Influence of Magnetized Mixing Water on Different Levels of Concrete Strength using Different Curing Processes

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ABSTRACT

This study investigated the impact of using Magnetic Water (MW) in concrete mixes on the mechanical properties of three normal concrete strength grades (15 MPa, 27.5 MPa, and 40 MPa) cured with three different methods (normal curing, water spraying, and coating). Compressive, flexural, and splitting strengths were tested. Results revealed that for the 15 MPa concrete, water spraying reduced compressive strength by 15.76% at 28 days compared to normal curing while coating curing increased it by 15.63%. Similar trends were observed for the 27.5 MPa (13.98% decrease for spraying, 13.60% increase for coating) and 40 MPa (10.81% decrease for spraying, 10.60% increase for coating) concrete grades. Flexural and splitting strength tests followed a similar pattern. For all concrete grades, water spraying led to reduced strength, while coating curing improved it. Overall, coating curing yielded the most favorable results across all strength grades, with the 15 MPa concrete showing the most significant improvements. These findings highlight the potential benefits of utilizing magnetic water in combination with coating curing to enhance the mechanical properties of concrete.

Keywords-compressive strength; magnetic water; normal curing; spray curing; flexural strength; splitting strength

I. INTRODUCTION

Water that pass through a magnetic flux becomes magnetized water. The method and quality of the water used determine the magnetism [1]. In the water molecule, the oxygen atom and the two hydrogen atoms are connected by angles of about (104.5°). This angle reduces to 103° after exposure to magnet flux. Bond deflection occurs and the molecules come closer to each other [2] forming clusters [3]. The magnetized water surrounding cement particulates is thinner than ordinary water and this is the reason for the low consumption of water for this kind of concrete. After magnetization, the structure of water is oriented in one direction, and the molecule sizes vary as the bond angle changes. As a result, viscosity and surface area rise by magnetism, broken hydrogen bonds result in the formation of stronger hydrogen bonds, which contribute to a higher viscosity [4, 5]. In addition to increasing characteristics of the resulting concrete, the use of MW also augments durability by lowering the ability of concrete to absorb water and lowering porous content by treating ordinary water [6, 7]. The consequences of using MW on concrete were explored in [8]. The outcomes revealed compressive strengths between 5.5 and 32.5 MPa, primary setting times between 4 and 32 min, and final setting times between 303 and 546 min, when utilizing ordinary and magnetized water. That recirculation time was also evidenced in [9]. When the pH of MW raised from 6.68 to 7.87, by about 60 min, the resulting workability was raised the moment the slump value of magnetic water was 50 mm with a water/cement ratio of 0.30, with an average increment in the compressive strength of 37.41% when matched to tap water. Authors in [10] revealed that there was a minor upsurge in concrete characteristics and a drop of about 7.5% in cement content achieved when utilizing WM in place of ordinary water, and hence, the resultant concrete was more sustainable. The curing process is the hydration of cement constituents, which is subjected to conditions like temperature and moisture content. Curing is successful when the water filled pores are replaced by products of hydration which give to the resulting concrete its known characteristics. It is necessary to allow for the infiltration of water into the concrete in order to replenish the additional water lost internally due to self-desiccation [11]. Concrete curing techniques fall into two primary categories: those that preserve water availability and those that reduce mixing water loss from concrete by sealing its exposed surfaces. The use of wet covers, ponding or immersion, fogging, and sprinkling are techniques for preserving the water supply for concrete curing [12, 13]. Proper curing helps retain the moisture within the concrete and slow down the hardening process, giving it time to settle and strengthen. Without curing, the surface will dry too quickly, causing the surface to shrink and crack [14, 15]. The aim of the study is to investigate the change in the properties of concrete with MW in three different curing conditions.

II. EXPERIMENTAL PART

A. Materials

1) Ordinary Portland Cement (OPC)

OPC type (IQS 5 Cem1 42.5R) was employed. The physical and chemical composition of the used cement are shown in Tables I and II. The cement utilized met both [16, 17] requirements.

