www.ijiarec.com

ISSN:2348-2079 Volume-6 Issue-2

International Journal of Intellectual Advancements and Research in Engineering Computations

Experimental study of GGBS-geopolymer concrete on strength and durability

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ABSTRACT

Cement Concrete is the most broadly utilized development material on the planet with around six billion tones being produced each year by releasing a large amount CO2 at production of pozzolana cement which results in increasing of Global Warming. There is need to reduce the global anthropogenic carbon dioxide, this has stimulated researchers in search of sustainable building materials. GPC can possibly control of CO2 discharge into the atmosphere because here we use binding material as natural or byproduct material like fly ash, rice husk, ground granulated blast furnace slag, silica fume , red mud etc. In this thesis GPC is made by solidified cementation paste produced using GGBS. The goal of the present investigation is to observe the impact of Ground Granulated Blast furnace Slag in GPC and by replacing of 100% Ground Granulated Blast furnace Slag with Ordinary Portland Cement. A study had done on GPC with Ground Granulated Blast furnace Slag, taking the alkaline solution i.e., sodium hydroxide of 6 molarity, 8 molarity and 10 molarity. The extent of dissolvable activators is 1:2. Calcium silicate is encircled when GGBS gets reacted with sodium hydroxide and sodium silicate. A blend mix for GPC was planned by accepting the unit weight of GPC as 2400 kg/m3. In this thesis we conduct the GPC with GGBS to analyze the progressions of properties like strength and durability

Keywords: Globalwarming, Pozzolana cement, Sustaining building materials, By Product of industries, GGBS, Alkaline solution, Molarity

INTRODUCTION

General

Primary binding material used to produce normal concrete is Portland cement. We are well aware of ecofriendly issues related with the production of OPC. The amount of the carbon dioxide released during the production of OPC due to the calcination of limestone and burning of fossil fuel is in the order of one ton per production of one ton OPC. In the development of infrastructure / construction business, essentially the generation of Portland cement results in environmental pollution. There is need to reduce the global anthropogenic carbon dioxide has stimulated researchers in search of sustainable building materials [1-6].

GPC history

GPC is an advanced and eco-friendly building material is an substitute to Portland Cement Concrete (PCC). The GPC is made from consumption of excess materials such as fly ash, silica fume, rice-husk ash, red mud ,GGBS etc., . In 1978, Davidovits is established the binders can be

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produced by a polymeric reaction of alkaline solution with the silica and the aluminum basis materials of geological derivation or by-product materials from industries. Sustainable concrete is the main importance given to the current study. World is boiling due to the emission of greenhouse gases by human activities, in one of them is Co2. To take away natural well-disposed cement, these materials are replacing with byproducts of industries or naturally occurring materials such as fly ash, silica fume, rice-husk ash, red mud ,GGBS etc.,. In this thesis Cement is replaced with industrial waste like Ground Granulated Blast Furnace Slag (GGBS). The production of Ground Granulated Blast Furnace Slag requires slight external energy [7-12].

Properties of GPC

High-early-quality pick up is a remarkable normal for Geopolymer solid when dry-warmth or steam cured, Geopolymer cement can likewise be cured in the surrounding temperature. It has been used to convey precast track sleepers and other pre-concentrated on strong building portions. The early-age quality gets is a trademark that can best be changed in the precast business where steam curing or warmed bed curing is essential to practice and is used to help the rate of the age of parts. As of late GPC has been attempted in the generation of precast box ducts with fruitful creation in a business precast yard with steam curing. GPC has astounding protection from compound assault and shows guarantee in the utilization of forceful situations where the toughness of Portland bond cement might be of concern.

GGBS - GPC

Primary contrast between Geopolymer cement and Portland bond concrete is the ring fastener. Reasonable cement is the primary significance given to the present investigation. Exhaustive simmering is because of the generation of studio gas carbon dioxide, to nature by humanoid occasions. To take away characteristic all around arranged bond, these materials are supplanting with by crops, for example, GGBS and others which incorporates fly powder. So as to create GPC. Bond can be supplanted with mechanical waste like Ground Granulated Blast Furnace Slag (GGBS). The creation of Ground Granulated Blast Furnace Slag requires slight supplementary imperativeness identified with the essentialness major for the improvement of Portland concrete. The additional of Portland security with GGBS settle major to a basic refund of Co2 gas spread. GGBS is, in this way, a circumstance material.

