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Experimental Investigation on Fresh and Hardened Properties of Concrete Mixed with Magnetically Treated Water

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ABSTRACT: *This paper presents the outcomes of an experimental study on the fresh and hardened properties of concrete made from local tap water and magnetically treated water. For this purpose, the M25 concrete was designed and the samples were made with tap water and magnetic water with different intensities, i.e. 0.8, 1.4, 2.0 and 2.6 tesla. Five concrete mixes were prepared in total, one with local tap water and four with magnetized water. The tap water went through a magnetic field composed of permanent magnets of same size and shape mixed in a series of 2, 4, 6 and 8 through opposite poles to magnetize the water at a speed of 0.25 liters/second. For all five mixes, slump, compressive, splitting tensile and flexural strength tests were conducted and it was observed, that compared to control mix, concrete samples made with magnetically treated water resulted enhanced strengths and improved workability when certain magnetic intensity levels were used.*

KEYWORDS:– *Magnetized water, Compressive strength, split tensile strength, Flexural strength, Permanent magnets.*

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I. INTRODUCTION

Every year, more than a billion tonnes of water is used in concrete manufacturing exercises [1]. The water used in the preparation of concrete plays an important part, with adequate care to obtain the desired strength, beginning with the operation of the cement hydration process, the maintenance of concrete structures and not to mention, workability and stability. Potable water or tap water is widely applied in concrete manufacturing to prevent the presence of contamination. In addition to this problem, the inadequate supply of potable water around the globe has posed a big problem of improving the incorporate of water in concrete construction. The use of magnetized water can increase the savings of water used in concrete buildings [1, 2].

Magnetic field treated water (MFTW) or magnetized water is the one which run through a magnetic field with a specific force. Magnetic force splits water clump into smaller molecules in the magnetic field, thereby enhancing water behavior. MFTW can percolate more effectively into the thrust region of cement particles when hydrating cement particles. Thus, on particles of cement, a lean layer of hydration product is produced, enabling the hydration phase more completely. Hydration thus can be carried out more effectively, which in result increases the strength of concrete. Besides the increase in compressive strength, the treatment of concrete with magnetic water also increases durability parameters, such as improving concrete density and reducing water absorption rate[3].Similar studies were carried out in Japan, with Taiwan confirming that concrete strength can be improved by 10-19% with the use of MTFW as compared to the concrete made with tap water [4, 5].Soto-Bernal et al.,[6], studied the effects of magnetic fields on the physical, micro-structural and mechanical properties of concrete. In their experimental work, three separate magnetic induction forces on cement paste in controlled environment conditions were used. It was discovered that the hydration rate was accelerated over a span of time and the hydration temperature was improved relative to non-magnetic water samples. With the magnetic treatment of tap water, a drop in porosity in concrete was also observed [6]. Myoung Sung Choi et al., [7], studied the consequences of the external imposition of the electromagnetic field on the arrangement of the greasing layer in the pumping of concrete. Tests were carried out on pumping circuits 1,000 m in original length and 125 mm in original diameter, suggesting that this process increased the capacity of the concrete pump-ability due to the improvement in the characteristics of the lubricant layer between the pipe wall and the concrete interface.H. Afshin et al., [8], used magnetic water in concrete mixes and enhanced the mechanical properties of high strength concrete. They observed that groups of water decreased from 13 to 5 or 6 when normal running water passed through the magnetic field, causing a drop off in the surface tension of the water. The compressive strength and workability of concrete were found to be increased by using magnetized water in concrete mixes and it reduced the requirement of the cement content, to achieve the specified compressive strength value [8]. Gholizadeh and Harabshahi [9], investigated the effects of the magnetically processed water on the compressive strength and workability of concrete. They found that the slump when magnetic water was applied to prepare the mix, had risen by 7 cm. They concluded that the need for

water had been decreased and that the concrete's compressive strength also increased by 23%. They also found that concrete prepared in this manner was more durable and more impermeable to the action of freezing and thawing.

II. MATERIALS AND METHODS

2.1 Cement

ASTM Type I Portland cement supplied by the Lucky cement factory (Karachi Sindh) and compatible with the American Association for Testing and Materials was used in the present study. The chemical composition of the cement is shown in Table 1.

Table 1 Chemical composition of Portland cement

Oxide	Content %
Silicon dioxide (SiO_2)	20.96
Aluminum Oxide (Al_2O_3)	5.24
Iron Oxide (Fe_2O_3)	2.93
Calcium Oxide (CaO)	63.94
Magnesium Oxide (MgO)	2.03
Sodium Oxide (Na_2O)	0.58
Potassium Oxide (K_2O)	0.22
Sulphur (SO_3)	2.59
Loss in Ignition (LOI)	1.42

2.2 Aggregates

Locally available fine and coarse aggregates were used in the preparation of all concrete mixes. Coarse aggregate had a maximum size of 20 mm, unit weight of 1395 kg/m^3, and specific gravity of 2.66. The particle size distribution of both fine and coarse aggregate is shown in Figures 1 and 2 respectively.