TABLE I. PHYSICAL CHARACTERISTICS OF THE OPC

Property	Value	Limits of [16]
Specific surface area (m^2/kg)	386	≥ 280
Soundness by Autoclave (%)	0.17	≤ 0.8
Setting time (Vicat's meyhod)-Initial	130 min	≥ 45
Setting time (Vicat's method)-Final	269 min	≤ 600
Compressive strength, 2 days (MPa)	25.55	≥ 20
Compressive Strength, 28 days (MPa)	45.48	≥ 42.5

TABLE II. OPC CHEMICAL COMPOSITION AND MAIN COMPLEXES

Oxide compositions	Abbreviations	Results	Limits of [17]
Insoluble residue	IR	0.64	Max (1.5)
Magnesia	MgO	2.78	Max (5)%
Loss on Ignition	LOI	2.68	Max (4)%
Sulfate	SO_3	2.45	2.8 if C_3A>3.5
***Main Compounds of Cement**			
Tricalcium Aluminate (C_3A) %		6.8	
Tricalciumsilicate (C_3S) %		58.91	
Dicalcium silicate (C2S) %		13.13	
Teracalcium alumino-ferrate (C4AF) %		12.84	

* Bogue equations calculation according to ASTM C150

2) Fine Aggregate

The physical and sulfate content tests for the sand deployed are presented in Table III, which confirms compliance with [16] for zone 2.

3) Coarse Aggregate

Coarse aggregate in saturated and surface dry conditions with nominal maximum aggregate size of 20 mm was used for the preparation of concrete mixtures. The physical and chemical properties of coarse aggregate were checked in accordance with [16] as evidenced in Table IV.

4) Water

Normal Water (NW) complying with the quality assurance requirement for mixing and curing concrete [18] was used for mixing and curing.

TABLE III. PHYSICAL AND CHEMICAL PROPERTIES OF THE USED SAND.

Physical and chemical characteristics	Result	Limits of [16]
Fineness modulus	2.79	------
Sulfate content (%)	0.09	Max.0.50
Specific gravity	2.62	-------
Absorption (%)	1.2	--------
Fine aggregate grading		
Sieve size (mm)	**Passing (%)**	**Limits of [16] zone 2**
10	100	100
4.75	88	90-100
2.36	76.8	75-100
1.18	68.8	55-90
0.3	55.8	35-59
0.6	26.24	10-30
0.15	5	0-10

TABLE IV. COARSE AGGREGATE PHYSICAL AND CHEMICAL ANALYSIS

Physical and chemical characteristics	Result	Limits [16]
Sulfate content (%)	0.08	Max.0.10
Specific gravity	2.57	-------
Absorption (%)	0.6	--------
Dry roded unit weight, %	1565	-
Grading of coarse aggregate		
Sieve size (mm)	**Passing (%)**	**Limits [16] zone 2**
37.5	100	100
20	98	95-100
10	34.5	30-60
4.75	1.25	0-10

5) Magnetized Water (MW)

MW production begun by passing NW throughout a magnetic water device of 0.9 T intensity [19-21]. Table V depicts the properties of NW and MW and Figure 1 portrays the MW system used.

TABLE V. CHEMICAL PROPERTIES OF NW AND MW

Water type	No. of cycles	PH	Total Dissolved Solids (TDS) (mg/L)	Surface tension (mN/m)
NW	-	7.1	620	71
MW	100	7.35	580	63
	150	7.5	576	56
	200	7.52	574	55

Fig. 1. Magnetic water system.

B. Mixing and Sample Preparation

1) Mixing

The prepared mixture was conducted adopting the American mix design method (ACI 211.1-91) [22]. Table VII presents the adopted compressive strength and its water-cement ratio. For a high compressive strength of 40 MPa for cylinders or 50 MPa for cubes, the content ratio of cement, fine aggregate, coarse aggregate, and water was 488, 655.3, 1000, 205 kg/m^3. The mix proportion was 1:1.34:2.05, for a moderate compressive strength of 27.5MPa for cylinders. For a modrate compressive strength of 34.5 MPa for cubes the mix proportion was 1:2.13:2.80. For a low compressive strength of 15 MPa for cylinders or 18.75 MPa for cubes the mix proportion was 1:3.23:3.85, as presented in Tables VI and VII. The slump range for all mixes ranged from 75 to 100 mm.