Objective

The objective and scope of the present study is

- Replacing 100% cementious material with GGBS to produce GPC

Adopting reverse mix design process to find Mix Proportin

- To study the mechanical properties Strength and Durability of GGBS based GPC for 6M, 8M and 10M (M - molarity) alkali activators for 7 days , 14 days and 28 days.
- Concluding which molarity got good strength and durability properties

Ground granulated blast furnace slag (GGBFS)

Ground Granulated Blast Furnace Slag (GGBS) is a result of the steel business. Blast Furnace Slag is all around characterized as "the non-metallic development comprising basically of calcium silicates and different bases that are built up in a molten condition at the same time with the iron in an extreme heat." In the production of iron, blast furnace are over-burden with iron ore, fluxing agents, and coke. At the point when the iron mineral, which is comprised of iron oxides, silica, and alumina, meets up with the fluxing operators, liquid slag and iron are delivered. The liquid slag at that point experiences a specific procedure relying upon what sort of slag it will progress toward becoming. Air-cooled slag has an unpleasant complete and bigger surface zone when contrasted with totals of that volume which enables it to tie well with Portland concrete and in addition black-top blends. GGBFS is created when liquid slag is lessened quickly utilizing water planes, which delivers a granular glassy aggregate.

Figure 1 Ground granulated blast furnace slag

Table 1: Chemical composition for GGBS

S. NO	CHEMICAL CHARACTERISTICS	(GGBS) % OF COMPOSITION
1	Magnesium Oxide	8.78
2	Sulphur Content	0.41
3	Sulphide Sulphur	0.48
4	Loss on Ignition	0.68
5	Insoluble Residue	0.48
6	Chloride	0.014
7	Moisture Content	0.40
8	Manganese Content	0.20
9	Glass content	93.00
10	Chemical Module	
	a) CaO + Mgo + SiO2	77.84
	b) (CaO + Mgo)/ SiO2	1.31
	c) CaO / SiO2	1.10

Physical properties of GGBS

Table 2: physical properties

Specific gravity	**2.6**
Colour	White
Surface moisture	Nil
Average particle size	4.75 mm down
Shape	Spherical

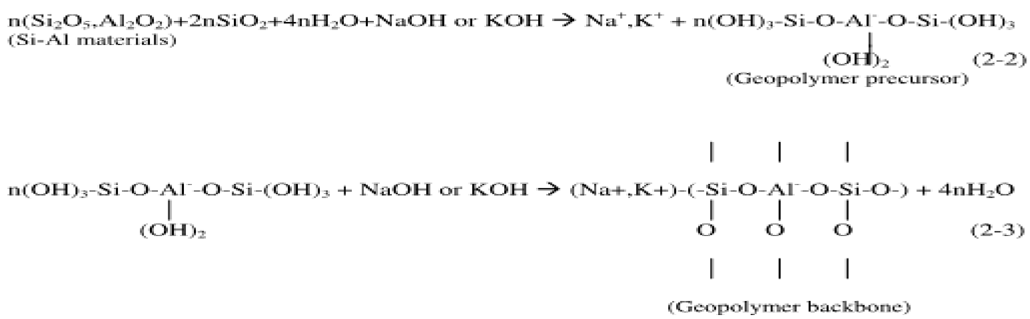
Pozzolanic materials physical and chemical properties

Table 3: Chemical and physical properties of Pozzolanic Materials

Chemical composition	Fly Ash (%)	GGBFS (%)	Silica Fume (%)
SiO2	35.8-42.83	32.6	90.11
Al2O3	18.0-26.9	12.8	1.63
Fe2O3	6.5-8.2	1.3	1.98
MgO	3.5-4.1	7.2	0.78
SO3	2.2-3.5	0.03	--
Na2O+K2O	--	--	1.97
P2O5	--	0.05	1.18
CaO	18.8-19.8	41.0	--
Moisture(H2O)	0.2-1.9	--	--

GPC

In 1978, Davidovits suggested that an alkaline liquid could be utilized to respond with the silicon (Si) and the aluminum (Al) in a source material of geological origin or by-product materials, for example, fly ash and rice husk ash to create binders. Since the substance response that happens, for this situation, is a polymerization procedure, Davidovits (1994, 1999)) authored the term 'Geopolymer' to speak about these binders.