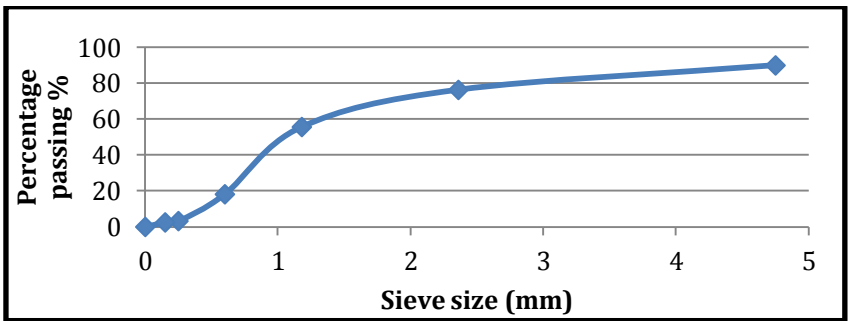

Figure. 1 Particle size distribution of fine aggregate

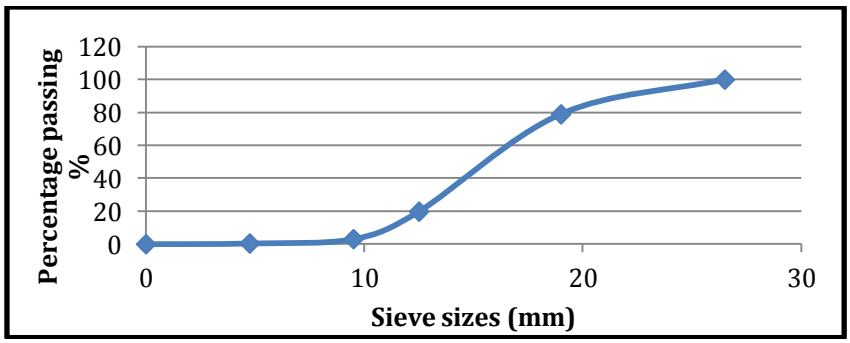

Figure. 2 Particle size distribution of coarse aggregate

2.3. Mixing Water

For preparing the concrete mixes, in this research study, two forms of water viz tap water and magnetized water were used. The magnetized water was produced at a constant rate of 25ml/sec by passing tap water through permanent magnets of different intensities, i.e. 0.8, 1.4, 2.0 and 2.6 tesla.

2.4. Mix Design

This experimental work was carried out on five mixes to evaluate fresh and hardened properties of concrete. For this purpose, control mix with target strength of 25MPa was designed. Water/cement ratio of 0.49 was kept constant and used for all the mixes. The quantities of different constituent materials are presented in Table 2.

Table 2: Concrete Mix Proportions

Materials	Quantity (kg/m^3)
Cement	370
Fine Aggregate	665
Coarse Aggregate	1085
Water	182

III. RESULTS AND DISCUSSION

3.1Fresh Properties:

To evaluate the fresh properties of all concrete mixes, the conventional slump test was performed. The slump test was performed in compliance with BS EN 12350-2[15] and assessed directly after mixing. Table 3 and Figure 4 present the slump test values for all five mix proportions. Test results indicate that concrete Mix:1 and Mix:2 prepared with magnetized water of intensity 0.8 and 1.4 tesla respectively produced higher slump values than those for non-magnetized concrete. The increase in slump of Mix: 1 and Mix: 2 by 33.3% and 55.5% respectively was observed. However, a decrease in slump values of Mix: 3 and Mix: 4 by 22.2% and 44.4% respectively were observed. Slump values illustrate that the workability of concrete was best with the use of magnetized water of intensities 0.8 and 1.4 tesla. This might be due to magnets which were combined by opposite poles and caused changes and effects on ion clusters and water molecules passing through their magnetic field. A magnetic field has a significant influence on the molecular clusters of water and causes a decrease in the size of molecules of water within it, resulting higher slump values [10, 11].

