PERFORMANCE OF GEO POLYMER CONCRETE WITH M-SAND

[1]Aditya D S 1st Author, [2]Rakshitha S of 2nd Author, [3]Arpitha C of 3rd Author
[1]M.Tech student of 1st Author, [2]M.Tech student of 2nd Author, [3]M.Tech student of 3rd Author
[1]Polymer science Department of 1st Author,
[1]JSS science and technology university of 1st Author, MYSURU,INDIA

Abstract : The cement production is not only highly energy-intensive, but also consumes significant amount of natural resources. On the other hand, already huge volumes of GGBS are generated around the world; most of the GGBS is not effectively used, and a large part of it is disposed in landfills. Both the above issues are addressed in this work. Geopolymer concrete is produced by mixing GGBS (Slag) and Alkaline liquids.The grade chosen for the investigation is M-30 grade. Molarity is grams of solute to be dissolved in one litre of solution. It represents the concentration of solution. The mixes are designed for molarities of 16, 17 and 18 respectively. The alkaline solution used for present study is the combination of sodium silicate and sodium hydroxide solution with the ratio of 2.5. The test specimens consists of cubes (150x150x150) mm, cylinders (150x300) mm and the specimens will be ambient cured. The various tests will be conducted on specimens are compressive strength and split tensile strength. The tests are conducted at 7 and 28 days after the specimens are prepared.

INTRODUCTION

1.1 General

Construction industry consumes large amount of concrete so there is enormous increase in demand of cement. Cement production is energy intensive causing environmental pollution by emitting carbon dioxide at the same consuming natural resources. There was need of alternative binder material other than OPC in order to replace it, in 1970's Davidovits given the new hope for application in construction industry by proposing GPC**.** Reducing usage of cement, lowering use of amounts of fuel for manufacturing result in reduced carbon emissions which lowers environmental impact is the primary goal. This can be achieved by using Flyash or Ground granulated blast furnace slag (GGBS) as binder. As the demand for pollution control is increasing, use of alternate materials for construction is also increasing so use of geopolymer concrete (GPC) is emerged as a new alternative for conventional concrete. On the other end availability of river sand is also scarce and polluting the river beds affecting the underground water table. Hence use of alternate materials is must. The scope of the present work is on investigating Performance of GGBS based concrete with alkaline activator using M-sand.

Globally from steel industries a by-product called GGBS is produced in a large quantity, which can be used as an alternative material to replace OPC in the preparation of GPC. Geopolymer concrete are showing great potential and several researchers have critically examined the various aspects of their viability as binder material at higher molarity (above 10M).

The project is carried out to replace OPC using GGBS in order to reduce pollution, ratio of Na_2Sio_3 to NaOH is fixed at 1.0 & M-sand is inevitable material for present and future construction due to scarcity of river sand. The study is about increase in the molarity of NaOH which is the only varying parameter, keeping all other parameters constant as 100% GGBS as binder, geopolymer solids to binder as 0.35, water to geopolymer solids as 0.3 & 100% M-sand.

1.2 Need For Study

Geopolymer concrete has very high chemical resistance and does not experience spalling unless it reaches over 1200^o Celsius. Geopolymer concrete is not permeable and will not experience significant shrinkage and creep. It reduces the need for Portland cement which reduces the emission CO_2 into atmosphere, hence the effect of global warming is reduced. Geopolymer concrete utilizes waste materials as the primary feedstock. Hence waste product of industries is brought into use. So because of these properties of the Geopolymer concrete, an eco-friendly concrete is produced.

1.3 Problem definition

Viewing through the above literatures, it is found that the strength increases with addition of GGBS. The above literatures have been performed for river sand & as the availability of river sand is decreasing day by day this investigation is carried out using replacement of M-sand in the place of river sand & strength parameters are evaluated.

Based on the above literature survey, it is intended to see the Performance of GGBS based GPC using M-sand at 7 and 28 days by keeping the following parameters unaltered .

1. Water to Geopolymer solid ratio as 0.3.
2. 100% GGBS.
3. NaOH to Na_2SiO_3 ratio is 1.0.

Hence the problem can be defined as "Performance of GPC using M-sand".

