# Effect of Magnetized Water on GPC With Recycled Tyre Steel Fibre As A ConstituentMaterial

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**ABSTRACT** - This paper briefs the research conducted on Geopolymer Concrete(GPC) produced with Magnetized water with Recycled Tyre Steel Fibre(RTSF) constituent material. Despite cement being core component in concrete, due to its high economy and eco-harming manufacturing process, a new space is generated for GPC for its eco-friendly and economic popularity. This research aims at producing 100% Ground Granulated Blast Furnace Slag(GGBS) based GPC with alkali activators(AA), also introducing a new era of Water Magnetization over normal water in GPC mix and incorporate RTSF as constituent material. This study analyze the impact of Magnetized water and RTSF on the workability, durability, compressive and split tensile strength of GPC at different molarities of AA solution of GPC and bring out a comparative analysis of with control GPC..The specimen comprising control mix, magnetized mix and RTSF magnetized mix(hybrid mix)were prepared with 8M and 12M of AA solution. Water is magnetized by 1.2T Permanent Magnet by passing it for 4,6 and 8hrs duration with constant discharge. RTSF were added at 0.25%, 0.5% and 0.75% to the optimum magnetized duration. Specimens were oven cured $70^0$C for 8hrs and ambient cured for 7, 14 and 28 days. Magnetized water has significantly improved the workability, durability, compressive and split tensile strength compared to control GPC. The optimum magnetization is obtained when water is magnetized for 6hrs. Optimum range of RTSF is 0.5%. Addition of RTSF reduces the workability but increases strength and durability. Magnetization increases the pH and reduces the hardness of water.

**Keywords: Geopolymer Concrete, GGBS, Magnetized water, Permanent Magnet, Recycled Tyre Steel Fibre**

## 1.INTRODUCTION

Concrete is one of the oldest and most common construction material and its usage is huge in the world due to its availability, ease of producing locally, its versatility, economic value, wide range of performance, sustainability, durability and applicability and so much is the cement which is a major contributing element for nearly, 7% of global $CO_2$ and CO emission. This amplified the need to bring an alternative to the cement which exhibit similar physical chemical properties to that of cement and replace the conventional concrete. Such a proxy is the Geopolymer Concrete which comprises cementatious material in place of cement. These cementatious materials are industrial byproducts such as GGBS, Flyash silica fumes which can be bought to use to produce GPC which solve the problem of its disposal. This makes this concrete economic and eco- friendly, hence it is also named as "Green Concrete". A proposal by Davidovits says that the aluminum and the silica in the source material can be reacted with the alkaline medium to produce binder through polymeric reaction. Many studies have proven that GPC attains better strength and durability than conventional concrete due to less workability. Francis N et al(2017), Rangarajan P. etal, Jeffery C. Petermann et al(2010) has evolved that GPC has more enhanced strength and durability when compared to conventional concrete. It shows more resistant to chemical attacks and attains strength in less curing period since it is either oven cured, ambient cured or steam cured. Fibres are the crack arrestor that beholds the developing drying and shrinkage cracks and its propagation.They improves the tensile nature of the concrete. S. Yuvaraj et al(2016) has conducted a study on the performance of GPC with varying sizes of steel fibre and found out that addition of steel fibre increased compressive Strength by 85.8% and flexural strength by 75% also Optimum fibre content is0.6% for 30mmand0.4% for 60mm.Also, short fibre delivers better result than long fibre.S. Elavarasan (2009) has also described that when steel fibre was added to volume fraction of 0.25%-o.75% keeping glass fibre constant at 0.03%, 0.75% of the steel fibre with 0.03% glass fibre gave maximum compressive,split tensile and flexural strength of 17%,8% and 29% respectively. Use of fresh steel fibre turn out to be expensive and to curb this, the recycled tyre steel fibre extracted from disposed tyres are made in to use which also solve the disposing problem of tyre industry by-products. NoralwaniModtifi et al(2017) and Marijanaserdar et al(2015) has studied on the mechanical properties of GPC containing recycled tyre steel fibre and recycled tyre polymer fibre respectively by adding in a volume of 0%, 0.3%, 0.7%. it has