Table:3 Slump Test Results of Different Concrete Mixes

Mix No.	Mix ID	Slump value (mm)
1	CM	45
2	MIX:1	60
3	MIX:2	70
4	MIX:3	55
5	MIX:4	25

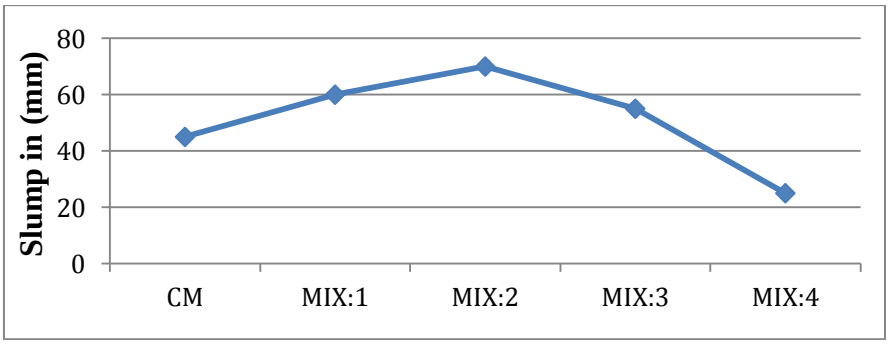

Fig: 4 Slump Test Results of Different Concrete Mixes

3.2. Hardened Properties:

To assess the hardened properties of concrete, compressive, splitting tensile and flexural strengths were performed. All the tests were performed in accordance with the BS EN 12390-3-5-6 [16-18] set at the ages of 3, 7, 28 and 90 days respectively. For each mix composition, a total of three concrete specimens were tested at each curing age and average of these is reported here.

A. Compressive strength of concrete.

The compressive strength test results of control mix and mixes prepared with different magnetic intensities of magnetized water are presented in Table 4 and shown graphically in Fig. 5. For the same w/c ratio, improved compressive strength was observed when magnetized water was used relative to standard tap water. It was observed that the magnets having intensities 0.8 tesla and 1.4 tesla enhanced the compressive strengths as compared to the strength values of control mix. This might be due to the fact that water molecules are polar in nature and are attracted to each other by clusters / molecular groups forming a hydrogen bond [12].

Decomposition of water molecule clusters into small groups and reorganization is accomplished by magnetic water treatment, allowing water to penetrate easily into cement grains [13, 14], leading to efficient hydration resulting higher compressive strength [4].However, it can be seen that the strength values increased up to an optimal limit of magnetic intensity and the concrete mixes produced with higher intensities of magnetized water i.e. 2.0 tesla and 2.6 tesla gave reduced compressive strength values at all ages. This might be due to the reason that PH of water increases too much and becomes alkaline leading to reduced compressive strength values.

Table: 4 Compressive Strength of Concrete Mixes at various ages

Mix ID	Compressive strength (MPa) at Different ages			
	3 days	7 days	28 days	90 days
CM	30.74	32.09	41.62	42.57
MIX:1	33.34	36.92	43.56	43.59
MIX:2	35.71	38.77	46.53	47.57
MIX:3	23.40	25.42	34.21	35.03
MIX:4	22.28	232.88	28.19	29.97

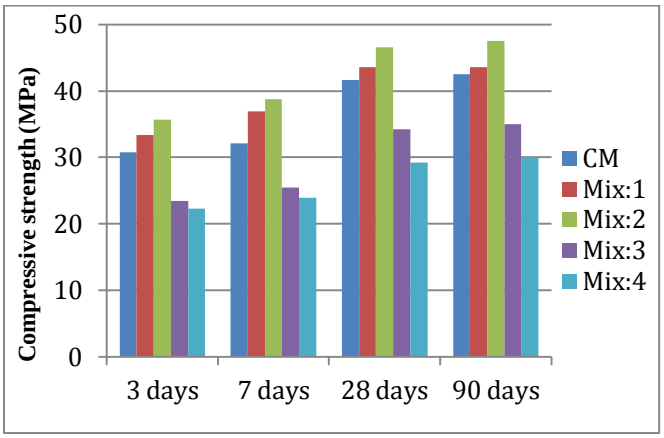

Fig: 5 Compressive Strength of Concrete Mixes at various ages

B. Split tensile strength of concrete.

The splitting tensile strength test results for all five mixes are presented in Table 5 and shown graphically in Fig. 6. From Table 5 and Fig.6, it can be seen that similar to compressive strength, the utilization of magnetized water in the concrete mixes up to certain limit increased the tensile strength of concrete mixes at all curing ages. It was observed that the concrete mixes prepared with magnetized water of intensities 0.8 tesla and 1.4 tesla produced higher results as compared to the control mix. Compared to 28 days tensile strength value of 3.21 MPa of control mix, a strength value of 5.08Mpa (58.25% increased) was achieved when magnetized water of 1.4tesla was used in the concrete mix. Also an enhancement of 47.6% in the tensile strength at 90 days was achieved. However, further increase in the intensities of magnetic water (i.e. 2.0 tesla and 2.6 tesla) in the concrete mixes reduced the strength values at all ages.

