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Strength Enhancement on Mechanical Properties of Geopolymer Concrete with Magnetized Water and Recycled Coarse Aggregate

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Abstract: ***Cement is probably the mostly widely used construction material in the world. However, the production of cement releases CO_2 into the air. Greenhouse effect is mainly caused by carbon- di-oxide. Hence, there is a need to develop sustainable alternatives to Portland cement. One of the suitable alternatives is usage of Geo-Polymer Concrete (GPC) which is made from utilization of waste materials like fly ash and ground granulated blast furnace slag (GGBS) with suitable alkali activators. In general, chemical admixtures are added to get concrete with increased strength. The chemical admixtures for increasing the strength are not easily accessible in rural areas. The fresh and hardened properties of concrete are improved by using magnetic water. The scaling and corrosion are greatly reduced using magnetic water. It is due to the change in microstructure of water molecules making it soft water. Further, recycled coarse aggregate was used with coarse aggregate in the study. The specimens were cast and were investigated for Compressive strength, Split Tensile strength and Flexural strength test after 7 days and 28 days of ambient curing. It was observed that Compressive, Split Tensile and Flexural strength of the GPC specimen with magnetic water increased compared to other mix proportions.***

Keyword **: *Cement, Corrosion, Geo-polymer, Magnetic water.***

I. INTRODUCTION

The word magnet is derived from the word magnesia which was an island found near Greece where the traces of magnetic ore deposits were found first in early 600 B.C[1]. The use of magnetized water with GGBS increases strength by 9-19% in mortar and 10-23% in concrete [2]. The workability of fresh concrete is improved when the magnetic strength of water is above is 1.0 T and having the velocity of 0.65-0.8 m/s [3].

The magnetic water increases the strength by breaking water cluster of large size molecules into smaller one i.e. 13 into 5 (or) 6 , so that the magnetic water is able to penetrate easily into the cement particles, which enhances the hydration process and decrease the surface tension of water[4].

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Magnetic water was prepared with different magnetic strengths varying from 6000 to 9000 Gauss at the same velocity by passing the tap water through magnetic devices and found that the treatment of water with 9000 Gauss magnetic field intensity is the best treatment of water for preparing fresh concrete with higher strength [5]. The pH of the water is improved by treatment with magnetic devices. The branched particles in non-treated water is changed into spherical shaped particles when the water is subjected to magnetic flux [6]. Concrete samples prepared with magnetic water will have a higher degree hydration of 20.140 C than samples prepared with normal water [7]. The workability of the concrete is improved. Compressive strength can be increased with reduced cement content and the use of magnetized water [8]. The strength of magnetization in water is to be at least for 24 hours after treatment with magnetic device [9]. The SEM images showed a denser structure for concrete with magnetized water when compared to the concrete with tap water [10].

II. MATERIALS

A. *Fly Ash*

Fly ash is a Mineral admixture which is a by-product collected by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys. Class F fly ash collected from Mettur Thermal Power plant is used as binder in this study.

B. *Ground Granulated Blast Furnace Slag*

Ground Granulated Blast furnace Slag (GGBS) is a waste from iron slag. This slag is rapidly quenched in large volumes of water produces granular particles. This is ground to a fine powder. GGBS is added as a binder to accelerate the initial setting time of the concrete.

C. *Permag N406*

PERMAG is a type of rare earth metal made of Neodymium (N406). This type of magnet is used instead of other types of magnet like para , dia and ferro magnetic materials because it has high intense and focused magnetic field having a strength of 0.9 Tesla.

Figure 1. Permag N406

D. *Fine Aggregate*

Manufactured sand is used as fine aggregate which is obtained by crushing of hard granite stone is then shaped into cubical shape with grounded edges, washed and graded to as a construction material is used in this study and the following tests were carried out on sand as per IS: 2386- 1968 Part III.

E. *Coarse Aggregate*

Coarse aggregates which is breaked from rocks using explosives and crushed into pieces using machines. Aggregates of size 20mm is used in this study and the following tests were carried out on Aggregates as per IS: 2386- 1968 Part IV.