1.4 Objectives.

1. To study the mechanical properties of geo-polymer concrete using M-sand.
2. To achieve M30 Grade concrete without using cement.

1.5 Methodology

1. To prepare alkaline solution for polymerization.
2. To prepare Geopolymer concrete cubes of 15cm x 15cm x 15cm.
3. To prepare cylinder of 15cm dia x 30cm length.
4. Ambient Curing of GPC cubes, beams & cylinders for 7 and 28 days.

1.6 SCOPE OF WORK

1. In the present work GGBS based GPC has attained good strength at 16M to 18M, it will be beneficial to study the properties without alkaline solution.
2. As GGBS based GPC produces stiffer mix, study can be carried out to make it workable easily without affecting the strength.
3. It is difficult to prepare the solution one day before construction in site and to control the heat liberated when NaOH pellets are mixed with water, hence in order to use this on site it would be beneficial to use it immediately and reduce the heat.

LITERATURE REVIEW

2.1 General

Only limited research data on geopolymer concrete are available in the literature. Earlier work by the authors reported the manufacturing process and the effect of various parameters such as curing temperature, curing time, sodium silicate-to-sodium hydroxide ratio, sodium hydroxide-to-free water ratio and the age of concrete on the compressive strength of geopolymer concrete. In this section, the various researches carried out in this field have been discussed in detail.

2.2 Review of literatures

Lloyd & Rangan (2010) conducted experiment on geopolymer concrete using low calcium fly ash (ASTM Class F) as source material & concluded that in GPC silica & alumina reacts with alkaline liquid. A simple method has been suggested to design GPC mixtures as there is no standard code for designing GPC mixture. They also studied the cost analysis based on cost of fly ash to OPC per ton & concluded that GPC is 10 to 30 percent cheaper after allowing alkaline liquids and all. In addition, significance of carbon-credit & its redemption is also studied. They also concluded that GPC can be used for manufacturing precast products & retrofitting works can be done.

V.Supraja & M. Kanta Rao (2012) carried over the study on geopolymer concrete incorporating GGBS fully & alkaline solutions of NaOH & Na_2SiO_3 were used. In the experiment cement has been fully replaced with GGBS with varying molarities of NaOH i.e 3M, 5M, 7M, & 9M used to prepare the mixes. The mix design is based on the density of concrete. The results of the study shown as the molar concentration of NaOH increases the compression strength also increases. No significant increase in strength after 3 days is observed & they studied both hot air oven curing as well as sunlight curing among both hot air oven curing specimens given better results.

Joshi and Kadu (2012) investigated on fly ash based GPC and the effect of geopolymer solids to alkaline solution, ratio of Na_2sio_3 to NaOH, & molar concentration of NaOH on material to withstand loads tending to reduce size of GPC. They concluded that the compressive strength of GPC is optimum at 0.25 geopolymer solids to alkaline solution is observed at 60°C. Mass ratio of sodium silicate to sodium hydroxide as 2.50 & it is observed that compressive strength of geopolymer concrete increases with increase in molar concentration.

Sanni & Kadiranaikar (2012) presents the work done on the variation of NaOH with 8 molarity on strength properties of GPC. The ratio of Na_2SiO_3 to NaOH being 2.0 to 3.5 with fly ash as binding material and curing method is by oven at 60°C. They observed that, workability increases with ratio of solution & strength increase with concentration of NaOH.

Krishnan et. al., (2014) studied the compressive strength characteristics of geopolymer concrete using fly ash & GGBS at ambient temperature and concluded that heat curing eliminated by using GGBS & also there is increase in strength by using GGBS.

Kalaivani (2015) conducted experiment on flexural strength on GPC and concluded that the flexural strength of the GPC increases with increase of concentration in terms of molarities. The compressive strength of the geopolymer concrete increases with increase in curing time. But flexural strength of GPC is lower than the conventional concrete. The ratio of alkaline liquid to fly ash, by mass does not affect the compressive strength of the GPC.

Janani & Revathi (2015) studied fly ash based geopolymer concrete with M-sand in varying proportions along with river sand. The mix design is based on the density of unit weight of concrete. In the mix proportion the variation is fine aggregate in proportion of 20% keeping all the parameters constant. The conclusion was compressive strength has increased by 9% when M-sand is fully replaced with river sand, there is 12% tensile strength increase for full replacement of M-sand & 10% increase in flexural strength for full replacement.

