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Influence of magnetized water on concrete by replacing cement partially with copper slag

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ABSTRACT

Magnetized water is an emerging technology in the construction industry. The benefits of using magnetized water in the production of concrete have been found significant in the present study. This paper describes the experimental study conducted by casting 150 copper slag concrete samples prepared with tap water and magnetized water to investigate the influence of magnetized water on the compressive strength, flexural strength and split tensile strength of concrete which contained copper slag. Water used for mixing the concrete was passed through a magnetic field of 1 Tesla. The decrease in the surface tension of tap water after magnetization was found to be 7.77%. The percentage of replacement of cement with copper slag was 0%, 10%, 15%, 20% and 30%. The results indicate that there was an increase in the compressive strength of concrete by 4-18% when mixed with magnetized water in comparison with the concrete mixed with tap water. Similarly, the split tensile and the flexural strength of concrete mixed with magnetized water was increased 6-17% and 5-10% respectively more than that of control mix. It was also determined that workability of magnetized water concrete containing copper slag was increased up to 50%. The microstructure of copper slag concrete prepared with magnetized water have large amount of C-S-H in comparison with tap water. It was observed that concrete with 85% cement + 15% copper slag shows the maximum strength parameters in comparison with other concrete mixes.

Keywords: Magnetized water, Copper slag, Cement replacement, TWC – Tap Water Concrete, MWC- Magnetized Water Concrete

1. INTRODUCTION

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement (M.S.Shetty, 2005). It governs the hydration of cement, workability, microstructure, strength and overall durability of concrete. Water used for manufacturing as well as curing of concrete should be clean and free from oils, acids, alkalis, salts, organic materials and any substance that affects the properties of concrete. Generally the water used for making the concrete is potable tap water (Pankaj Goel and Dr Rakesh Kumar 2014). Some researchers have used magnetized water in the preparation of concrete. Magnetized water is formed by passing the water through a magnetic field of certain strength under specific conditions. Generally, when water gets magnetized, there is a reduction in the surface tension of water which is measured using the apparatus called Tensiometer.

Further, Magnetization of water leads to change in structural elements of water, viscosity and electrical conductivity of water (Joshi et al. 1966). The reduction in the surface tension of water provides the breakage of large water clusters into smaller water clusters. This leads to the change in the trajectory of water particles providing much better bonding between the other materials added to the water (Lazarenko and Zhuravlev 1985) and faster and complete hydration of cement takes place (Nan Su et al. 2000). This leads to the improved engineering properties of concrete such as workability, compressive strength, flexural strength and split tensile strength.

Research papers of Tawfic et al. (2013), Saddam M. Ahmed (2009) and Karam et al. (2013) reviewed the potential use of magnetized water in improving the engineering properties of concrete. The effect of magnetized water on concrete containing GBFS and Fly ash was investigated by Nan Su et al. (2000, 2003). He observed that the increase in the compressive strength was significant at an early age of concrete when the magnetic strength of water was 0.8 T and 1.2 T. H.Afshin et al. (2010) investigated the Mechanical Properties of High Strength Concrete by Magnetic Water Technology and he observed that the increase in slump and compressive strength was up to 45% and 18% respectively when magnetic water was used for concrete preparation. He also determined that, with the same slump and compressive strength, cement content could be reduced by 28% in the case of magnetic concrete. These improved properties of concrete can be obtained without the use of any chemical admixture which avoids environmental pollution.

On the other hand, Copper slag is a by-product obtained from the process of manufacturing of copper. Copper slag is widely used in the sand blasting industry and it has been used in the manufacture of abrasive tools. Nowadays, Copper slag, due to cheaper cost, has been used in the production of concrete as a partial replacement of cement and fine aggregate. Its mechanical and chemical properties makes it suitable to be used in the production of concrete (Gorai et al. 2003). Copper slag exhibits pozzolanic properties since it contains a low calcium oxide content and other oxides such as Al2O3, SiO2 and Fe2O3. The summation of these three oxides in copper slag is nearly 95%

which is more than the minimum requirement (70%) of any pozzolana that can be used as a cement binder in concrete as specified by ASTM C618-78.

Lot of studies have proved that copper slag could be used as a partial replacement material for cement and sand in concrete. However, there are no studies available about the effect of copper slag as partial replacement of cement on magnetized water concrete. This study would be helpful to reduce the consumption of cement in concrete and to obtain enhanced properties of concrete without the use of chemical admixtures.

This paper presents the study of the effect of copper slag has as a supplementary cementing material in concrete, engineering properties of concrete containing copper slag at 0%, 10%, 15%, 20% and 30% replacement levels when magnetized water is used for mixing the concrete.