been found that more than 0.7% is not recommended for RTSF. RTPF improves the concrete behaviour and increases tensile stress. Water is a core ingredient in concrete and researches are leading its way towards the innovative steps taken on a special type of experiment on water named as Water Magnetization. In bygone days, this phenomenon was restricted to agricultural and medical field alone, but now it has started gaining popularity in the construction sector also, by using magnetized water for concrete preparation over normal water. Many researchers have been conducted in the past and still continuing on this developing trend.Amirsalar R et al(2018) has coined in his research that, magnetized water has reduced the dosage of admixture by 30% with increase in the compressive strength by 12% and reduction in water content by 10%. Also, it significantly improved the flowability of SCC.Rabab Mohammed et al(2017), R Malathy et al (2017), Saddam M. Ahmed(2009) have given a picture that the magnetized water when magnetized for a particular duration at a specific magnetic field increases the mechanical strength and the durability of the concrete. It reduces the water consumption and improves water quality, although have good workability which, in turn, is the reason for good strength. Authors also elucidated that magnetized water have its optimum after which there is no significant improvement in the properties of concrete. This paper introduces a collaboration of eco- friendly and cost effective materials comprising GGBS based GPC, Recycled Tyre Steel Fiber(RTSF) and Magnetized Water over conventional concrete.

## 2.MAGNETIZED WATER AND ITS MECHANISM

### 2.1 Origin

Magnetized Water, as the term suggests, is the water that has undergone magnetization for a specific duration under a permanent magnet or electromagnet of specific magnetic flux. In the past century, this technology was used in the countries like China, Russia, Poland, Bulgaria where they utilized magnetized water in the chemical industries, for irrigation, agriculture, medical and domestic use. Later it gained its popularity in rest part of the world including India. Earlier, the use of magnetized water was restricted to agricultural, irrigation and medical field only but later construction sector has also undertaken this trend and producing innovation in all possible way through researches.

### 2.2 Magnetization in water – Mechanism

Many investigations have been conducted in bygone days due to which magnetized water is trending in different sector whether it is agriculture or be it in construction. Water is diamagnetic, hence by the term magnetization it doesn't mean that water will attract magnetic materials, instead it is the fact that when water is subject to the magnetic field produced either from a permanent magnet or an electromagnet for a specific duration, the water molecules gets reoriented in much more minor size. The water molecules of a normal water are bulkier in size and have a bond angle of $104^0$ which when magnetized get reduced to a smaller angle which makes them more soluble and efficient. The magnetized field will be perpendicular to the orientation of water molecules thus this helps to de clutter the large cluster into smaller groups of molecules. The effect of magnetization is temporary and get nullifies with time. Magnetization depends on magnetic field intensity, duration of magnetization, water quantity.

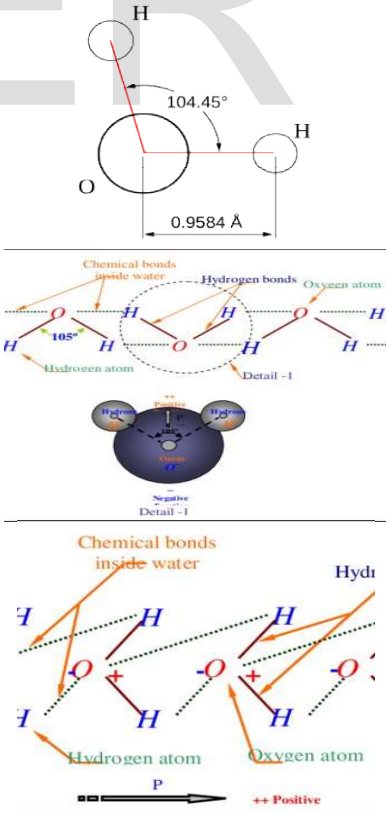


FIG 2.1NORMAL WATER BOND ARRANGEMENT
MAGNETIZED WATER BOND ARRANGEMENT
SOURCE: SADDAM M. AHMED (2009)

# 3.EXPERIMENTAL WORK

## 3.1 Materials

*Ground Granulated Blast Furnace Slag (GGBS)*

The quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam produce a glassy, granular product that is then dried and ground into a fine powder. This product is called Ground Granulated Blast Furnace Slag. For this study GGBS was collected from Aastra Chemicals, Chennai. Table 3.1 gives the properties of GGBS provided by the company. Fig 3.1 shows GGBS.