F. *Recycled Coarse Aggregate*

The recycled aggregates were obtained by crushing unknown waste concrete by use of an impact crusher and then sieved by using 20mm sieve is used up to 20% by total volume of coarse aggregate in this study.

G. *Alkaline Solution*

A suitable binder solution is prepared by mixing sodium hydroxide and sodium silicate. Sodium hydroxide is available in pellet form which is mixed with water to required molarity. Sodium silicate is available in liquid form.

III. MATERIAL PROPERTIES

The physical properties of Fly Ash, Ground Granulated Blast Furnace Slag is as shown in the table below

Table- I: Physical Properties of Fly Ash and GGBS

Property	Fly Ash	GGBS
Color	Grey	Pure White
Form	Powder	Powder
Specific Gravity	3.56	2.37
Consistency	29 %	34%

The physical properties of Fine Aggregate and Coarse Aggregate is as shown in the table below

Table- II: Physical Properties of Aggregates

Property	Fine Aggregate	Coarse Aggregate	Recycled Coarse Aggregate
Specific Gravity	2.37	2.71	2.71
Fineness Modulus (%)	2.96 %	5.59 %	7.1 %
Crushing Value (%)	-	34.67 %	29 %
Bulk Density (kg/m3)	1699	1463	1254

IV. CHEMICAL PROPERTIES OF MATERIALS

The Chemical properties of supplementary materials such as Fly Ash, Ground Granulated Blast Furnace Slag is as shown in the table below

Table- III: Chemical Properties of Fly Ash and GGBS

Property	Fly Ash	GGBS
SiO_2	54.92 %	51.25 %
Al_2O_3	23.01 %	11.89 %
MgO	3.84 %	3.21 %
CaO	2.82 %	22.45 %
Loss on Ignition	2.88 %	3.26 %

V. MAGNETIZED WATER SYSTEM

This setup consists of Autotransformer, 0.5 HP motor, Permag N406 which is arranged in series forming a closed-circuit system. The autotransformer is used to control the supply voltage of the motor so that the velocity of water in the setup is controlled. The water from the tank flows through the inlet of the motor and then the water flows through the magnetic flux induced by Permag N406 connected around the pipe in a closed system as shown in Fig. 2. The water can flow through the circuit for a certain period so that the physical state of the water minerals gets changed thus exhibiting soft water nature. By this process the resistance to corrosion of steel reinforcement is increased. The water can recirculate for at least 2 hours as the magnetic flux intensity is low in order of 0.9 Tesla. The processing of magnetized water can be reduced by using higher strength magnets having magnetic flux intensity greater than 1 Tesla. This processed magnetic water is used as solvent for preparing NaOH and Na_2SiO_3 solution.

Figure 2. Experimental Setup of Magnetized Water System

VI. PROPERTIES OF MAGNETIZED WATER

A. *pH*

The *pH* is the measure of hydrogen ion concentration. The *pH* is conducted after every 30 minutes recirculation of time. The *pH* test is conducted for both magnetic water and normal tap water. The *pH* of magnetized water and Normal tap water is shown in Table 4. The graph in Fig. 3 shows the reduction in value of *pH* when it is exposed to magnetic field for a long time. The change in colour of *pH* for magnetic water and normal tap water is observed and shown in Fig. 4 and Fig. 5.

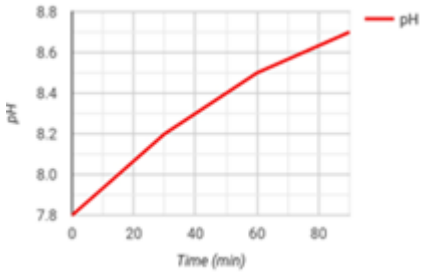

Figure 3. Graph showing pH vs Time

Table- IV: pH of Water Samples

S No	Water sample (min)	pH value
1	0	7.8
2	30	8.2
3	90	8.5
4	120	8.7

Figure 4. Magnetic Water

Figure 5. Normal Tap Water

B. *Hardness of Water*

The Hard water usually consists of salts of chlorides and sulphates which are responsible for scaling property. The hardness of the magnetic water is reduced because of change in physical state of the water minerals. The values of hardness of magnetic water and normal tap water is as shown in table below

Table- V: Hardness of Water Samples

S No	Water sample	Hardness (ppm)
1	Tap Water	1500
2	Magnetized Water	1200

VII. MIX PROPORTIONS

There are no mix design standard codes as such for conventional concrete. For this study a mix of 12M of NaOH is taken. The ratio between the NaOH and Na2SiO3 is 2.5.

