# STRENGTH AND DURABILITY PROPERTIES OF GEOPOLYMER CONCRETE MADE WITH GGBS

[1] Adanagouda, [2] Murthy B
1 Assistant Professor, Dept. of Civil Engineering, RYMEC Ballari, Karnataka, India
2 PG Student, Dept. of Civil Engineering, RYMEC Ballari, Karnataka, India

---

*Abstract:* Concrete is till now most fashionable material in construction industries and one of the most environmentally harmful materials. Due to environmental concerns of cement industry, there arises a strong need to make use of alternate technology which is sustainable. Geopolymer is an alternative material which can act as a binder by replacing cement. In this experimental work have analysis the strength and durability properties of fly ash and ground granulated blast furnace slag (GGBS) based geopolymer concrete and also the cost comparison with the normal concrete. The concentration of sodium hydroxide is 13 molarity(M) solutions kept a constant to prepare the mix and alkaline liquid to binder ratio as 0.40, but changing ratio of sodium hydroxide (NaOH)to Sodium silicate ($Na_2Sio_3$) 1.50, 2.00 and 2.50. The cube compressive strength was calculated for different alkaline activator solution for different mix Id. i.e. $F_{100}G_0$, $F_{90}G_{10,}$ $F_{80}G_{20,}$ $F_{70}G_{30}$ and $F_{60}G_{40,}$ (Where F and G are, respectively, Fly Ash and GGBS and the numerical value indicates the percentage of replacement of fly ash by GGBS). The cube specimens are taken of size 100 mm x 100 mm x 100 mm. ambient curing of concrete at room temperature was adopted. In total 45 cubes were cast for different mix Id and the cube specimens are tested for their compressive strength at age of 7 and 28 days respectively. The strength of geopolymer concrete was increased with increase in percentage of GGBS in a mix. It was observed that the mix Id $F_{60}G_{40}$ gave maximum compressive strength of 66 MPa was observed for ratio of NaOH to $Na_2Sio_3$ 2.50. Thus the geopolymer concrete have a relatively higher strength and better durability.

***IndexTerms*** **- Geopolymer concrete, Fly ash, GGBS, Alkali Activators, RCPT, Sorptivity.**

---

## I. INTRODUCTION

Concrete is the most commonly used construction material, its usage by the communities across the globe is second only to water. The worldwide demand for Ordinary Portland Cement (OPC) would increase further in the future. OPC production is a major contribution to carbon dioxide emissions. The global warming is caused by the total green house emission to the earth atmosphere contributing greatly to the global warming. Many efforts are being made in order to reduce or replace the use of OPC in concrete. These efforts are being made to utilization of supplementary cementitious materials such as fly ash, GGBS, silica fume and rice-husk ash etc. In terms of reducing the global worming the geopolymer technology could reduce the CO2 emission to the atmosphere cause by cement about 80%. The word Geopolymer introduced to the world by Davidovits in year 1980s, proposed that binders could be produced by a polymeric reaction of alkaline liquids with the Silicon and the Aluminum in source materials of geological origin or by-product materials such as fly ash and GGBS, he termed these binders as “Geopolymer”.

## II. LITERATURES ON GEOPOLYMER CONCRETE

An attempt is made to get the information regarding the work already done in the area of geopolymer concrete and replacement of cement with other materials. Following research articles are presented.

**Suresh.G.Patil, Manojkumar** reported in this paper to study effects of several factors on the properties of fly ash based geopolymer concrete on the compressive strength and alsi the cost comparison with the normal concrete. The test results indicated that the highest compressive strength 54Mpa was observed for 16M of NaOH, ratio of NaOH to Na2Sio3 2.5 and alkaline liquid to fly ash ratio of 0.35, lowest compressive strength of 27Mpa was observed for 8M of NaOH ratio of NaOH to Na2Sio3 is 1 and alkaline liquid to fly ash ratio of 0.40.

**Matghew Sudhakar and Natarajan** presented the increase of GGBS content, Compressive Strength is gradually increases. In this Coal Ash and GGBS Combination is taken along with 15M Alkaline Solution and total replacement of about 30% is taken into consideration and Higher Compressive Strength up to 57Mpa is achieved .However the cost of GGBS added Geopolymer is 7% Higher than OPC but when we Consider Strength aspect, it is almost 3 times than OPC at 7 days.