TABLE 3.1 PROPERTIES OF GGBS FROM THE SOURCE – AASTRA CHEMICALS, CHENNAI

| S.No. | Characteristics | Value |
|---|---|---|
| 1 | Surface Area ($m^2/kg$) | 390 |
| 2 | Particles Size (cumulative %) | 97.10 |
| 3 | Moisture Content | 0.10 |
| 4 | Loss in Ignition | 0.26 |
| | Chemical Characteristics | |
| | $(CaO+MgO)/SiO_2$ | 1.30 |
| | $(CaO+MgO)+SiO_2$ | 76 |
| | $CaO/SiO_2$ | 1.07 |

FIG: 3.1 GGBS

*Fine Aggregate and Coarse Aggregate*

Manufactured Sand(M-Sand) is used in this study which is a common substitute of river having no silt and organic impurities and mostly well graded. As per IS 383:1970, the size of fine aggregate should be in the range 4.75mm to 75μ. Locally available crushed stones of size 20-25mm are used in this study. IS383:1970 gives specification for coarse aggregate and the size should be ranging from 20 mm to 4.75 mm.

*Alkali Activators*

The alkali activators are the compound that are initially responsible for the polymeric reaction since these solutions leaches out $Al^{3+}$ and $Si^{4+}$ from the precursor, in this study, GGBS and makes them available for hydration and polymerization process. NaOH and $Na_2SiO_3$ are the alkali activators used in this study. KaOH is also preferred in place on NaOH. NaOH will be in the form of pellets out of which solution is prepared for overnight since dissolution is highly exothermic and is mixed with $Na_2SiO_3$ solution few minutes before the casting. NaOH solution are prepared for 8M and 12M in this study.

TABLE 3.2 PROPERTIES OF NAOH AND $NA_2SIO_3$ SOURCE – AASTRA CHEMICALS, CHENNAI

| S.No. | Properties of NaOH | Value |
|---|---|---|
| 1 | State | Solid/flakes |
| 2 | Specific gravity | 2.13 |
| 3 | Colour | White |
| 4 | $Na_2CO_3$ | 2% |
| 5 | Cl | 0.01% |
| 6 | $SO_2$ | 0.05% |
| 7 | Pb | 0.01% |
| 8 | Fe | 0.01% |
| 9 | K | 0.1% |
| 10 | Zn | 0.02% |

| S.No. | Properties of $Na_2SiO_3$ | Value |
|---|---|---|
| 1 | State | liquid |
| 2 | Specific gravity | 1.6 |
| 3 | Colour | colourless |
| 4 | $Na_2CO_3$ | 15.9% |
| 5 | $SiO_2$ | 31.4% |
| 6 | $H_2O$ | 52.7% |

*Recycled Tyre Steel Fibre*

Reuse of tyres and material recovery has become the most environmentally viable ways for disposing used tyres. The by-products from tyre industry mainly extracted from the obsolete tyre contain steel fibre is used as substituent of fresh steel fibre to attain fibre reinforced GPC. In this study RTSF is used and is examined for its impact on strength workability and durability. Compared to RTSF the industrially produced steel fibres are much costly. KyprosPilakoutas et al(2004) proposed that UK price of Industrial steel fiber(ISF) ranges from $450to $10000 per tonne. The value of RTSF ranges from $30 to $80 per tonne. This estimation is corresponding to the demand and production of ISF and RTSF per year. This not only curbs the high expense of virgin steel but it reduces the by-products going to the land fill and reduce the need to produce virgin steel. This form a way to open a alternate market for used tyres and stop the fly tipping of

unused tyres. The RTSF used in this study are shredded RTSF having an average length of 10mm, diameter of 0.23mm and the aspect ratio is 43. Fiber are very fragile in nature when pull out test were conducted and is ionized.

FIG 3.2 RECYCLED TYRE STEEL FIBRE

### 3.2Experimental set up of Magnetized Water

The water is made to pass through a permanent magnet of 1.2T by continuous recirculation with the aid of a submersible pump having a constant discharge of 600l/hr. The water is magnetized for different durations of 4, 6 and 8hrs. At a time 2.5l of water is magnetized

FIG 3.3 MAGNETIZATION OF WATER EXPERIMENTAL SET UP

### 3.2 Design of Geopolymer Concrete

Based on past studies conducted on GGBS based GPC, mix design for M30 was prepared referring to the similar literatures. NaOH solutions of 8M and 12M were used for the comparison. Alkali activator solution to GGBS ratio is taken as 0.45. Specimen for control GPC, Magnetized GPC and RTSF Magnetized GPC(hybrid GPC) for 8M and 12M are prepared. Magnetized GPC with 4, 6 and 8hrs of water magnetization is compared. RTSF were added at 0.25%, 0.5% and 0.75%. Optimum of duration of magnetization and addition of RTSF were obtained and compared with control GPC for workability, durability, compressive and split tensile strength.