Four different M30 mix preparations were made by changing the water and recycled coarse aggregate. M1 mix consists of 100% flyash with Normal tap water. And M2 mix consists of 50% flyash and 50% GGBS with Magnetic water. M3 mix consists of 50% flyash and 50% GGBS with Recycled Coarse Aggregate and Normal Tap Water. M4 mix consists of 50% flyash and 50% GGBS with Magnetic water and 20 % Recycled Coarse Aggregate.

Table- VI: Mix Proportion

S No	Material	Kg/m3
1	Fly Ash	213
2	GGBS	213
3	NaOH to Na_2SiO_3	2.5
4	NaOH pellets	21
5	NaOH Solution	55
6	Na_2SiO_3 Solution	138
7	Fine Aggregate	630
8	Coarse Aggregate	1249

VIII. RESULTS AND DISCUSSIONS

A. *Compressive Strength Test*

The compressive strength test for cubes was conducted in compression testing machine as per IS 516: 1964. The cube of size 150mm x 150mm x 150mm were used for testing The cubes were tested in compressive testing machine at the rate of 140 kg/cm^2/min and the ultimate loads were recorded.

Twelve cubes are casted and cured at ambient temperature. The compressive strength test is conducted at 7th and 28th days after ambient curing. The results are as shown in table below.

Table- VII: Compressive Strength Test Values

Property	*7th day (N/mm2)*	*28th day (N/mm2)*
GPC (100% FA) + NW	17.7	32,33
GPC(50% FA +50%GGBS) + RCA	27.1	38
GPC(50% FA +50%GGBS) + MW	48	56.4
GPC(50% FA +50%GGBS) + 20% RCA + MW	45.3	53.7

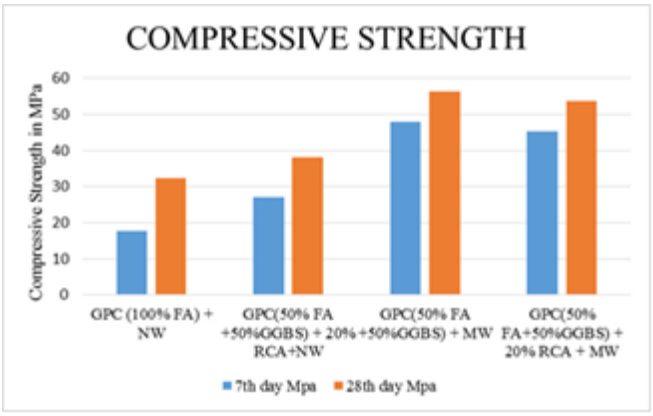

Figure 6. Graph Showing Compressive Strength

From the compressive strength test results, it is found that the strength of the GPC specimen with MW is 38% more when compared to the Conventional GPC specimen. And also it is found that the Strength of the concrete gets reduced when recycled coarse aggregates are used but if magnetic water is used along with recycled coarse aggregate the strength can be achieved unto 80% compared to conventional GPC specimen.

It is also observed that the GPC specimen achieve early strength by the usage of GGBS. The fig 6 shows the graphical variation of all the mixes.

B. *Split tensile Strength Test*

The split tensile strength test for cylinders was carried out as per IS 516: 1964. The cylinder of size 150 mm diameter and 300mm height were used for testing The cylinders were tested in compressive testing machine by placing the cylinders between two plates at the rate of 140 kg/cm^2/min and the ultimate loads were recorded.

Twelve cylinders are casted and cured at ambient temperature. The split tensile strength test is conducted at 7th and 28th days after ambient curing. The results are as shown in table below. Fig 7 shows the graphical variation of all the mixes.