TABLE VI. WATER-CEMENT RATIO AND COMPRESSIVE STRENGTH OF 28 DAYS CURED CONCRETE

Compressive strength at 28 days (MPa)	Water cement ratio by mass	Design strength level
40	0.42	High W/C = 0.42
35	0.47	
30	0.54	Medium W/C = 0.575
25	0.61	
20	0.69	
15	0.79	Low W/C = 0.79

TABLE VII. MATERIAL CONTENT FOR CONCRETE DESIGNED ACCORDING TO [22]

Specified compressive strength (MPa)	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Water (kg/m^3)
Maximum level 40 MPa (50 MPa for cubes)	488	655.3	1000	205
Medium level 27.5 MPa (34.5 MPa for cubes)	357	762	1000	205
Minimum level 15 MPa (18.75 MPa for cubes)	260	840	1000	205

2) Sample Preparation

The freshly mixed concrete was poured into 100 × 100 × 100 mm cube-shaped steel molds, which were later used for testing the concrete's compressive strength and density. The 100 × 100 × 400 mm specimens were utilized for testing the concrete's flexural strength and 150 × 300 mm specimens were employed for testing the concrete's tensile strength. All the molds were thoroughly cleaned before being lubricated with mineral oil to prevent concrete adhesion after the hardening process. Cube molds were compacted in two layers, with each layer being manually stacked at a rate of 25 strokes/layer, according to [23, 24]. The prisms were poured in two layers and manually stacked at a rate of 28 strokes/layer, while the cylinders were cast in three layers and manually stacked at a rate of 25 strokes/layer. After having completed the preparation of specimens, they were immediately covered with a layer of nylon sheet to maintain moisture and prevent evaporation for a period of 24 h. They were then opened from the molds and immersed in NW tank at 23° C for curing, water spraying, and coating, until the time of the examination, i.e. after 7, 28, 90 days. Figures 2 and 3 display the curing of specimens.

3) Testing

The compressive strength of cubes was tested according to the specifications from [24, 27] and the splitting tensile test according to the specifications from [25], while the flexural strength test followed [26].

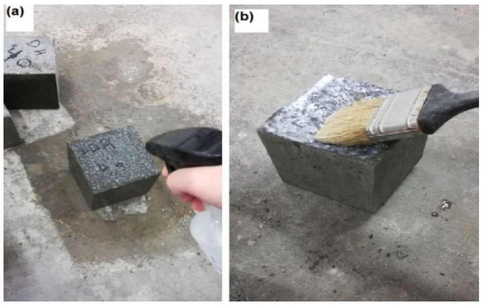

Fig. 2. (a) Water spraying, (b) coating.

Fig. 3. Normal curing of samples.

III. RESULTS AND DISCUSSION

A. Compressive Strength for Different Curing Methods (Normall Water)

The compressive strength results show higher improvement in the compressive strength for coating curing for 40 MPa in NW equal to 5.41, 4.19, and 3.45%, for 27.5 MPa equal to 4.47, 3.59, and 3.38%, and for 15 MPa equal to 4.05, 2.93, and 2.70% after 7, 28, and 90 days, respectively, in comparison with normal curing .When using water spraying as a curing method, the compressive strength reduced: For 15 MPa, the reduction was equal to 11.45, 10.47, and 8.11%, for 27.5 MPa it was 10.07, 9.11, and 7.27%, and for 40 MPa, it was 9.02, 8.38, and 7.07% after 7, 28, and 90 days, respectively, (Figure 5).

B. Compressive Strength for Different Curing Methods (Magnetic Water)

The improvement in compressive strength tests in 15 MPa when utilizing MW in the coating method was equal to 17.53, 15.63, and 13.59%. For 27.5 MPa it was equal to 14.64, 13.60, and 11.81%, and for 40 MPa it was 11.98, 10.60, and 10.35% after 7, 28, 90 days, respectively.