Schematic formation of Geopolymer material

Table 5: Applications of Geopolymer

Si/Al	Application
1	Blocks, ceramics, fire safety
2	Low CO2 earthenware, concrete, radioactive & toxic waste encapsulation
3	Heat struggle compounds, foundry equipment, fiber glass composites
>3	Sealants for industry
20<Si/Al<35	Fire resistance and warmness resistance fiber composites

Alkaline liquids

The most well-known alkaline liquid utilized as a part of GPC is a mix of NaOH or KOH and Na2SiO3 or K2SiO3. Palomo et al (1999) are inferred that the sort of alkaline liquid plays a vital part in the polymerization procedure. The reaction happens at a high rate when the fundamental liquid contains solvent silicate, either sodium or potassium silicate, contrasted with the utilization of just basic hydroxides. Moreover, after an investigation of the Geopolymerisation of sixteen common Al-Si minerals, they found that for the most part, the NaOH arrangement caused a higher degree of disintegration of minerals than the KOH arrangement.

Factors affecting the properties of geopolymers

A couple of segments have been recognized as fundamental parameters impacting the properties of Geopolymers. Palomo et al (1999) deduced that the curing temperature was a reaction stimulating operator in fly ash based Geopolymers, and on a very basic level impacted the mechanical quality, together with the curing time and the kind of fundamental liquid. Higher curing temperature and longer curing time were exhibited to realize higher compressive quality. The alkaline liquid that contained dissolvable silicates was exhibited to extend the rate of reaction appeared differently in relation to solvent courses of action that contained just hydroxide.

MATERIALS

Materials that used in this project

Fine aggregate, Coarse aggregate, Ground granulated blast furnace slag (GGBS) and Alkaline solution

Fine aggregate

The Fine aggregate used in this project is confirmed for detailed severity, in accordance with IS: 2386-1963 and it is 2.719, while its fineness modulus is 2.31. The sieve analysis results are presented in table. The sand confirms zone-II. Fine aggregate ought to comprise of common sand or squashed stone sand. The residue substance ought not to surpass 4%

Figure 2 fine aggregate

Table 6: Property of Fine Aggregate

Sieve No.	**Cumulative Percent passing (%)**	**IS: 383-1970 – Zone II requirement**
	Fine Aggregate	
10 (mm)	100	100
4.75 (mm)	98.3	90-100
2.36 (mm)	94.2	75-100
1.18 (mm)	71.2	55-90
600 (μm)	47.8	35-59
300 (μm)	18.2	8-30
150 (μm)	3.12	0-10
Fineness modulus	3.11	
Specific Gravity	2.76	
Bulk Density	1378 Kg/m³	

Coarse aggregate

Machine crinkled angular Basalt metal used as coarse aggregate. The coarse aggregate is free from clayey matter, silt and organic foams etc. The coarse aggregate is also tested for specific gravity and it is 2.68. Fineness modulus of coarse aggregate is 4.20. Aggregate of nominal size 20mm and 10mm is used in the experimental work, which is acceptable according to IS: 383-1970.

Figure 3 coarse aggregate

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Table 7: Properties of Coarse aggregates

Sieve Size (mm)	**20 mm**		**12 mm**	
	Requirement as per IS: 383-1970	**Percentage passing**	**Requirement as per IS:383-1970**	**Percentage passing**
80.00	----	----	----	----
63.00	----	----	----	----
40.00	100 %	100 %	----	----
20.00	85 – 100 %	95.12 %	----	----
16.00	----	----	100 %	100 %
12.50	----	----	85 – 100 %	97 %
10.00	0 – 20 %	12.72 %	0 – 45 %	42.53 %
4.75	0 – 05 %	2.78 %	0 – 10 %	8 %
2.36	----	----	----	----
Specific gravity		2.76	-	2.72
Water Absorption %		0.34	-	0.54
Aggregate Impact Value		9.6 %	-	9.56 %
6Bulk Density (kg/m3)		1679	-	1632
Flakiness		14 %	-	13 %
Elongation		10 %	-	10 %

Ground granulated blast furnace slag (ggbs)

GGBS got purchased from online (India Mart). The specific gravity of GGBS is 2.9. Bulk density is 1200 kg/m3 and Quality is >350m2/kg. The colour of GGBS is off-white.