P Abhilash et.al.,(2016) worked on the mechanical properties of fly ash(FA) & GGBS in GPC in different proportions of FA & GGBS such as 50-50, 75-25, 100-0 with Na_2SiO_3 to NaOH alkaline solutions ambient cured for a period of 7, 14, 28, 56 and 112 days.

The observation was as the percentage of GGBS increased there was increase in compressive strength i.e. when FA increased from 50% to 100% there was a significant decrease in compressive strength in all curing periods. They also concluded that the increase in Fly ash replacement level weakens the microstructure of GPC thus leads to detriment of splitting tensile strength of GPC but the decrement is less.

They also observed that there was a significant decrease in flexural strength with the increase in percentage of Fly ash from 50% to 100% in all curing periods. They also concluded that ambient room temperature cubes attained enhanced mechanical properties without the need of heat curing.

B Sarath Chandra Kumar et. al. (2016), studied strength properties of GPC with different proportion of metakaolin & GGBS and recommended the combination of 100% GGBS based GPC for structural applications as the results were satisfactory (i.e. 53.62 MPa compressive strength at 7 days) with 100% GGBS. They also observed that 90% of the total strength was achieved within 7 days.

EXPERIMENTAL WORK

3.1 General

This Chapter elaborates the details of the process of preparing of GGBS based Geopolymer concrete, the mixes are designed based on method proposed by Lloyd & Rangam by considering the density of concrete since there is no standard method for mix design of Geopolymer concrete. In the present work, GGBS is used as the binder. The GGBS based geopolymer paste binds the coarse aggregates, fine aggregates and other materials together to form the geopolymer concrete. The GPC cubes are casted and cured at room temperature for 7 and 28 days.

3.2 Materials

Following are the materials used in the Geopolymer concrete for the investigation work :

1. GGBS
2. Fine aggregate i.e. M-sand
3. Coarse aggregate
4. Alkaline liquid- Mixture of Sodium silicate and Sodium hydroxide solution
5. Water

3.2.1 Ground Granulated Blast Furnace Slag (GGBS)

Ready to use GGBS was obtained from Jindal steel Industry (JSW), Vidyanagar,

Thorangallu Bellary, Karnataka. Physico-chemical properties of GGBS are in conformation with IS: 12089-1987. GGBS is a non-metallic powder consisting of aluminates and silicates of calcium and other variant bases.

The molten slag is rapidly chilled by quenching in water to form a gassy sand like granulated material. The granulated material when further ground to less than 45 micron will have specific surface of about 400 to 600 m^2/kg. The chemical composition of blast furnace slag (BFS) is similar to that of cement clinker. Use of GGBS in concrete is certified by LEED (Leadership in Energy & Environmental Design) .

Advantages of GGBS

- Concrete made with GGBS has better particle packing due to particle shape.
- Higher replacement is possible as specific gravity of cement to that of GGBS based concrete is close enough.
- Long term strength, sulphate resistance, chloride resistance & durability are better due to closer bonding of particles.
- Low Environmental Impact.

3.2.2 Aggregates

The aggregate is the matrix or structure containing of relatively fine and coarse materials. The aggregate provides about 75% of the body of concrete and hence its influence is extremely important. The physical, thermal and also sometimes chemical properties of aggregate greatly affect the performance of the concrete. The properties influenced are workability, strength, durability and economy. As the aggregates are cheaper than cement, it is economical to add into concrete as much of the aggregate as possible. The aggregates used in the Normal concrete usually ranges from 75% to 80% of the entire mixture by mass. Therefore in the design of geopolymer concrete, total aggregates are assumed as 75% of entire mixture. Coarse aggregates are taken as 70% and Fine aggregates are taken as 30% of the aggregates in the mixture.

Coarse Aggregate

Crushed angular granite rocks of 20 mm size from local quarry confirming to zone II as per IS-383-1970 was used as coarse aggregate. The specific gravity of coarse aggregate is obtained as 2.7 & fineness modulus is 8.3.