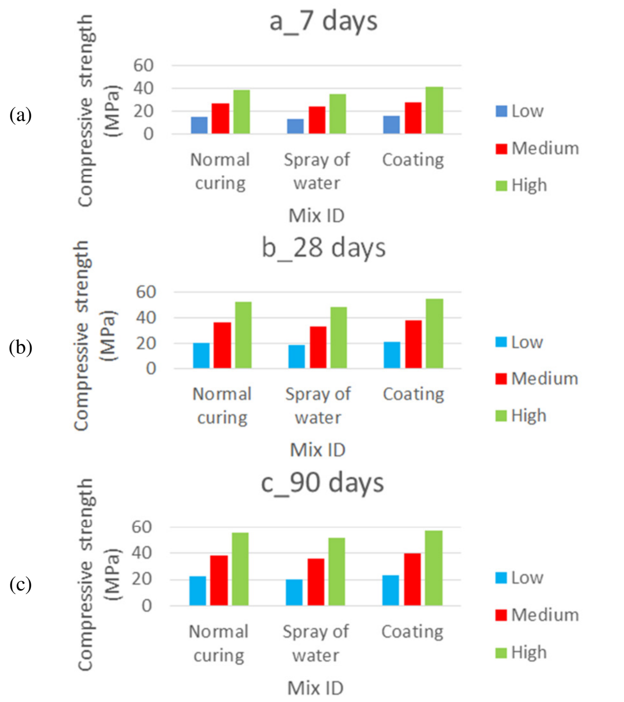

Fig. 4. Compressive strength results for different curing types utilizing NW after (a) 7, (b) 28, and (c) 90 days.

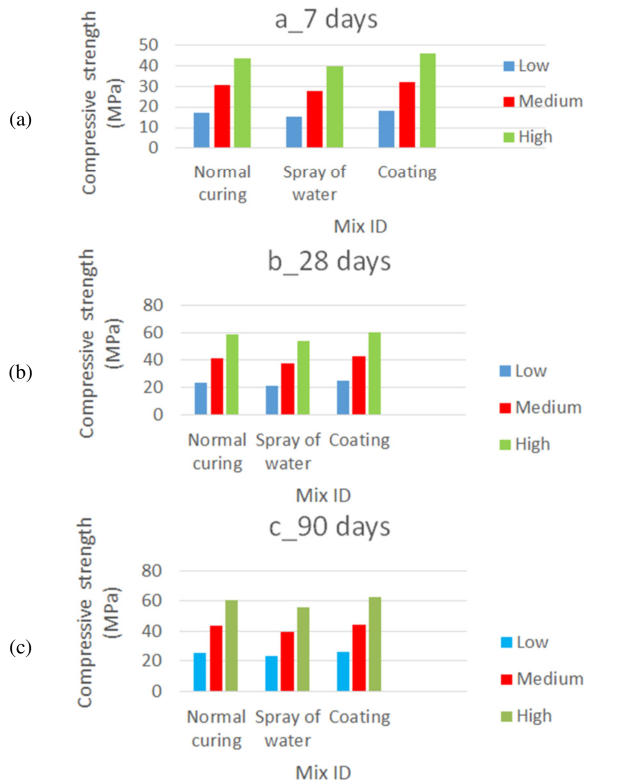

Fig. 5. Compressive strength results for different curing types utilizing MW after (a) 7, (b) 28, and (c) 90 days.

Water spraying in mixtures containing MW showed a reduction compared to normal curing: for 15 MPa, the reduction was equal to 11.56, 9.75, and 9.09%, for 27.5 MPa it was equal to 10.42, 9.20, and 8.08%, and for 40 MPa, the reduction was 9.40, 8.88, and 7.74% after 7, 28, and 90 days, respectively, (Figures 5 and 6). These results comply with [28]. The magnetic field causes reduction in the molecular weight of water in which the number of molecules reduces by half. This reduction leads to increased number of molecules participating in the hydration of cement thus the compressive strength tends to increase when using MW.