Figure 4 Ground granulated blast furnace slag

Table 8: GGBS Chemical composition

Oxide	**GGBS**
Cao	36.77
SiO2	30.97
Al2O3	17.41
MgO	9.01
SO3	1.82
Fe2O3	1.03
Na2O	0.69
K2O	0.46

Figure 5 NaOH

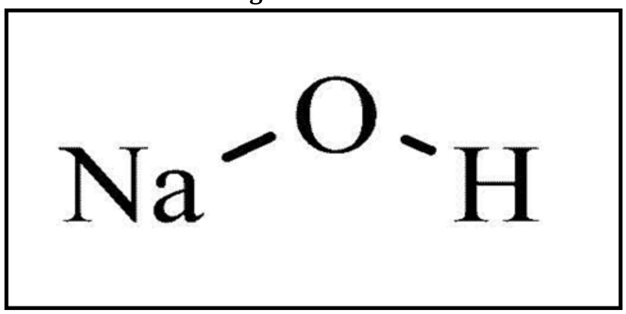

Figure 6 Structure of Sodium Hydroxide

Figure 7 Sodium silicate Na2SiO3 (gel type)

Alkaline Solution

The alkaline liquid are used in GPC production, it is a combination of sodium hydroxide (NaOH) and sodium silicate (Na2SiO3). It is recommended that the alkaline liquid is prepared by the mixing both the solutions collected at least 24 hours previous to use. The sodium silicate is commercially available in different grades. The sodium silicate solutionA53 with SiO2-to-Na2O ratio by mass of approximately 2, i.e., SiO2 = 29.4%, Na2O = 14.7%, and water = 55.9% by mass is used. The sodium hydroxide is available in flacks. The solids must be melted in distilled water to make a solution with the required concentration. The concentration of sodium hydroxide solution can vary in the range among 6 Molar to 16 Molar. In this investigation 6M,8M and 10M is adopted

EXPERIMENTAL PROGRAMME

An experimental program is conducted on "GGBS is full replacement of cement concrete.. The test program consists of resonant out compressive asset test on cubes and split tensile strength on cylinders and Flexural strength of Beams. Experimental study is accepted to investigate the compressive and flexural and split tensile strengths of concrete.

METHODOLOGY

Preparation of mix and alkaline solution

Unit Weight of concrete 2400, Mass of combined aggregate 77% of concrete mass. So mass of combined aggregate = (fine aggregate + coarse aggregate) = 1848 kg / m3.The Mass of GGBS and alkaline solution = 2400 - 1848 = 552 kg / m3
In this thesis we are taking (Alkaline / GGBS) =0.35
Mass of GGBS = (552)/(1+0.35)= 408 kg/m3
Mass of Alkaline liquid (Na2Sio3 + NaOH) = 552-408 = 144 kg/m3

We here considered (Na2Sio3) / (NaOH) = 2.5
NaOH =41.14 kg/m3
Na2Sio3 = 144 - 41.14 = 102.86 =103 kg / m3
Na2Sio3 is readily available in the market with different grades here we choose A53 used the solution contain Na2O = 14.7%, SiO2 = 29.4% and water = 55.9% by mass
NaOH solution is prepare according to the molarity we require, in this thesis we have used 6M, 8M and 10M for each molarity we have to calculate weight of solids per litre

TABLE 9: Properties of Different Molarity NaOH

NaOH (molarit)	Weight of solids	Total litres	Wt of solids/litre	of solids to soln	%of water to soln
6	40*6=240	1+0.24=1.24	240/1.24=195	195/1000=19.5	100-19.5=80.5
8	320	1.32	243	24.3	75.7
10	400	1.4	285.71	28.5	71.5

For trail mix

Water present in Sodium silicate

- % of only water in (Na2SiO3) other than solids =55.9%

NaOH

- We need Na2Sio3 = 144 - 41.14 = 102.86 =103 kg / m3
- Water in Na2SiO3 = (1.3)*(55.9/100) = 58 kg
- Only solids in Na2SiO3 = 103-58 = 45 kg