**Ganapati Naidu.etl** presented in this paper to study strength properties of geopolymer concrete using low calcium fly ash replacing with slag in 5 different percentages. Higher concentrations of GGBS result in higher compressive strength of geopolymer concrete 90% of compressive strength was achieved in 14 days.

**Salmabanu Luhar etl**. During this study, the water absorption and Sorptivity properties of fly ash based geopolymer concrete were studied in detail. The test result was found that the Sorptivity curve is less linear as compared to that of control concrete. That means the rate of absorption of geopolymer is less. Test results of water absorption test shows that the porosity of geopolymer concrete is less as fly ash is finer than OPC and results in to less water absorption than the control concrete.

## III. MATERIALS USED

The constituent materials used in the present investigation were:

- Fly ash
- GGBS ( Ground Granulated Blast Furnace Slag)
- Fine Aggregate
- Coarse Aggregate
- Alkaline liquid (NaOH,Na2SiO3 )
- Super Plasticizer(SP)
- Distilled water and Preparation of Alkali Solution

**3.1 Fly ash** was taken from thermal power plant at KUDITHINI BELLARY THERMAL POWER STATION was used in the investigation. The specific gravity is 2.20.

**3.2 GGBS** ash was taken from Jindal Steel plant at Vidynagar; Ballari was used in the investigation. The specific gravity is 2.11 .

**3.3 Fine aggregate** locally available sand, free from silt and organic matters was used. The particle size of the sand used in this study was such a way that it passed through 4.75mm sieve conforming to zone III. The specific gravity was 2.55 and Fineness modulus was 2.59.

**3.4 Coarse aggregate** crushed granite metal with 60% passing 20 mm and retained on 12.5mm sieve and 40% passing 12.5mm and retained on 4.75mm sieve were used. The weight of coarse aggregate was 60% of the total aggregate and specific gravity of coarse aggregate was 2.84.

**3.5 Super plasticizer** to improve the workability of the mixes, a high range water reducing agent Fosroc conplast SP430 (SNF-Sulphonated Naphthalene Formaldehyde) 2% of fly ash is used.

**3.6 Alkaline Solutions** the solution of sodium hydroxide and sodium silicate are used as alkaline solutions in the present study. Commercial grade sodium hydroxide in pellets form and sodium silicate solution are used.

**3.7 Preparation of Alkaline Solutions**

The mixture of sodium silicate solution and sodium hydroxide solution forms the alkaline liquid. A combination of alkaline silicate solution and alkaline hydroxide solution was chosen as the alkaline liquid. In this research work the compressive strength of Geopolymer concrete is examined for the mixes of 13 Molarity of sodium hydroxide. The molecular weight of sodium hydroxide is 40. To prepare 13 Molarity of solution 520 gm of sodium hydroxide flakes are weighed and they can be dissolved in distilled water to form 1 litre solution has to be prepared 24 hours advance before use. Sodium hydroxide flakes are added slowly to distilled water to prepare 1liter solution.

## IV. MIX PROPORTIONS

The conventional method used in the making of normal concrete is adopted to prepare geopolymer concrete. First, the fine aggregate, coarse aggregate, GGBS and fly ash is mixed in dry condition for 3- 4 minutes and then the alkaline solution which is a combination of Sodium hydroxide solution and Sodium silicate solution with a ratio of 1:2.5 and super plasticizer is added to the dry mix. The mixing is done about 6-8 minutes for proper bonding of all the materials. After the mixing, the specimens are casted by giving proper compaction in three layers.

**Table - 1.0:** Material requirement for 1 Cu.mt

| Materials (Kg/m$^3$) | Mix Id | | |
|---|---|---|---|
| | M1 | M2 | M3 |
| Fly Ash and GGBS | 394.30 | 394.30 | 394.30 |
| Sodium hydroxide | 63.22 | 52.68 | 45.41 |
| Sodium silicate | 94.83 | 105.37 | 112.65 |
| Fine aggregates | 554.40 | 554.40 | 554.40 |
| Coarse aggregates | 1293.00 | 1293.00 | 1293.00 |
| Ratio of alkaline activator | 1.5 | 2.0 | 2.5 |
| Mix proportion ratio | 1:1.40:3.28 | 1:1.40:3.28 | 1:1.40:3.28 |
| Distilled water: 10% of cementitious material. | | | |
| Super plasticizer material: 2% of cementitious material. | | | |

**V.TEST RESULTS**

The various strength tests that are to be done listed as below.