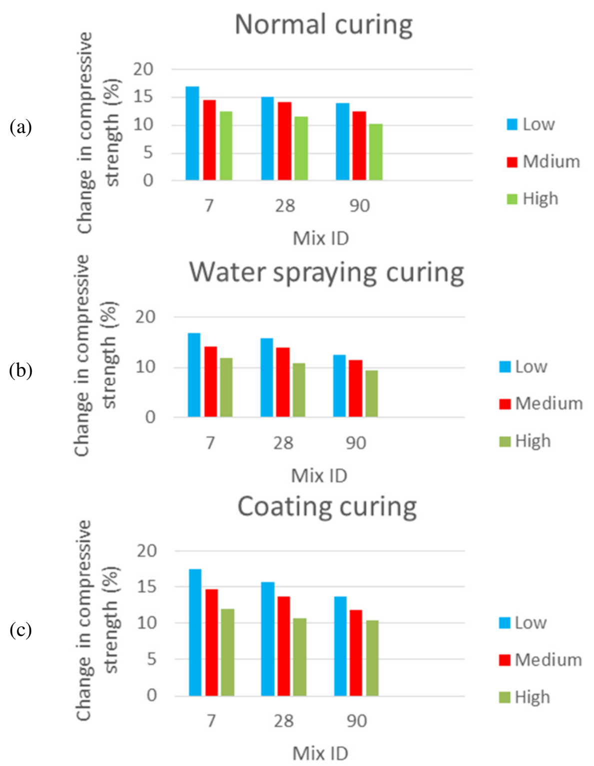

Fig. 6. Effects of MW vs curing method.

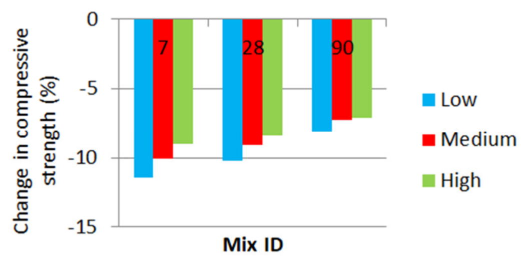

Fig. 7. Change in strength for spray curing vs normal curing with NW.

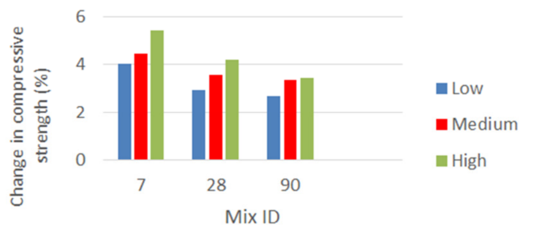

Fig. 8. Change in strength for coating curing vs normal curing with NW.

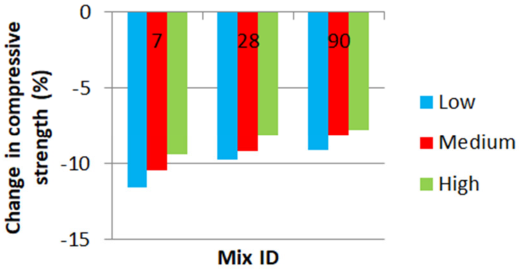

Fig. 9. Change in strength for spray curing vs normal curing with MW.

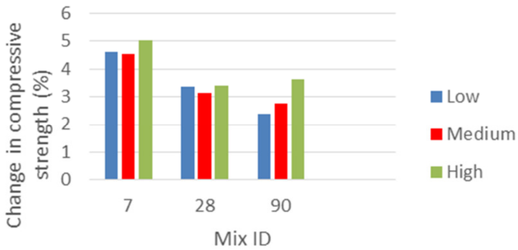

Fig. 10. Change in strength for coating curing vs normal curing with MW.

C. Flexural strength

Flexural strength improved when using MW in coating curing in comparison with normal curing, as can be seen in Figures 11 and 12. For 15 MPa, the increase was 11.44, 10.09, and 9.45%, for 27.5 MPa it was 7.92, 7.57, and 7.11%, and for 40 MPa, it was 7.39 ,7.18, and 6.08%, after 7, 28, and 90 days, respectively (Figures 11 and 12). These results comply with the findings of [29].