Table10: NaOH solution required

NaOH (Molarity)	Solids required to prepare solution (Kg)	Water required to prepare solution (Kg)
6	(19.5/100)*41.14=8.02	41.14-8.02=33.12
8	(25/100)*41.14=10.285	41.14-10.285=30.855
10	(29/100)*41.14=11.930	41.14-11.930=29.21

GPC must be wet mixed at least four minutes and steam cured at 60 degrees centigrade for 24 hours after casting. The workability of fresh mixed concrete is moderate. If more workability is required add some superplasticizer upto 1.5% by mass of binding material

Preparation of specimens

It was found that the Geopolymer blend was dark in shading. The measure of water in the blend assumed a critical part on the conduct of the crisp blend. Davidovits (2002) recommended that it is desirable over blend the sodium silicate arrangement and the sodium hydroxide arrangement together no less than one day before adding the fluid to the strong constituents.

After making the mix we have to cast the required test specimen w.r.t its mould. In this thesis we are testing the compressive strength, flexural strength, split tensile strength and durability aspects like acid attack, suphate attack, Chloride attack. After gaining partial strength to concrete specimen has to be cured.

5.4 CURING METHOD adopted is AMBIENT CURING: At that point, the shapes are demoulded and kept in oven at 500 c for 3 days and 7 days. For the daylight curing, the blocks are demoulded following 1 day of throwing and they are put in the immediate daylight for 3, 7 and 28 days.

Figure 11 Air dry curing at room temperature

Durability study

Durability is a major factor to be considered for the structure to with stand for a long period. So, my experimental investigation take me to identify the structural behavior on different environmental like Chloride attack, Acid attack and Sulphate attack. Therefore, the results and discussions are processed as follows.

In analyzing the durability parameter of concrete the procedure involves nine polyester tubs of capacity approximately 20 litres which are filled with 2% of chemical solution in 98% distilled water. The existing cubes are preserved for 28 days with each tub three cubes. The chemicals are H2So4, MgSo4 and NaCl.

Figure 18 chemical curing

RESULTS AND DISCUSSIONS

Table 12: Test results for Average Compressive strength, Split tensile strength, Flexural Strength

S. No.	Molarity	Average Compressive Strength (Mpa)			Average Split tensile Strength (Mpa)			Average Flexural Strength (Mpa)		
		3days	7 days	28 days	3days	7 days	28 days	3days	7days	28days
1	6	23.2	27.02	37.2	2.54	2.8	2.99	4.5	5.6	6.4
2	8	27.8	28.9	39.1	2.9	3.2	3.4	4.8	5.4	6.9
3	10	31.1	32.3	41.2	3.1	3.5	3.8	4.8	5.9	7

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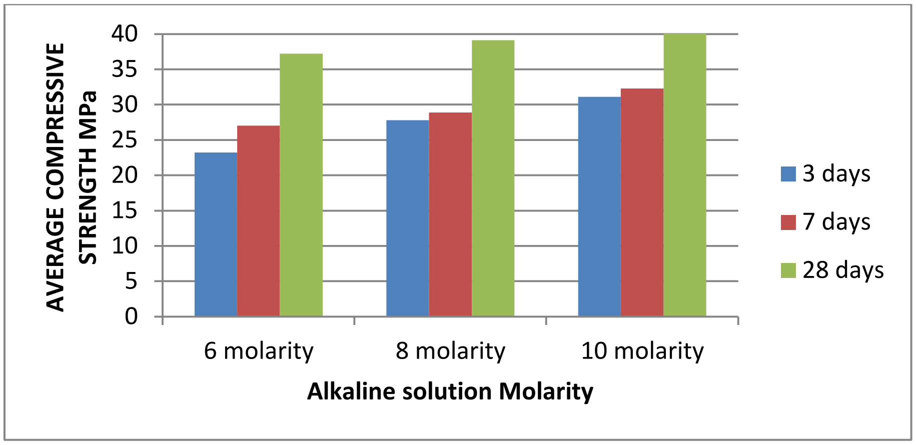