- Compressive Strength
- Split Tensile Strength
- Sorptivity Test
- Rapid Chloride Permeability Test

**5.1Compressive Strength Test**:

Concrete cubes are tested in compressive testing machine (200 Tonne capacity) to determine their compressive strength of 3 specimens at the age of 7th and 28th days with optimum percentage of GGBS and fly ash were given below in Table 3.0. From the test results, it was observed that the maximum compressive strength was obtained for mix M3 with 60% fly ash (F) and 40% GGBS (G).

**Figure - 1.0** Compressive test on concrete cube.

**Table - 2.0** Experimental results of compressive strength of cube at 7days of age in N/mm$^2$

| Mix Id | M1 | M2 | M3 |
|---|---|---|---|
| F100G0 | 30.00 | 32.38 | 35.66 |
| F90G10 | 34.37 | 38.40 | 42.34 |
| F80G20 | 39.20 | 41.62 | 43.50 |
| F70G30 | 41.00 | 43.28 | 45.67 |
| F60G40 | 52.64 | 56.23 | 58.73 |

**Chart -1**: Cube compressive strength results at 7 days.

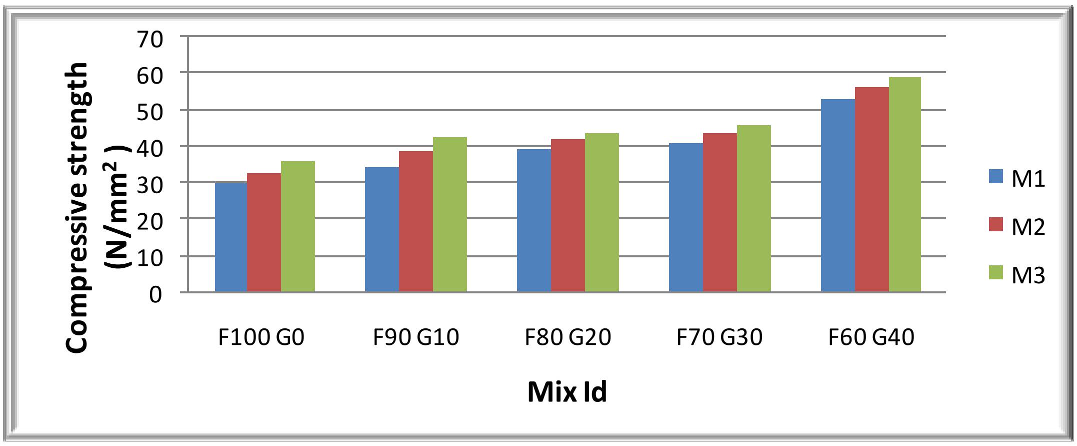
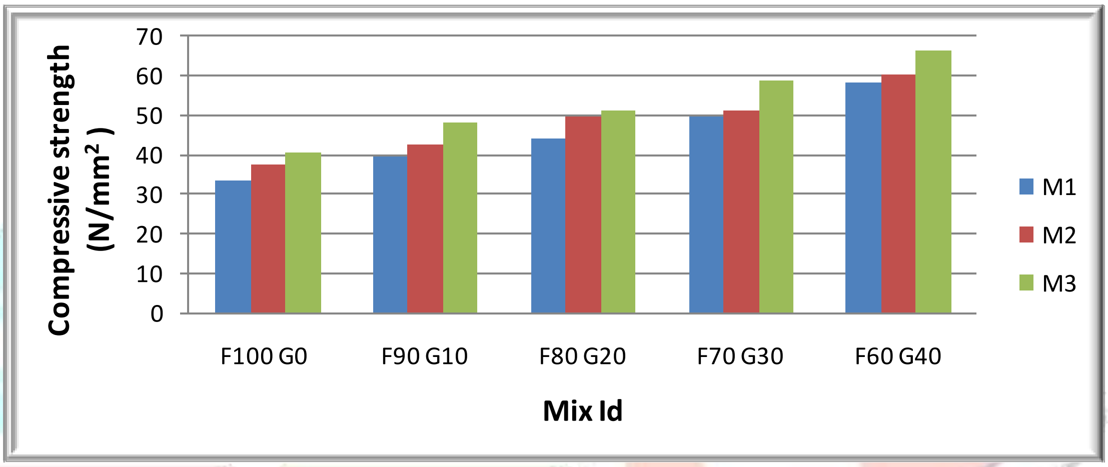