## 4.RESULTAND DISCUSSIONS

Fresh concrete test, hardened concrete tests and durability tests were conducted on different categories of specimen for both 8M and 12M. Fresh concrete test involves test for workability i.e. Slump test. Compressive strength test and Split tensile strength test are the hardened concrete tests conducted and for durability, Carbonation, water absorption, Acid Attack, Sulphate attack and Chloride attack tests are conducted.

| Mix | Designation |
|---|---|
| GPC | Normal GPC with 8M |
| GPC1 | 4 hours Magnetized GPC 8M |
| GPC2 | 6 hours Magnetized GPC 8M |
| GPC3 | 8 hours Magnetized GPC 8M |
| GPC2-0.25 | 6 hrs Mag. GPC 8M0.25 RTSF |
| GPC2-0.5 | 6 hrs Mag. GPC 8M0.5 RTSF |
| GPC2-0.75 | 6 hrs Mag. GPC 8M0.75 RTSF |
| GPC | Normal GPC with 12M |
| GPC1 | 4 hours Magnetized GPC 12M |
| GPC2 | 6 hours Magnetized GPC 12M |
| GPC3 | 8 hours Magnetized GPC 12M |
| GPC2-0.25 | 6 hrs Mag. GPC 12M0.25 RTSF |
| GPC2-0.5 | 6 hrs Mag. GPC 12M0.5 RTSF |
| GPC2-0.75 | 6hrs Mag. GPC 12M0.75 RTSF |

Mix Designation

### 4.1 Workability of the mixes

Workability, which is basically, the ease with which concrete can be placed and having a homogeneous mix is measured by slump test. Generally, GPC mixes are less workable and it is compared with magnetized GPC and hybrid GPC. Table 4.1 shows the slump values.

TABLE 4.1 SLUMP VALUES

| 8M | | 12M | |
|---|---|---|---|
| Mix | Slump in mm | Mix | Slump in mm |
| GPC | 90 | GPC | 85 |
| GPC1 | 115 | GPC1 | 100 |
| GPC2 | 130 | GPC2 | 128 |
| GPC3 | 125 | GPC3 | 123 |
| GPC2-0.25 | 95 | GPC2-0.25 | 90 |
| GPC2-0.5 | 93 | GPC2-0.5 | 87 |
| GPC2-0.75 | 90 | GPC2-0.75 | 85 |

TABLE 4.2 COMPRESSIVE STRENGTH VALUES

| Mix | 7th day | 14th day | 28th day |
|---|---|---|---|
| 8M | | | |
| | | | |
| GPC8M | 22.085 | 34.86 | 36.75 |
| GPC1(8M) | 25.85 | 36.23 | 40.57 |
| GPC2(8M) | 27.469 | 38.034 | 42.26 |
| GP3(8M) | 27.469 | 38.034 | 42.26 |
| GPC2(8M)-0.25 | 28.32 | 3813 | 42.05 |
| GPC2(8M)-0.5 | 28.96 | 40.05 | 43.83 |
| GPC2(8M)-0.75 | 27.74 | 37.38 | 41.77 |
| 12M | | | |
| GPC12M | 25.42 | 35.19 | 38.10 |
| GPC1(12M) | 27.83 | 38.99 | 42.34 |
| GPC2(12M) | 29.82 | 40.13 | 44.08 |
| GP3(12M) | 29.93 | 40.005 | 44.002 |
| GPC2(12M)-0.25 | 28.99 | 40.10 | 44.5 |
| GPC2(12M)-0.5 | 30.16 | 41.62 | 45.01 |
| GPC2(12M)-0.75 | 27.13 | 39.15 | 43.25 |