Sieve No	Weight of Aggregate	Cumulative	% Cumulative	% Passing
20	1540	1540	30.8	69.2
10	3420	4960	99.2	0.8
4.75	40	5000	-	-
Pan	-	-	-	-

Table 3.1: Sieve analysis of coarse aggregate

Fine Aggregate

With the increasing demand for river sand, the availability is depleting and the effects of extracting from the river beds has caused degradation of rivers, lowering the stream beds & leading to bank erosion. M-sand is used as replacement for river sand which is taken from local quarry from magadi village, Tq. Shirahatti, Dist. Gadag. The specific gravity of M-sand was obtained as 2.97. Water absorption of M-sand is 2%. As per IS-383-2016 sieve analysis is done using 1000gm M-sand. Confirming to Zone II & fineness modulus is 2.97 & Silt content is 12.1%.

Sieve No	Weight of Aggregate	Cumulative	% Cumulative	% Passing
4.75	13.75	13.75	1.38	98.63
2.36	220.83	234.58	23.46	76.54
1.18	272.08	506.67	50.67	49.33
0.6	70.42	577.08	57.71	42.29
0.3	167.08	744.17	74.42	25.58
0.15	148.75	892.92	89.29	10.71
Pan	107.08	1000	--	--

Table 3.2: Sieve analysis of M-sand

3.2.3 Alkaline solution

The most common alkaline activator used in geopolymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide and sodium silicate (Na_2SiO_3) or potassium silicate. Reactions occur at a high rate when the alkaline activator contains soluble silicate, either sodium or potassium silicate, compared to the use of only alkaline hydroxides. Xu and van Deventer (2000) confirmed that the addition of Na_2SiO_3 to NaOH as alkaline activator enhanced the reaction between the source material and the solution.

In this project a combination of Na_2SiO_3 to NaOH is being chosen as the alkaline activator. Sodium silicate solution and sodium hydroxide solution of 16, 17 and 18M concentration is prepared. Sodium silicate is purchased from Ravi Chemicals, Hubli, Karnataka and Sodium hydroxide pellets are obtained from Venkatesh TRADING CO. Dharwad, Karnataka.

Generally sodium hydroxide is available in solid state in the form of pellets and flakes. Sodium silicate is also known as water glass or liquid glass, available in liquid (gel) form. In present investigation sodium silicate to sodium hydroxide ratio 1.

Fig 3.1: Sodium Hydroxide pellets composition

3.2.4 Water

The water used is fresh potable, and is satisfactory to use in concrete.

3.3 Mix design

In the design of geopolymer concrete mix, coarse aggregates were taken as 75% of entire mixture by mass. This value is similar to that used in OPC concrete in which it will be in the range of 75 to 80% of the entire mixture by mass. Fine aggregate was taken as 30% of the total aggregates. The density of geopolymer concrete is taken similar to that of OPC as 2400kg/m^3.

Density of concrete=2400 kg/m^3

Molarity of NaOH =16M

Ratio of sodium silicate to sodium hydroxide =1

Ratio of alkaline solution to binder=0.35

Ratio of water to Geopolymer solids =0.3

Step.1. Calculation of Total Aggregate (Coarse and Fine Aggregate)

1) Total Aggregates = 75% of total mass

= 0.75 x 2400 = 1800 kg/m^3

2) Coarse Aggregates = 70% of total aggregates

= 0.70 x [1800] = 1260kg/m^3

3) Fine Aggregate = 30% of Total Aggregates

= 0.30 x [1800] = 540 kg/m^3

Step 2: Calculation of quantity of Binder And alkaline solution

1) Remaining Mass = Density of GPC -Total Aggregates

= 2400-1800= 600 kg/m^3

Geopolymer paste (Alkaline solution + Binder) = 600 kg/m^3

2) Alkaline Solution/Binder Ratio = 0.35

Therefore Binder = 600/1.35 = 444.44 kg/m^3

3) Quantity of Alkaline Solution = Geopolymer Paste - Quantity of Binder

= 600 – 444.44 = 155.56 kg/m^3

Step 3: Calculation of Proportion of Na_2SiO_3 + NaOH in Alkaline Solution

Alkaline Solution = Na_2SiO_3 + NaOH

We have taken ratio of Na_2SiO_3 to NaOH as 1.0

Na_2SiO_3/ NaOH= 1.0

Therefore, Quantity of NaOH Solution

= 155.56 / 2.0

= 77.78kg/m^3

Quantity of Na_2SiO_3 Solution = Qty. of Alkaline Solution – Qty of NaOH.