**Table - 3.0** Experimental results of compressive strength of cube at 28 days of age in $N/mm^2$.

| Mix Id | M1 | M2 | M3 |
|---|---|---|---|
| F100G0 | 33.50 | 37.35 | 40.64 |
| F90G10 | 39.63 | 42.50 | 48.00 |
| F80G20 | 44.30 | 49.67 | 51.24 |
| F70G30 | 49.52 | 51.38 | 58.67 |
| F60G40 | 58.55 | 60.40 | 66.48 |

**Chart -2**: Cube compressive strength results at 28 days




**5.2 Split tensile strength test:**

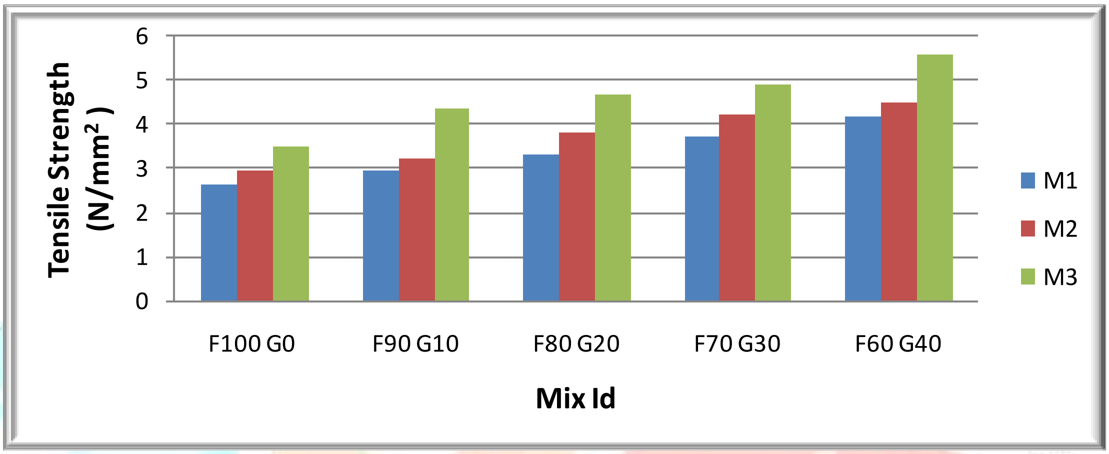
Tensile strength is one of the basic and important properties of concrete. Size of test sample of 10cm diameter, 20cm height cylindrical mould is used. The variation of split tensile strength at the age of 28th days with optimum percentage of Fly ash and GGBS were given below. It was observed that the maximum split tensile strength was obtained for mix M3 with 60% Fly ash and 40 % GGBS.

**Figure 2.0** Testing cylinder specimens in a CTM

**Table - 4.0** Split Tensile Strength results at 28 Days of age in $N/mm^2$.

| Mix Id | M1 | M2 | M3 |
|---|---|---|---|
| F100G0 | 2.65 | 2.95 | 3.49 |
| F90G10 | 2.95 | 3.22 | 4.37 |
| F80G20 | 3.30 | 3.83 | 4.68 |
| F70G30 | 3.72 | 4.24 | 4.92 |
| F60G40 | 4.20 | 4.48 | 5.60 |