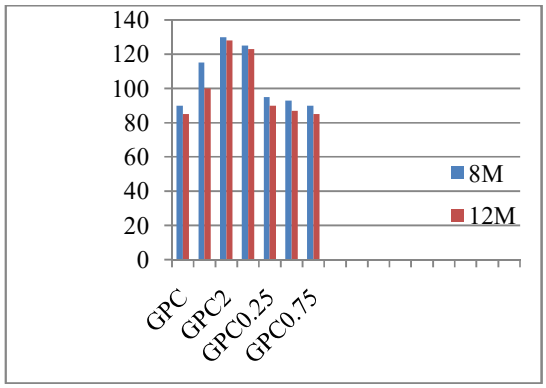


FIG 4.1 GRAPHICAL REPRESENTATION OF SLUMP VALUES

Fig: 4.1 shows the variation in slump for different mixes. Magnetization of water significantly increased the workability than control mix. But result also depict that 12M shows less workable mix than 8M. addition of RTSF has reduced the workability since the fibre tends toball up during mixing. Magnetizing duration of 6hrs has max slum value making it more workable than 4 hrs and 8hrs magnetized mix.

## 4.2 Compressive strength of Mixes

The compressive strength test is determined by testing a cube of 150X150X150mm in compression testing machine after giving a oven curing for 8 hrsat 70$^0$C and ambient curing for 7, 14 and 28 days asper IS 516-1959.

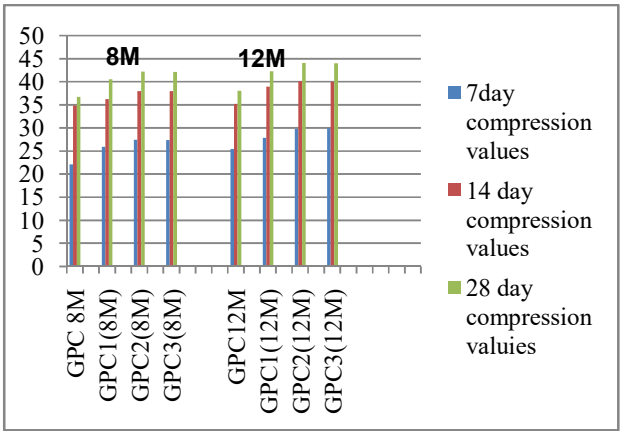


FIG 4.2 GRAPHICAL REPRESENTATION OF COMPRESSIVE STRENGTH VALUES

There is a considerable amount of increment in the compressive strength of optimum Magnetized GPC by 24%, 15%, 9% for 8M and 17%, 16%, 16% for 12M at 7, 14 and 28 day of curing respectively than the control mix. Magnetization for 6 hrs is obtained as the optimum.

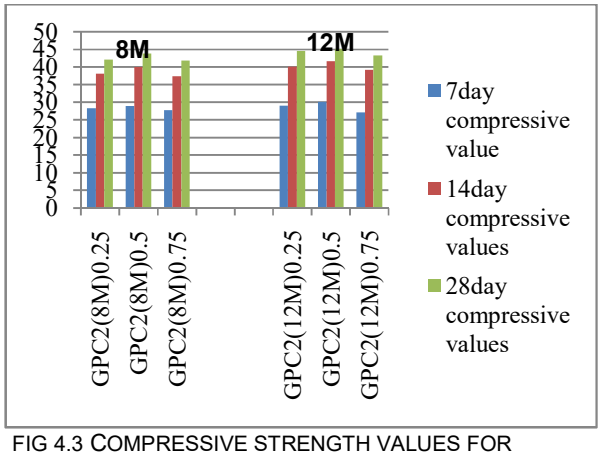


FIG 4.3 COMPRESSIVE STRENGTH VALUES FOR RTSF ADDED OPTIMUM MIX

The compressive strength is getting increased for hybrid GPC containing RTSF by 31%,15% and 19% for8M and 18%, 18% and 18% for 12M at 7, 14 and 28 day of curing respectively than the control mix. The optimum magnetized GPC is

added with different proportion of RTSF. The specimen with 0.5% of RTSF is having maximum compressive strength and is obtained as the optimum amount. Also, compressive strength is higher for 12M than 8M.

### 4.2 Split Tensile Strength of the Mixes

Cylinders of 200X100mm of different set of mixes are casted, cured for 8hrs at 70 and ambient curing for 7, 14 and 28 days and tested to obtain split tensile strength as per IS 516-1959.