2. EXPERIMENTAL WORK

Materials: The materials used in the experimental program were Cement, Copper slag, coarse aggregates, Fine aggregates, Magnetized Water.

Cement: Ordinary Portland cement of 43 grades conforming to IS: 8112 – 1989 has been used. The physical properties of the cement were studied by conducting appropriate tests. The specific gravity and standard consistency of cement was found out to be 3.6 and 31% respectively. The initial and final setting time of cement was determined as 60 and 400 minutes respectively.

Copper slag: Copper slag used in this experimental work was grinded to match the size of the cement particle. It is black glassy and granular in nature. The specific gravity of copper slag was found to be 3.56. The chemical composition of copper slag are given in Table 1.

Table.1.Chemical Composition of Copper Slag

Fe as FeO	SiO	Al_2O_3	CaO	MgO	CuO	Free Silica	Sulphates
55%	30%	5%	1%	0.8%	0.075%	<0.5%	0.1%

Coarse aggregates: The coarse aggregate used in this study was crushed (angular) aggregate of size 20 mm and 10 mm conforming to IS 383: 1970 reaffirm 1997. Tests such as sieve analysis, specific gravity and water absorption were conducted for coarse and fine aggregates as per the specification of IS: 383-1970 reaffirm 1997 and IS 2386-1963 reaffirm 1997.

Fine Aggregates: Locally available clean river sand passing through 4.75 mm sieve have been used. The fine aggregate was of Zone II. The physical properties of coarse and fine aggregates are shown in Table 2.

Table.2.Physical Properties of Coarse and Fine Aggregates

Properties	Type of Aggregate		
	Coarse Aggregate		Fine Aggregate
	10 mm	20 mm	
Specific gravity	2.74	2.73	2.63
Water Absorption (%)	0.94	1.01	1.3

Magnetized water**:** Water used for mixing the concrete was circulated through a magnetized water-setup as shown in Figure 1. PERMAG N406 magnetizer of strength 1 Tesla was used in the study. A pump was used to pass the water through the magnetizer and the velocity of water passed through the magnetizer was determined as1.32 m/s. The surface tension of tap water was found to be 0.07275 N/m

Figure.1.Magnetized Water Setup

and it was reduced by 7.77% after magnetization. The parameters of potable tap water and magnetized water were tested and shown in Table 3.

Table.3.Properties of Tap Water and Magnetized Water

Test Parameter	Test Results	
	Tap water	Magnetized water
Surface Tension (N/m)	0.07275	0.06750
Viscosity (m^2/s)	7.65×10^{-6}	7.13×10^{-6}
Electrical Conductivity (µs/cm)	343.20	353.30
pH	8.10	8.15

Mix design and testing plan: Mix design for M25 grade concrete was prepared confirming to IS 10262-2009. Two trail mixes were attempted and the best suitable mix was adopted for casting the concrete samples. Ingredients of different mixes used in the study are given in Table 4.

Table.4.Ingredients of different mixes for 1 cum of concrete (in kg)

Ingredients	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Remarks
Cement (C)	365	328.5	311	292	256	Total cementitious material in all mixes were 365 Kg/m^3
Copper Slag (CS)	0	36.5	55	73	110	
Water Content	199	199	199	199	199	All mixes were prepared with tap water (M-TW) and magnetized water (M-MW) separately.
Fine Aggregate	862	862	862	862	862	
Coarse Aggregate 10 mm 20 mm	 452 739	 452 739	 452 739	 452 739	 452 739	

Mix 1 consists of 100 % Cement. Mix 2, Mix 3, Mix 4 and Mix 5 were replaced with 10%, 15%, 20 % and 30 % of cement respectively. All other ingredient was kept same in the investigation. Cubes of size 100mm X 100mm X100mm, beams of size 100mm X 100mm X 500mm and cylinders of diameter 150mm and height 300mm were casted using a pan mixer. For compaction of the concrete specimens, each layer was given 25 to 35 manual strokes using 20 mm rod. Concrete specimens were vibrated using vibration table for another 10 to 15 seconds. Then, it was pond cured at room temperature and was tested at 7, 28 and 56 days.