Chart showing Average Compressive Strength

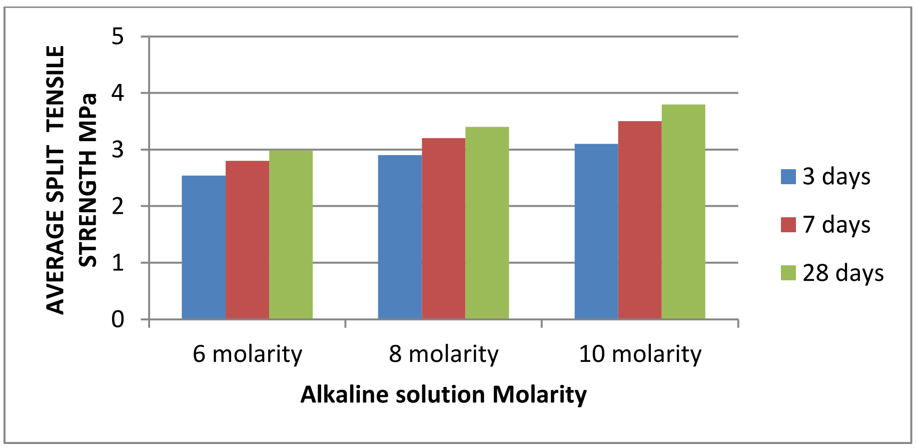

Chart showing Average Spilt Tensile Strength

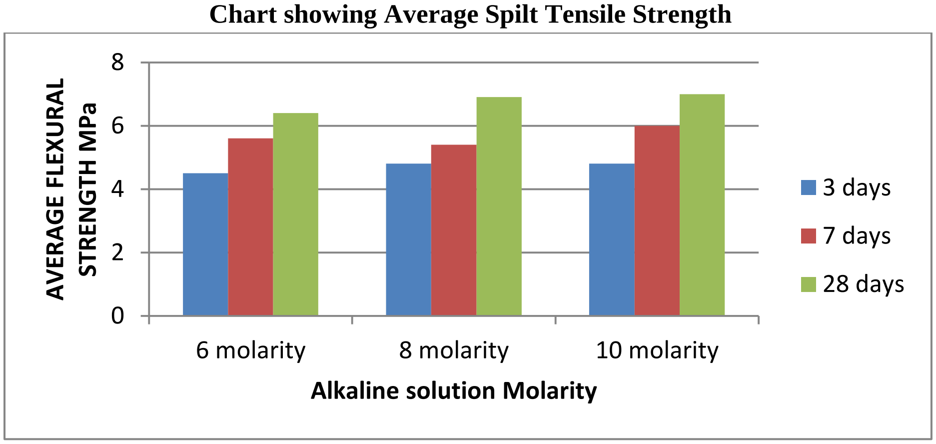

Chart showing Average Flexural strength

Durability parameters of GPC

Average compressive strength at 28 day has been found after curing in different solutions of Acid (H2So4), Chloride (NaCl) and Sulphate (MgSo4).

Table: Average Compressive Strength before and after curing in different solutions

S.NO	Alkaline solution Molarity	Average Compressive Strength (MPa)			
		Before Curing	Acid Attack	Chloride Attack	Sulphate Attack
1	6	37.2	29	38.2	38
2	8	39.1	30	40.12	39.2
3	10	41.2	32	43.9	42.3