Table- VIII: Split Tensile Strength Test Values

Property	*7th day (N/mm2)*	*28th day (N/mm2)*
GPC (100% FA) + NW	2.1	3.2
GPC(50% FA +50%GGBS) + RCA	1.49	2.4
GPC(50% FA +50%GGBS) + MW	2.2	3.5
GPC(50% FA +50%GGBS) + 20% RCA + MW	1.66	2.6

The result shows a similar trend as in compressive strength is found as same in split tensile strength. From the split tensile strength test results, it is evident that the strength of the GPC specimen with MW is 8.5% more when compared to the Conventional GPC specimen.

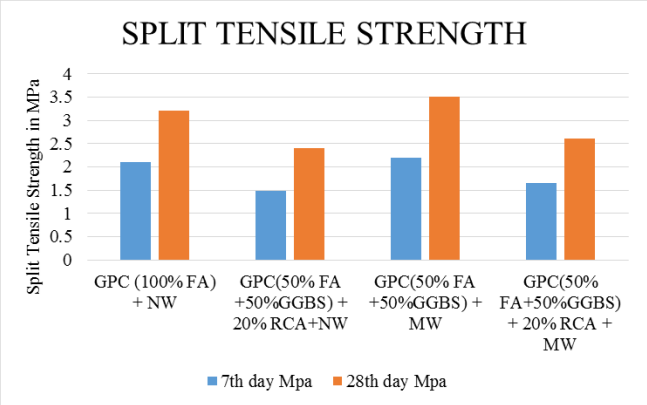

Figure 7. Graph Showing Split Tensile Strength

C. *Flexural Strength Test*

Flexural strength is a measure of tensile strength of concrete for an unreinforced prism, slab, beam etc. The prism of size 500mm x 100mm x 100mm were used for testing. A load was applied on the specimens with an increasing rate until the failure if the specimen occurred.

Twelve prisms are casted and cured at ambient temperature. The flexural strength test is conducted at 7th and 28th days after ambient curing. The results are as shown in table below. Fig 8 shows the graphical variation of all the mixes.

Table- IX: Flexural Strength Test Values

Property	*7th day (N/mm2)*	*28th day (N/mm2)*
GPC (100% FA) + NW	4.32	6.84
GPC(50% FA +50%GGBS) + RCA	3.41	9.45
GPC(50% FA +50%GGBS) + MW	7.12	13.43
GPC(50% FA +50%GGBS) + 20% RCA + MW	6.38	12.42

From the flexural strength test results, it is evident that the strength of the GPC specimen with MW is 36% more when compared to the Conventional GPC specimen.

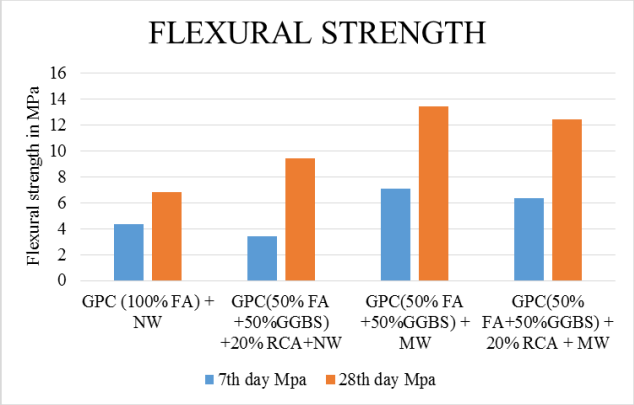

Figure 8. Graph Showing Flexural Strength

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Figure 9. Testing of Specimens

IX. CONCLUSION

A detailed experimental investigation on the geopolymer concrete with magnetized water was initiated and completed. The following study and observations were made at the end of the investigation.

- The characterization of the Magnetized water and Recycled Coarse Aggregate were determined, observed, tested and interpreted for its physical and chemical properties.
- Ground granulated blast furnace slag was replaced 50 % by flyash and natural aggregate was replaced 20% by recycled aggregate, with magnetized water at the proposed proportion was observed and studied.
- The compressive strength split tensile strength, flexural strength of geopolymer with magnetized water showed better strength compared to conventional geopolymer concrete and also when replaced with 20% Recycled Coarse Aggregate with magnetized water the mechanical properties was nearly closer to geopolymer with magnetized water.
- The increase in strength of the concrete is due to the alteration of physical mineral structure in the water so that the fineness of the geopolymer concrete is increased and the fine particles like flyash, ground granulated blast furnace slag enters further deep and settle in the voids of the concrete making the concrete impermeable.
- The workability is high when Magnetic Water is used in concrete; it helps to reduce the cement content.