= 155.56 - 77.78 = 77.78 kg/m^3

Step 4: Calculation of Water and NaOH Solid Required Preparing NaOH Solution

1) Quantity of NaOH Solution = 77.78 kg/m^3

Molecular weight of NaOH = 40

Molarity of NaOH = 16M

= 16 x 40 = 640 gm

Therefore, NaOH Solids = 640/ (1000 + 640) = 0.39
NaOH Solids = 0.39 x 77.78 = 30.33 kg/m^3.

2) Water content in NaOH Solution = 1 – 0.39 = 0.61

= 0.61 x 77.78

= 47.44 kg/m3

Step 5: Calculation of Water & Na_2SiO_3 Solids Present in Sodium Silicate Solution

Na_2SiO_3 Solution = 77.78 kg/m^3

Water, Na_2O & SiO_2 ratio is obtained from the sodium silicate preparers

Na_2O = 16.51%

SiO_2 = 34.80 %

Water = 48.69%

Total Solids = 16.51+ 34.8 = 51.31%

Total Solids in Na_2SiO_3 Solution = 0.5131x 77.78 = 39.90 kg/m^3

Water content in Na_2SiO_3 Solution = 48.69%

Water present in Na_2SiO_3 Solution = 0.4869 x 77.78 = 37.86 kg/m^3

Total Water content in alkaline solution = water present in NaOH Solution

+ Water present in Na_2SiO_3

= 47.43 + 37.86 = 85.29kg/m^3

Step 6: Calculation of Extra Water Required

1) Water to Geopolymer solids = 0.3

Total water = total water present in solution + Extra water

Geopolymer Solids = Binder + NaOH Solids + Na_2SiO_3 Solids

= 444.44+ 30.33 +39.9 = 514.67 kg/m^3.

2) Water to Geopolymer solids = (total water in Solution + Extra water)/ total solids

Extra water = (0.3 x 514.67) – (47.43 + 37.86)

Therefore, Extra water = 69.11 kg/m^3.

Material Calculation

Number of cubes = 2

Volume of cubes = 0.15 X 0.15 X 0.15 X 2

= 0.00675 m^3

Coarse aggregate = 1260 X 0.00675

= 8.505 kg/m^3

Fine aggregate = 540 X 0.00675

= 3.645 kg

Slag required = 444.44 X 0.00675

= 2.99 kg

NaOH (16M) solid = 0.444 X 77.78 X 0.00675 (16M NaOH = 0.444 kg)

= 0.233 kg

(Na_2SiO_3) = 77.78 X 0.00675

= 0.525 kg

Water = 69.11 X .00675

= 0.466 kg

Similarly Cylinders ,

Number of cubes = 2

Volume of cubes = (π X 0.15^2 X 0.3 0X 2) / 4

= 0.0106 m^3

Coarse aggregate = 1260 X 0.0106

= 13.356 kg/m^3

Fine aggregate = 540 X 0.0106

= 5.724 kg

Slag required = 444.44 X 0.0106

= 4.711 kg

NaOH (16M) solid = 0.444 X 77.78 X 0.0106 (16M NaOH = 0.444 kg)

= 0.366 kg

(Na_2SiO_3) = 77.78 X 0.0106

= 0.824 kg

Water = 69.11 X 0.0106

= 0.732 kg

Therefore,

Total coarse aggregate required = 13.356+8.505 = 21.861Kg

Total M-Sand or fine aggregate required= 5.724+3.645 = 9.369 Kg

Total Slag required = 4.711+2.99 = 7.701 Kg

Total NaOH required = 0.366+.233 = 0.599 Kg

Total Na_2SiO_3 required =0.824+0.525 = 1.349 Kg

Total water required = 0.732+.466 = 1.198 Kg

3.4 Preparation of Cubes

The manufacturing of geopolymer concrete is similar to cement concrete. The process involves following steps.