3. RESULTS AND DISCUSSIONS

Effect of Magnetized Water on Workability of Concrete: Concrete mixes were checked for workability through slump test. Adequate workability or slump value was achieved for the control mix (TWC1). Due to the low water absorption, high specific gravity and glassy surface of copper slag, more amount of free water was present when copper slag was added in concrete. There was further increase in the slump value when magnetized water was added with copper slag in concrete. This was because of the dispersion effect of magnetized water on cementitious material. From the experimental study, it was observed that the slump of MWC containing copper slag was increased up to 50% in comparison with TWC containing the same amount of copper slag. It was also observed that, same slump value was achieved with reduced water content (10-12%) in MWC containing copper slag. The graph was prepared comparing the slump values of TWC and MWC for 0%, 10 %, 15%, 20% and 30% of replacement of cement with copper slag as shown in Figure 2.

Effect of magnetized water on compressive strength of concrete: The compressive strength of the concrete samples was measured at 7, 28 and 56 days. The graph was prepared between Compressive Strength vs. % of Copper slag used in the concrete for 7, 28 days as shown in Figure 3.

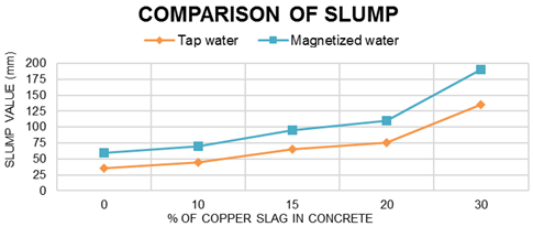

Figure.2.Slump vs. % of Copper slag (Water Content is Constant)

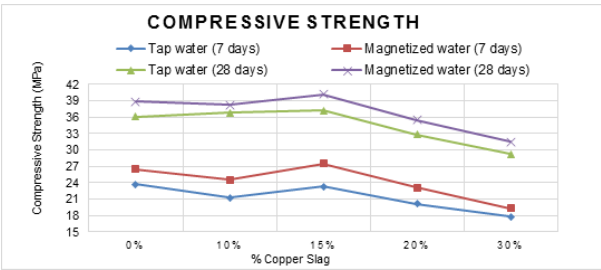

Figure.3.Comparison of Compressive Strength for Tap water and Magnetized water (7 & 28 Days)

Experimental results of compressive, split tensile and flexural strength (average of 3 cubes) are tabulated in Table 5.

The increase in compressive strength of MWC over TWC was significant at 7 days. It was observed the 7 day compressive strength of MWC with 85% Cement + 15% Copper slag (85C+15CS) as 27.53 MPa which was higher than 23.33 MPa that of control mix (TWC1). This 18% increase in the compressive strength of MWC over TWC1 could be due to the formation of more homogeneous mixture because of using magnetized water that cause complete hydration of cement particles, moreover copper slag provide filler and pozzolanic effect which reduce the

capillary pores and the discontinuity in packing. Nan Su et al. (2003) also observed 15% increase in 7 day compressive strength in MWC containing Fly ash.

Table.5.Experimental Results (Compressive, Split Tensile and Flexural Strength)

Concrete Mix	Average Compressive strength (MPa) (Days)			Average Split Tensile Strength (MPa)(Days)		Average Flexural Strength (MPa) (Days)	
	7	28	56	7	28	7	28
Mix 1 (100% C + 0% CS)							
TWC1	23.33	36.12	41.66	2.72	4.38	4.00	4.47
MWC1	26.43	37.50	43.16	2.87	4.43	4.27	4.53
Mix 2 (90% C + 10% CS)							
TWC2	21.33	36.80	42.33	2.88	4.72	3.87	4.40
MWC2	24.53	38.26	43.60	2.95	4.75	4.20	4.54
Mix 3 (85% C + 15% CS)							
TWC3	23.70	37.20	43.12	2.96	4.76	4.13	4.60
MWC3	27.53	40.16	44.46	3.18	4.80	4.40	4.73
Mix 4 (80% C + 20% CS)							
TWC4	20.14	32.87	38.33	2.74	4.60	3.73	4.33
MWC4	23.16	34.40	39.53	2.80	4.67	3.80	4.40
Mix 5 (70% C + 30% CS)							
TWC5	17.76	29.26	32.91	2.38	4.11	3.43	4.13
MWC5	19.36	30.16	33.13	2.41	4.14	3.46	4.20

Effect of magnetized water on split tensile and flexural strength of concrete: The Split Tensile and Flexural strength of concrete samples were measured at 7 and 28 days. The graphs were prepared for Split Tensile and Flexural Strength against % of Copper Slag in concrete for 7 and 28 days as shown in Figure 4 & 5 respectively.