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REFERENCES

1. H.Afshin, M.Gholizadeh and N.Khorshidi, "Improving Mechanical Properties of High Strength Concrete by Magnetic Water Technology", *Scientia Iranica*, vol. 17, pp. 74-79, 2010.
2. Nan Su, Yeong- Hwa Wu, Chung – Yo Mar, "Effect of magnetic water on the engineering properties of concrete containing granulated blast furnace slag", *Cement and concrete research*, vol. 30, pp. 599-605, 2000.
3. Sadam Ahmed, "Effect of Magnetic Water on Engineering Properties of Concrete", *Al-Rafidian Engineering*, vol. 17, pp. 71-82, 2009.
4. H.Afshin, M.Gholizadeh and N.Khorshidi, "The Improving Mechanical Properties of High Strength Concrete by Magnetic Water Technology", *Transaction A: Civil Engineering* , vol. 17, pp. 74-79, 2010.
5. Ali Faris, Riadh Al- Mahaidi, Awad Jadooe, "Implementation of Magnetized water to improve the properties of concrete." *International Journal of Civil Engineering and Technology* , vol. 5, pp. 43-57, 2014.
6. P.Sivakumar, E.Poornima, " Experimental Study on Strength Enhancement of Concrete using Magnetic and Normal Water", *International Journal of Engineering Research & Technology*, vol. 4, pp. 1-5, 2016.
7. Malathy, Karuppasamy and Barnidharan, "Effect of Magnetic Water on Mixing and Curing of M_{25} Grade Concrete", *International Journal of ChemTech Research*, vol. 10, pp. 131-139, 2017.
8. Taghried Isam Mohammed Abdel-Magid, Rbab Mohammed Hamdan, Abeer Abdelrahman Bukhari Abdelgader, Mohammed Emadeldin Attaelmnan Omer and Najla'a Mohammed Rizg-Allah Ahmed (2017), "Effect of Magnetized Water on Workability and Compressive Strength of Concrete", *Procedia Engineering* , vol. 193, pp. 494-500, 2017.
9. Srinivasa Reddy, Kranthi Kumar and Sumanth, " Effect of Magnetic Field Treated Water on Fresh and Hardened Properties of Concrete", *Journal of Civil Engineering and Environmental Technology* , vol. 4, pp. 134-138, 2017.
10. Saied Ghorbani , Mostafa Gholizadeh and Jorge de Brito, " Effect of Magnetized Water on the Mechanical and Durability Properties of Concrete Block Pavers" *Materials* , vol. 11, pp. 1-16, 2018

AUTHORS PROFILE

Janarthanan.R Currently doing Master's program in the Civil Engineering Department at Sri Krishna College of Technology. Completed higher secondary in the year of 2014 and joined as Undergraduate student in the Department of civil engineering at Sona college of Technology. Completed my undergraduate degree in the year of 2018. And also I have completed Autocaad, Revit, Staad Pro and DV Pro certified courses. Presented paper in international conference on Civil, Mechanical, Chemical Engineering and Technologies, organized by ICCMCT, February 2018.Publications: 1. "Utilization of waste plastic in Concrete" in International Research Journal of Engineering and Technology.UG Project - Phase I- Experimental study on Partial Replacement of Cement by GGBS and Natural Sand by M- Sand in Concrete. Phase II- Experimental study on Partial Replacement of Cement by GGBS and Rice Straw Ash in Concrete.PG Project- Phase I- Investigation on Mechanical Properties of Geopolymer Concrete with Magnetized Water and Recycled Coarse Aggregate .Patents: 1. Mechanically Enhanced Durable Geopolymer Concrete with Magnetized water and Recycled Coarse Aggregate, Published in IPR Journal. 2. Utilization of Arecaceae plant family fibers to Increase the Strength Property, Published in IPR Journal.

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