1. Preparation of Solution
2. Mixing
3. Curing
4. Testing

3.4.1 Preparation of Solution

To prepare 16 molarity (16M) sodium hydroxide solution, 640 g (16 x 40) that is, (Molarity x molecular weight) of sodium hydroxide flakes are dissolved in 1.0 litre of water.

3.4.2 Mixing

3.4.2.1 Mix the sodium hydroxide pellets with water till all the pellets get dissolved in water then add sodium silicate solution. This has to be done at least one day before adding the solution to the dry materials.

3.4.2.2 GGBS, coarse aggregates & M-sand are mixed dry on a water tight platform for about three minutes until uniform colour is obtained.

3.4.2.3 The prepared alkaline solution is mixed with dry mix and the mixing is continued for another 3 minutes.

3.4.2.4The mixing of total mass will be continued until the binding paste covers all the aggregates and the mixture become homogeneous and uniform in colour.

3.4.2.5 Inner faces of cube and cylinder are applied with oil then homogeneous mixture of GPC is poured into the moulds.

3.4.2.6 Compaction is done using vibrating table.

3.4.2.7 Then the moulds are left to curing in open air.

3.4.3 Curing

For curing, cubes are left open to air, no water curing is done.

3.4.4 Testing

3.4.4.1 Compression Strength

The standard cube specimen of 15cm x 15cm x 15cm was used to determine the compressive strength of concrete. Three specimens were tested for 7 and 28 days with varying proportion of Na_2SiO_3 to NaOH solution. Compressive test is conducted on CTM of 2000 KN capacity. The compression strength of a cube is calculated using the formula : Strength = P / (B X D) (N/mm^2) .

Where, P is the failure load, B & D are the cross section dimensions perpendicular to P.

Fig 3.2: Cube testing on compression testing machine

3.4.4.2 Split tensile strength

The standard cylinder specimen of 15cm diameter and 30cm length were used to determine split tensile strength. The specimens were tested according to IS 5816-1999. Testing was done on CTM. Three specimens were used to determine strength and average is taken as the strength. The split tensile strength of a cylinder is calculated using the formula Strength = 2P /(ΠDL) (N/mm^2) where P is failure load, D and L are diameter and height of cylinder respectively.

Fig 3.3: Cylinder testing on compression testing machine

RESULTS & DISCUSSION

4.1 General

The experimental results are being tabulated in this chapter. The specimens were casted as per the mix design for GPC, four different variations of molarity of NaOH are considered (i.e 16M, 17M, 18M) are carried out keeping all the parameters constant. Then the cubes were tested for compressive strength test and cylinders for split tensile strength.

4.2 Compressive strength

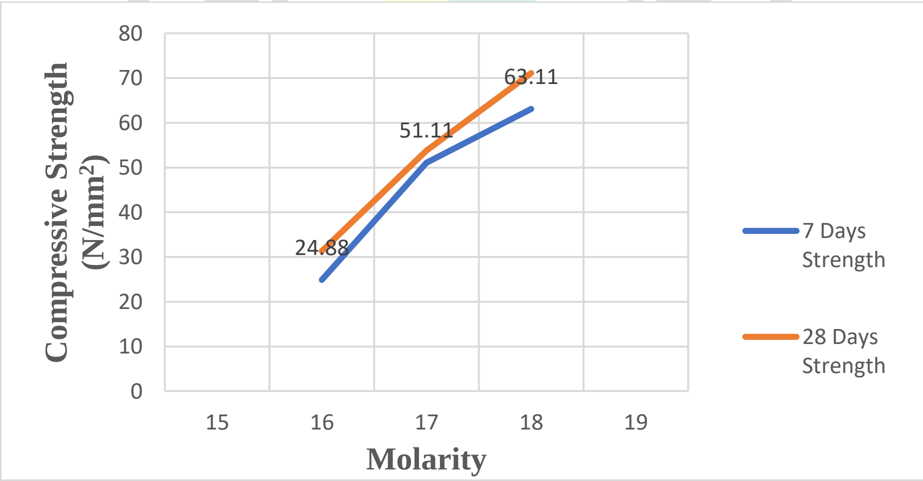
Compressive strength test results of cubes for different molarity of NaOH for 7 and 28 days are tabulated in the below table.