TABLE 4.3 SPLIT TENSILE STRENGTH VALUES

| 8M | | | |
|---|---|---|---|
| **Mix** | **7th day** | **14th day** | **28th day** |
| GPC8M | 1.62 | 1.90 | 2.08 |
| GPC1(8M) | 2.72 | 3.08 | 3.25 |
| GPC2(8M) | 2.81 | 3.791 | 3.92 |
| GP3(8M) | 2.64 | 3.515 | 3.78 |
| GPC2(8M)-0.25 | 2.85 | 3.815 | 3.98 |
| GPC2(8M)-0.5 | 2.91 | 3.9 | 4.03 |
| GPC2(8M)-0.75 | 2.87 | 3.85 | 4.10 |
| **12M** | | | |
| GPC12M | 1.73 | 2.428 | 2.66 |
| GPC1(12M) | 2.52 | 3.42 | 3.6 |
| GPC2(12M) | 3.08 | 3.942 | 4.15 |
| GP3(12M) | 2.97 | 3.79 | 4.03 |
| GPC2(12M)-0.25 | 2.88 | 3.87 | 4.01 |
| GPC2(12M)-0.5 | 2.95 | 4.03 | 4.21 |
| GPC2(12M)-0.75 | 2.91 | 3.93 | 4.16 |

The water re-circulated for 6hrs through PM depicts maximum split tensile strength and is attained as the optimum magnetization duration into which RTSF are added in 0.25%-0.75%.

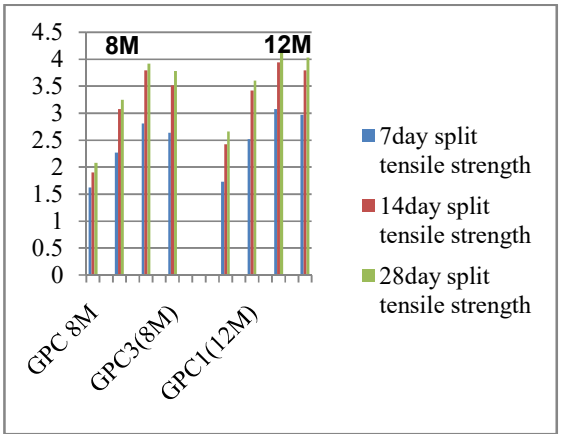


FIG. 4.4 GRAPHICAL REPRESENTATION OF SPLIT TENSILE STRENGTH VALUES

The mix with optimum duration of magnetization when added with RTSF shows improvement in split tensile strength and o.5% is the optimum amount obtained that delivers max split tensile strength amongst all. Split tensile strength is higher for 12M than 8M.

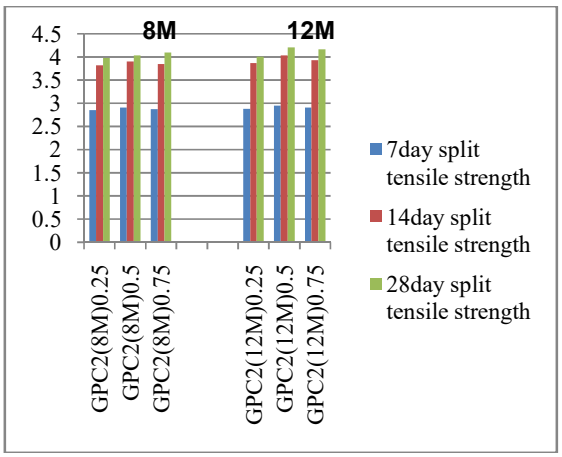


FIG 4.5 SPLIT TENSILE STRENGTH VALUES FOR RTSF ADDED OPTIMUM MIX

### 4.3 Durability of the Mix

Tests like Carbonation, Sulphate resistance, Acid resistance, Chloride resistance and Water Absorption have been conducted on 12M control mix, optimum magnetized mix and optimum hybrid mix for 28 and 56 days of immersion in corresponding testing solutions.

Carbonation is visually analyzed by dropping 2 drops of phenolphthalein indicator on the specimen and if it turns pink colour the specimen is free from carbonation attack.

FIG. 4.6 CARBONATION

Sulphate resistance, acid resistance, chloride resistance and water absorption are conducted as per the procedures followed in previous studies by mixing 5% of $Na_2SO_4$, $H_2SO_4$, NaCl in water and immersing the specimen for 28 and 56 days. The loss in weight and loss in compression strength is measured at 28 and 56 days.