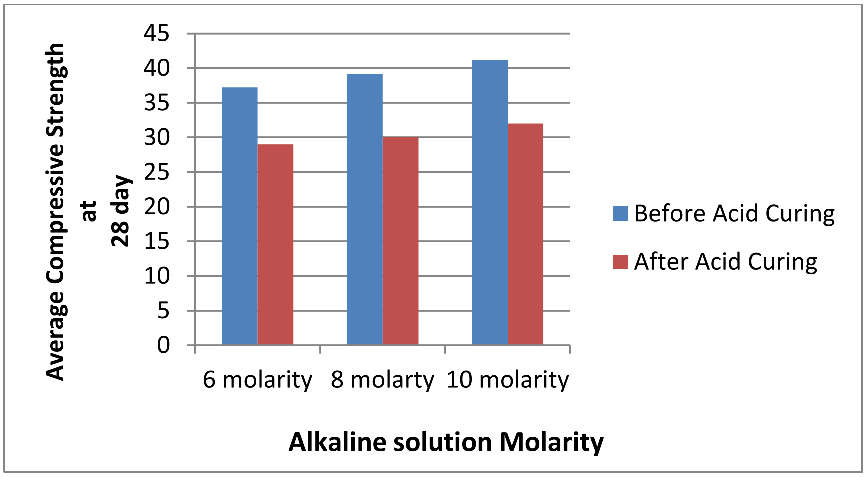

Chart about Average Compressive Strength of cube Before and After Acid attack

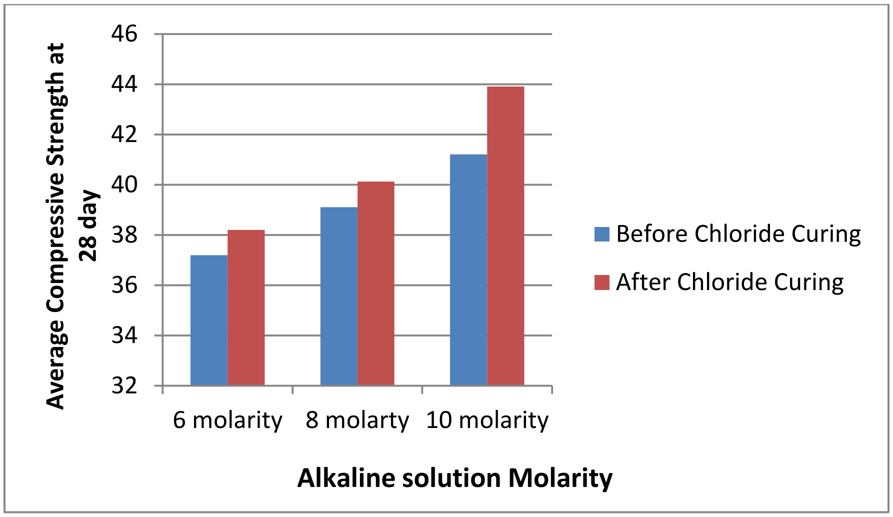

Chart about Average Compressive Strength of cube Before and After Chloride attack

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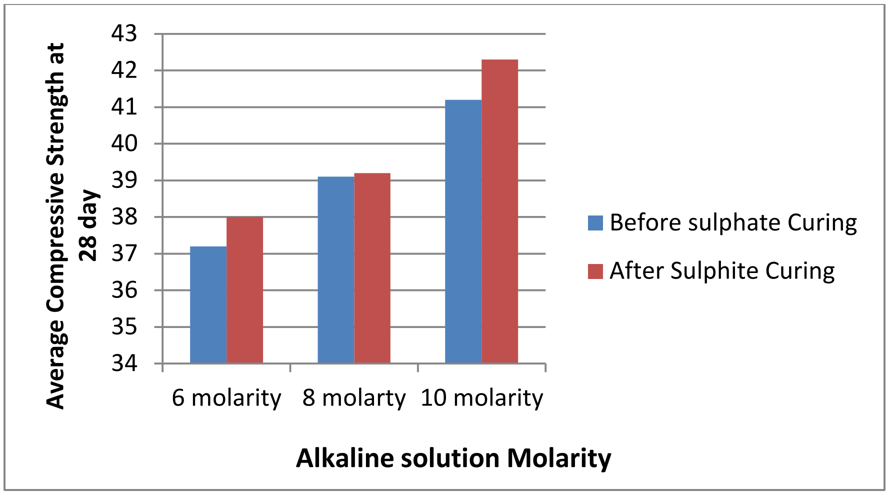

Chart about Average Compressive Strength of cube Before and After Sulphate attack

CONCLUSIONS

- Based on experimental investigations the following were observed:
- We have noticed when molarity of alkaline solution increased there is an increment in compressive strength, spilt tensile strength and flexural strength of GPC.
- In durability point of view when GPC get in contact with magnesium sulphate (MgSo4) there is an increase in compressive strength.
- In durability point of view when GPC get in contact with hydro sulphuric acid (H2So4) there is an decrease in compressive strength.
- When GPC get in contact with sodium chloride (NaCl) there is an slight increase in compressive strength.
- Ultimately if we use Geopolymer Concrete there will be reductions in CO2 emissions at manufacturing of Ordinary Portland Cement.

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