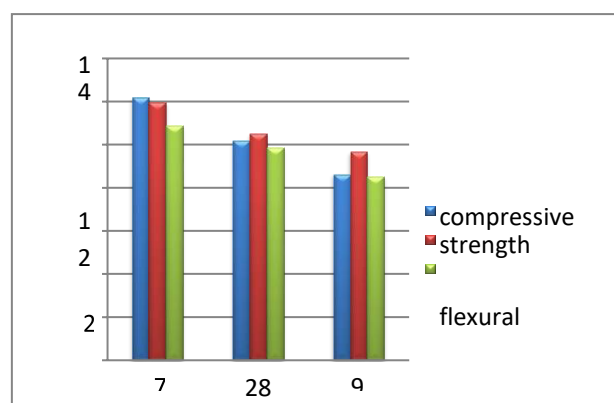


Figure 10. Percentages increases in strengths.

4. CONCLUSION

- Magnetic water technology offers significant improvement in the mechanical characteristics of ordinary concrete (compressive, flexural, and splitting tensile strength) without the need for supplementary materials.
- The compressive strength of ordinary concrete prepared with magnetic water (intensity of 9,000 Gauss), shows percentage increases of about 12.16, 10.16, and 8.62% at test ages 7, 28, and 90 days, respectively, as compared with the control tap water mix.
- The flexural strength of ordinary concrete made with the same magnetic water showed percentage increases of about 11.92, 10.48, and 9.66% at the same ages, respectively, as compared with the control tap water mix.
- The splitting tensile strength of ordinary concrete made with the same magnetic water showed percentage increases of about 10.88, 9.83, and 8.52% at the same ages, respectively, as compared with the control tap water mix.

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