Sl. No	Molarity	Load in KN	7 days strength (MPa)
1	16	560	24.88
2	17	1150	51.11
3	18	1420	63.11

Table 4.1: 7 days compressive strength

Sl. No	Molarity	Load in KN	28 days strength (MPa)
1	16	705	31.33
2	17	1210	53.77
3	18	1600	71.11

Table 4.2: 28 days compressive strength



Graph 1: The Compressive Strength of M30 GPC for 7 & 28 days.

4.3 Split Tensile Strength

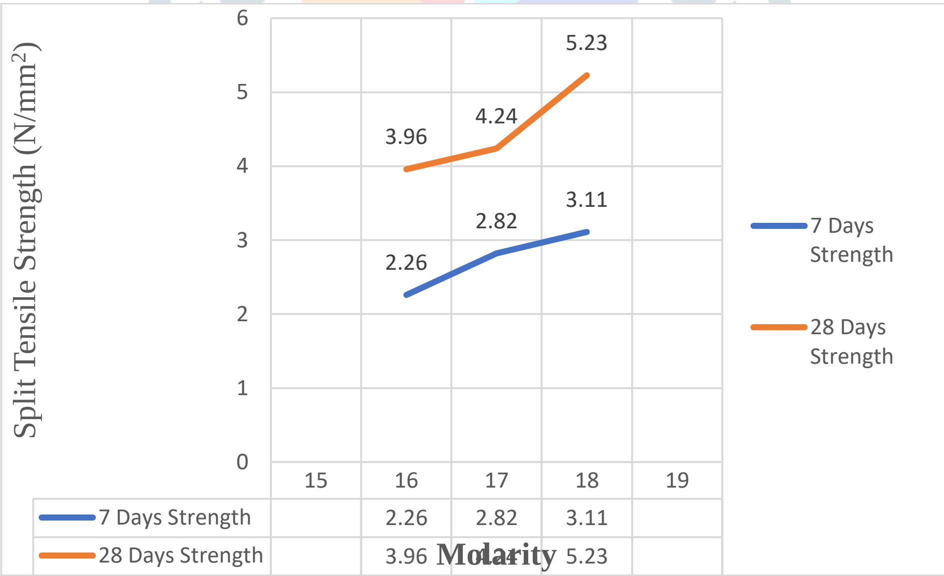
Split Tensile strength test results of cylinders for different molarity of NaOH for 7 and 28 days are tabulated in the below table.

Sl. No	Molarity	Load in KN	7 days strength (MPa)
1	16	160	2.26
2	17	200	2.82
3	18	220	3.11

Table 4.3: 7 days split tensile strength

Sl. No	Molarity	Load in KN	28 days strength (MPa)
1	16	280	3.96
2	17	300	4.24
3	18	370	5.23

Table 4.4: 28 days split tensile strength



Graph 2 : The Split Tensile Strength of M30 GPC for 7 & 28 days.

As concrete is weak in tension & brittle in nature, split tensile strength has to be carried in order to see the load at which the concrete members crack. The cracking is a form a tensile failure. The split tensile strength of geopolymer concrete is small when compared to compressive strength, as in case of OPC. From the graphs it is clear that at alkaline solution ratio of 1.0 split tensile strength is near to 4 MPa,, hence we can conclude that the results obtained from split tensile strength can be compared to that of compressive strength i.e with increase in molarity strength increases and gives good results compared to rest.

Alkaline / Slag ratio & Na_2SiO_3 / NaOH ratio	Molarity	Compressive strength (N/mm^2) 28 days	% increase in compressive strength	Split tensile strength (N/mm^2) 28 days	% increase in split tensile strength
0.35 & 1	16	705	-	280	-
	17	1210	41.74	300	6.66
	18	1600	24.37	370	18.9

Table 4.5: Percentage increase in compressive and split tensile strength after 28 days.