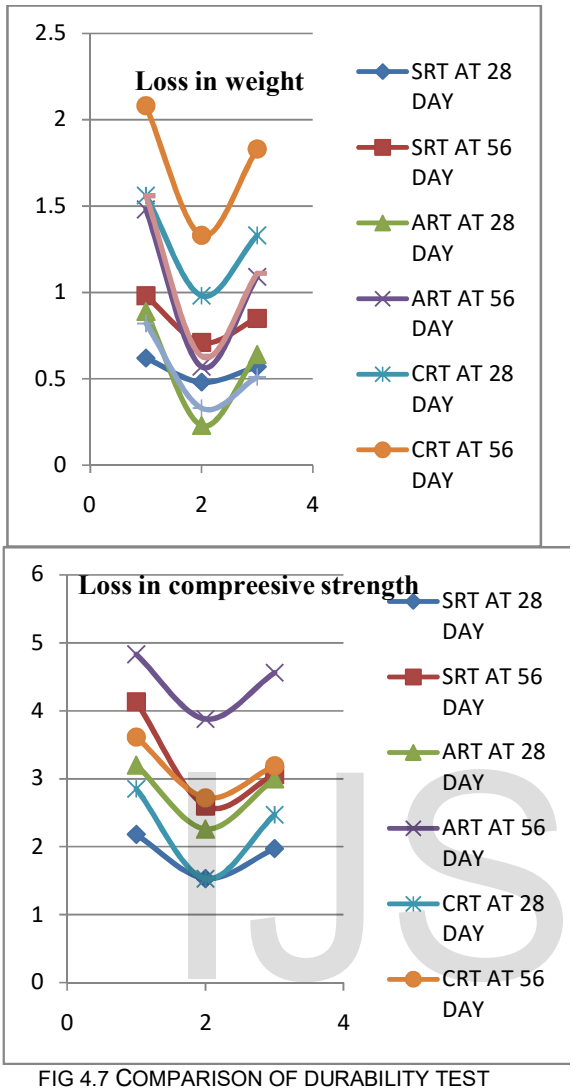


FIG 4.7 COMPARISON OF DURABILITY TEST RESULTS

Magnetized mix is found to more resistant all the attacks and water absorption than the control mix and the hybrid mix.

### 4.4 pH and Hardness of Magnetized water

When water is magnetized for specific durations (4hrs, 6hrs, 8hrs) it effects the physical properties of water, the pH value increases and after reaching optimum it becomes almost constant,the hardness of water decreases upto optimum and thereafter the change is negligible.

| Properties | Normal water | 4hr | 6hrs | 8hrs |
|---|---|---|---|---|
| pH | 7.78 | 8.9 | 9.4 | 9.07 |
| hardness | 150 | 130 | 80 | 90 |

TABLE 4.4 PH AND HARDNESS VALUES OF MAGNETIZED WATER

## 5.CONCLUSION

This was an experimental research conducted on Geopolymer concrete to find the effect on its properties when it is treated with a new phenomenon of "Magnetized water" along with the addition of recycled tyre steel fibre as a constituent material. Specimen of control mix were compared with magnetized mix and hybrid mix and appropriate optimum for the duration of magnetization and percentage addition of RTSF were obtained.

- The GPC controlled specimen, Magnetized GPC and hybrid GPC showed greater compressive and split tensile strength with increase in molarity but workability of the mix got reduced with the increase in morality for all the GPC mixes
- Workability of the magnetized GPC is higher than the controlled GPC Mix because of higher solubility and more water molecules available for hydration. This reduces the usage of any admixtures (superplasticizer).
- Compressive strength, split tensile strength and durability properties of Magnetized GPC mix is much pronounced than the controlled GPC mix.
- The optimum amount of Magnetization obtained is when the water is magnetized for 6hours.Strength and workability is maximum. After that the strength properties and the workability start decreasing.
- The optimum percentage of RTSF is 0.5 where the compressive strength and the split tensile strength is maximum. After that the strength value reduces. Addition of RSTF reduces the workability but can deliver good crack resistance
- Magnetization of water increase the pH up to optimum, making it less acidic hence it resists corrosion mainly in reinforced concretes and reduces hardness of the water up to optimum which in turn reduces the scaling of the pipe surface.
- Magnetized water improves the durability of the GPC than normal GPC and fibre reinforced GPC. Fibres get more susceptible to sulphate and acid attacks but due to involvement of

magnetized water the effect of attack is reduced than control mix.

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