Table:5.Tensile Strength of Concrete Mixes at various ages

Mix ID	Tensile strength (MPa) at Different ages			
	3 days	7 days	28 days	90 days
CM	1.01	1.92	3.21	3.78
MIX:1	2.79	3.82	4.32	4.70
MIX:2	4.04	5.33	5.08	5.58
MIX:3	3.46	3.69	2.35	2.77
MIX:4	1.21	1.90	2.13	2.60

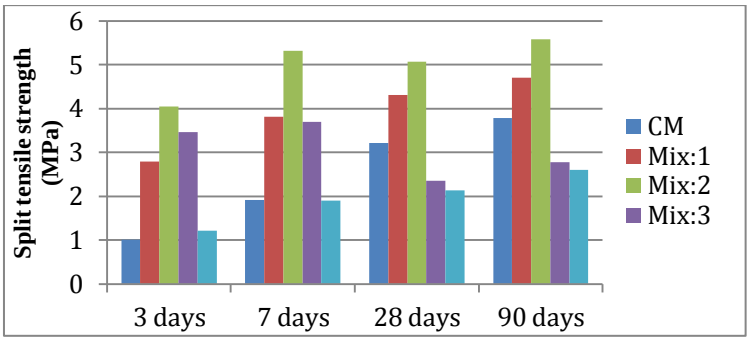

Fig:6. Tensile Strength of Concrete Mixes at various ages

C. Flexural strength of concrete.

The flexural strength test results of all concrete mixes prepared by replacing tap water with magnetized water at various curing ages are displayed in Table 6 and Figure 7. For the same w/c ratio, improvements in flexural strength were observed when magnetized water was used relative to standard tap water. From Table 6 and Fig 7, it can be seen that similar to compressive and tensile strengths, the utilization of magnetized water in the concrete mixes increased the flexural strength of concrete mixes up to certain limit, however, further increase in the magnetic intensity of water in the concrete mix reduced the flexural strength of concrete at all respective ages. Compared to 28 days strength value of 8.66 Mpa of control mix, a strength value of 10.30 MPa (18.9% increased) was achieved when magnetized water of 1.4tesla was used in the concrete mix. Also, resulted an enhancement of 18.5% in the flexural strength at 90 days. However, further increase in the intensities of magnetic water (i.e. 2.0tesla and 2.6 tesla) in the concrete mixes reduced the strength values at all ages.

Table: 6. Flexural Strength of Concrete Mixes at various ages

Mix ID	Flexural strength (MPa) at Different ages			
	3 days	7 days	28 days	90 days
CM	5.43	7.41	8.66	9.19
MIX:1	6.52	8.61	9.40	9.90
MIX:2	8.14	9.53	10.30	10.89
MIX:3	3.81	6.08	8.31	8.89
MIX:4	3.55	5.25	1.09	7.86

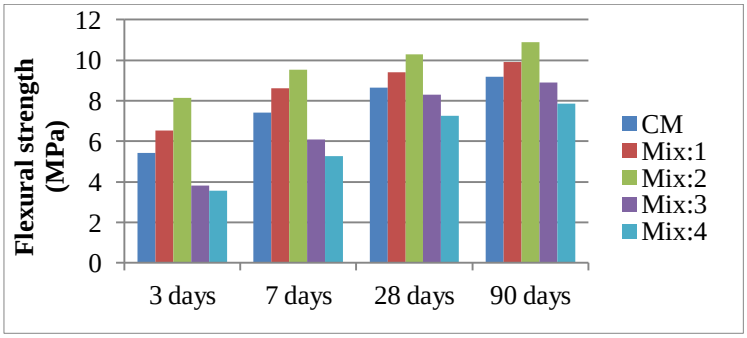

Fig: 7. Flexural Strength of Concrete Mixes at various ages

IV. CONCLUSION.

Experimental work was carried on fresh and hardened concrete to find out effect on properties of concrete made from local tap water and magnetically treated water. Based on the experimental investigations, the following conclusions can be drawn:

1. Magnetized water improved the workability of concrete. Compared to control mix, magnetized water increased the workability of concrete by 33.3% and 55.5% respectively when magnetic intensity of 0.8 tesla and 1.4 tesla respectively were applied. However, further increase in magnetic intensities caused reduction in the slump values of concrete. A decrease of 49.3% was observed when magnetic intensity of 2.6 was applied.

2. Compared to control mix, a maximum of 12 % increase in compressive strength of concrete was observed when magnetized water with a magnetic intensity of 1.4 tesla was used in the concrete mixes. Further increase in the magnetic intensity of water resulted decrease in the compressive of the concrete mix.
3. Similar trend of results was observed for tensile and flexural strengths of concrete. Compared to control mix, a maximum of 58.3% and 19% increase was recorded for splitting tensile and flexural strengths of concrete, respectively when magnetized water with a magnetic intensity of 1.4 tesla was used in the concrete mixes. Further increase in the magnetic intensity of water resulted reduction in the strength values of concrete.

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