CONCLUSIONS

The construction industry is in demand of eco- friendly and greener materials which are durable. The present project work shows that OPC could be utilized as an alternative for normal concrete. The project work reveals with preparation of test samples of different molarities. The samples are prepared with the different molarities such as 16, 17 and 18. Tests for compressive strength and split tensile strength are carried out on samples as above for ambient temperature for 7 & 28 days, as per prevailing standards for respective properties. Based on the experimental results reported in the project, the following conclusions are drawn:

- Workability of GPC is very less (So to have the workable concrete extra water 30 percent of alkaline solids is added).
- The compressive strength of geopolymer concrete increases with the age of concrete.
- Compressive strength and split tensile strength of GPC increases with increase in the molarity.
- An eco-friendly construction material can be produced using GGBS, M-sand & Coarse aggregate.
- At ratio of 1.0 of alkaline solution, the results were considerably good in compression and tension. Hence this dosage can be considered for use.

REFERENCES

[1] B Sarath Chandra Kumar & K Ramesh, " Experimental study on strength properties of metakolin & GGBS based geopolymer concrete", APRN Journal of Engineering & Apllied Sciences ISSN1819-6608, November 2016.

[2] IS-383-1970: Specification for Coarse and Fine Aggregates from Natural sources for Concrete.

[3] Janani R, Revathi A, "Experimental Study of Geopolymer Concrete with Manufactured Sand", International Journal of Science, Engineering and Technology Research (IJSETR) Volume 4, Issue 4, April 2015.

[4] L Krishnan, S Karthikeyan, S Nathiya & K Suganya, " Geopolymer Concrete an ecofriendly Construction", IJRET June 2014

[5] M Kalaivani, "Experimental Investigation For Flexural Strength Of Fly Ash Concrete With Addition Of Alkaline Activater", ARPN Journal of Engineering and Applied Sciences VOL. 10, NO. 11, JUNE 2015.

[6] N A Lloyd and B V Rangan, "Geopolymer Concrete with Fly Ash". Coventry University and The University of Wisconsin Milwaukee Centre for By-products Utilization, Second International Conference on Sustainable Construction Materials and Technologies June 28 - June 30, 2010, Università Politecnica delle Marche, Ancona, Italy.

[7] Nimitha Vijayaraghavan and A S Wayal, "Effects of manufactured sand on compressive strength and workability of concrete", International Journal for Structural & Civil Engineering Research ISSN 2319 – 6009 www.ijscer.com Vol. 2, No. 4, November 2013 © 2013 IJSCER.

[8] P Abhilash, C.Sashidhar, I.V.Ramana Reddy, "Strength properties of Fly ash and GGBS based Geo-polymer Concrete", International Journal of ChemTech Research ISSN: 0974-4290 Vol.9, No.03 pp 350-356, 2016.

[9] Prakash R. Vora, Urmil V. Dave, "Parametric Studies on Compressive Strength of Geopolymer Concrete", Chemical, Civil and Mechanical Engineering Tracks of 3rd Nirma University International conference on Engineering (NUiCONE-2012)

[10] Shankar H. Sanni & R. B. Khadiranaikar, "Performance of alkaline solutions on grades of geopolymer concrete". IJRET: International Journal of Research in Engineering and Technology, IC-RICE Conference Issue, Nov-2013.

[11] Prof B V Venkatarama Reddy, "Suitability of manufactured sand (M- Sand) as fine aggregate in mortars & concrete".

[12] V. Supraja, M. Kanta Rao, "Experimental study on Geo-Polymer concrete incorporating GGBS", International Journal of Electronics, Communication & Soft Computing Science and Engineering ISSN: 2277-9477, Volume 2, Issue 2.

APPENDIX

Characteristics	**Fly ash (%wt.)**
Silica	55-65
Iron oxide	5-7
Aluminum oxide	22-25
Calcium oxide	5-7
Magnesium oxide	<1
Titanium oxide	<1
Phosphorous	<1
Sulphates	0.1
alkali oxide	<1

Table 1: Chemical composition of GGBS as supplied by JSW

Physical properties	**Properties of fly ash used**	**Properties of fly ash according to IS 1320-1981**
Specific gravity	2.51	-
Initial setting time	120 minutes	-
Final setting time	280 minutes	-
Fineness specific surface in m^2/ kg min	320	340

Table 2**:** Physical Properties of low calcium class F GGBS

Fig 1: Prepared alkaline solution.

.

Fig 2: Dry mix of GGBS and aggregates.

Fig 3: Split Tensile Test specimen after failure.