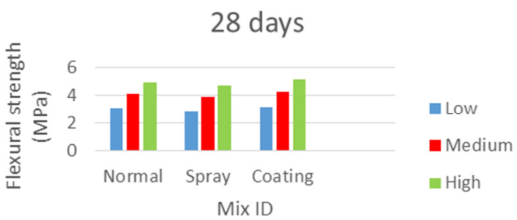

Fig. 11. Flexural strength results for different curing types utilizing NW after 28 days.

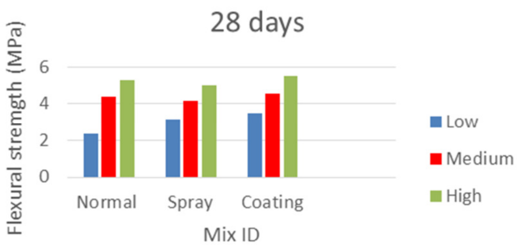

Fig. 12. Flexural strength results for different curing types utilizing MW after 28 days.

D. Splitting Strength

In 15 MPa mixtures. tensile strength increased when using MW in coating curing by 11.21, 10.0, and 9.59, while for 27.5MPa, the increment was equal to 7.41, 6.76, and 6.53%, and for 40 MPa, it was equal to 7.10, 6.60, 5.54%, after for 7, 28, and 90 days, respectively as observed in Figures 13 and 14. These findings are in accordance with [30].

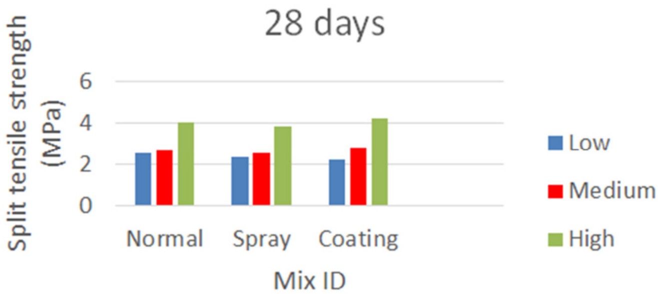

Fig. 13. Split tensile strength results for different curing types utilizing NW after 28 days.

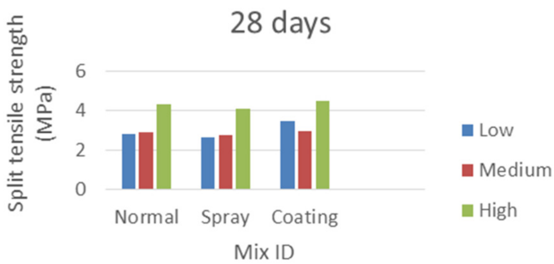

Fig. 14. Split tensile strength results for different curing types utilizing MW after 28 days.

IV. CONCLUSION

This paper discussed the effects of adding magnetized water to concrete mixtures and the impact of three different curing systems on the resulting concrete properties. For both normal and magnetic water, the best results were acquired for coating curing. The best percentage increase was for the results of low level (15 MPa) concrete. The main conclusions of the current study are:

- Compressive strength results for the three levels (15, 27.5, and 40 MPa) of concrete revealed a reduction for the spray curing and an improvement for the coating curing method when compared with normal curing. This proves that coating curing is the best choice for increasing compressive strength.
- The same trend was observed after testing flexural strength. There was a reduction in flexural strength for spray curing while there was an improvement in coating curing. This also proves the efficiency of coating curing in improving concrete properties.
- The splitting strength test also disclosed a reduction in the spray curing and an improvement in the coating curing method. This proves that coating curing enhances the mechanical properties of concrete and that the spray curing method was not proved to be useful in improving concrete properties.
- It was observed that the change percentage or the three strength tests (compressive, flexural, and splitting) is more

pronounced in the low level (15 MPa) concrete and it is almost the half for the high level (40 MPa) concrete.

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