Flexural strength of MWC with (85C+15CS) was 4.40 MPa which was higher than 4 MPa of TWC1. The 16.91% increase in split tensile strength and 10% increase in flexural strength of MWC over TWC1 was due to the mutual effort of magnetized water and copper slag. It was also observed that beyond 15% of cement replacement by copper slag in concrete exhibited lesser strength. This could be because of less cementitious material present in the mix and beyond 15% replacement, magnetize water might not support the increase in strength of concrete.

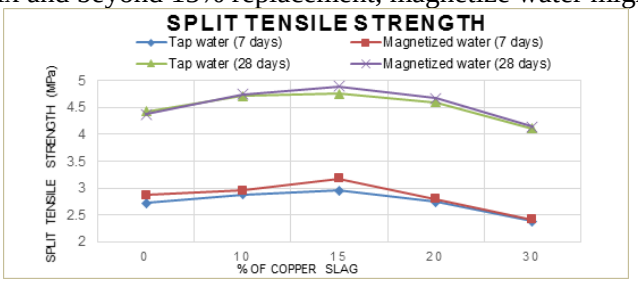

Figure.4.Comparison of Split Tensile Strength for Tap water and Magnetized water (7 & 28 Days)

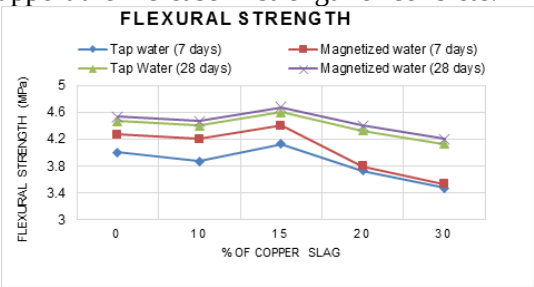

Figure.5.Comparison of Flexural Strength for Tap water and Magnetized water (7 & 28 Days)

Effect of Magnetized Water on Microstructure of Concrete: The engineering properties of concrete with (85C+15CS) was higher comparing to other mixes. Therefore, (85C+15CS) mix was observed under scanning electron microscope after 28 days of curing. Figure 6 (a) and (b) show the Scanning Electron Microscope (SEM) image of concrete prepared with tap water and magnetized water respectively. It was observed that large amount of C-S-H was found in magnetized water in comparison with tap water. It was also observed that larger calcium hydroxide Ca(OH)2 crystals were present in concrete prepared with tap water. However, Ca(OH)2 crystals were smaller and separated in the concrete prepared with magnetized water as cement reacts with the smaller molecules of magnetized water more easily resulting in faster and complete formation of C-S-H. This could be the reason for the increase in strength parameters of MWC.

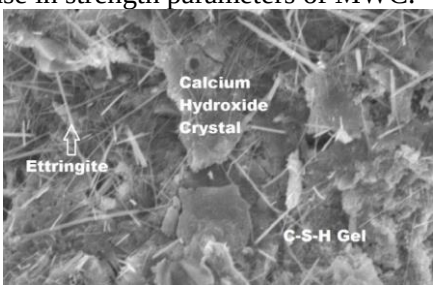

Figure.6(a).Microstructure of TWC at 5000X

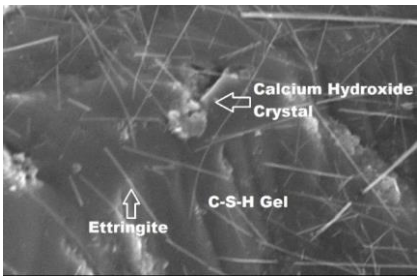

Figure.6(b).Microstructure of MWC at 5000X

Figure.6.Microstructure of copper slag concrete (85% cement + 15% copper slag)

4. CONCLUSION

Based on the results obtained in this experimental study, and within the limitations of the test parameters, the following conclusions could be drawn.

The use of magnetized water improves the workability (slump) of concrete containing copper slag up to 50% over control mix due to low water absorption of copper slag and dispersion effect of magnetized water. Hence, 10-12% of water content could be reduced without compromising the workability of the concrete. Since magnetized water has improved the flow properties, it could be advantageous to use in SCC mixes as it does not have any setting time issue which is generally found with admixtures used in SCC.

The Compressive, Split Tensile and Flexural strength were found maximum in concrete with 85% of Cement + 15% of Copper Slag with magnetized water. Hence replacement could be carried out for effective saving of cement in sustainable construction.

Early significant increase in strength parameters of concrete due to the use of magnetized water would be helpful for early removal of formwork of concrete. For high rise structures where time is important, the magnetized water could be the best option for concrete production.

The microstructure study shows that large amount of C-S-H at early age in MWC in comparison with TWC.

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