**Chart -3**: Split Tensile strength results at 28 days.




**5.3 Sorptivity Test:**

The Sorptivity can be determined by the measurement of the capillary rise absorption rate on reasonably homogeneous material. Water was used of the test fluid. The cylinders after casting and curing for 28 days. The specimen size 100mm dia x 2000 mm height after drying in oven at temperature of 100 + 10 °C were drowned as shown in with water level not more than 5 mm above the base of specimen and the flow from the peripheral surface is prevented by sealing it properly with non-absorbent coating. The quantity of water absorbed in time period of 30 minutes was measured by weighting the specimen on a top pan balance weighting up to 0.1 mg. surface water on the specimen was wiped off with a dampened tissue and each weighting operation was completed within 30 seconds. Sorptivity (S) is a material property which characterizes the tendency of a porous material to absorb and transmit water by capillarity. The cumulative water absorption (per unit area of the inflow surface) increases as the square root of elapsed time (t) ; I=S.t½ therefore S=I/ t½ ; Where; S= Sorptivity in mm;t= elapsed time in mint; I=Δw/Ad Δw= change in weight = W2-W1 W1 = Oven dry weight of cylinder in grams W2 = Weight of cylinder after30 minutes capillary suction of water in grams. A= surface area of the specimen through which water penetrated.

d= density of water.

**Table - 5.0** Sorptivity results.

| Mix Id | Dry Weight in grams (W1) | Wet Weight in grams (W2) | I $10^{-6}$ | Sorptivity in mm $10^{-6}$ mm/ min0.5 |
|---|---|---|---|---|
| M1 | 3780 | 3800 | 1.60 | 0.40 |
| M2 | 3730 | 3750 | 2.48 | 0.62 |
| M3 | 3700 | 3720 | 3.59 | 0.89 |

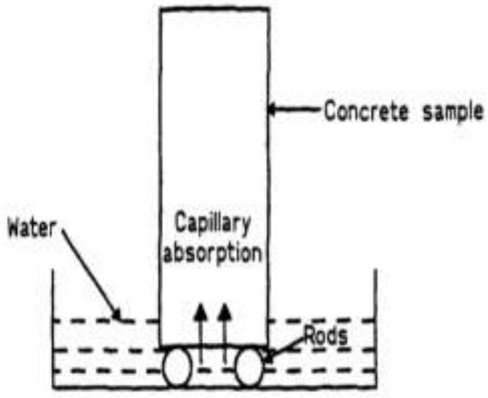



**Figure - 3.0** Schematic of Sorptivity Test.

**Figure - 4.0** Sorptivity Test.

### 5.4 Rapid Chloride Permeability Test (RCPT):

This tests methods covers the determination of the electric conductance of concrete to offer a fast indication soffits resistance to the penetration of chloride ions. the rcpt methods is the fastest techniques and is regularly used for specifications and high-quality manage purposes. the digital led presentations shows the voltages available across the concrete specimen underneath assessments. the diffusion consists of two chambers. nacl solutions concentration 2.four m and NaOH answer concentration 0.3m are prepared. nacl solutions concentration 2.4 m is crammed in a single chambers and in every other chambers0.3 m NaOH solutions is taken. the chloride ions had been compelled emigrate thru the centrally placed vacuum saturated concrete specimens under an inspired dc voltages of 60 volts. the procedures of this exams technique for measuring the resistance of concrete to chloride ion penetrations has no bias because the value of this resistance may be described handiest in phrases of a test techniques. the methods replies on the consequences from a take a look at wherein electrical current passes through a concrete samples during a six hour publicity intervals. the whole charge handed is a degree of the electrical conductance of the concrete during the length of the take a look at fast chloride entrance tests methods (as reliable with astm c1202) in solid example gives a quick sign in their protection from chloride particle penetrations by assessing the electric conductance of solid specimens (rcpt is an electrical sign to measures the ability of cement to look up to the infiltration of chloride particles). the electrical conductance results have demonstrated proper correlations with the consumption of the fortification in bond concrete. this tests methods comprises of following the amount of electrical current gave by means of fifty one-mm thick cuts of 102-mm ostensible measurement center during 6 h periods (checked every 30 min). a potential differences of 60 v from a dc power sources is kept up over the finishes of the examples. the mechanical assembly comprises of a components cell meeting (which checked for is hermetically sealed and water tights) whose cathode compartments is submerged in a sodium chloride reply (three%), the anode compartments in a 0.3msodium hydroxide answers. the general charge outperformed, in coulombs, has been seen to be related with the protection of the example to chloride particle nitration. as with regards to the code, if the charges passed is short of what one hundred _c, chloride particle vulnerability is irrelevant, 100e1000 could be low vulnerability, 1000e2000 _c is low vulnerability, 2000e4 000 _c is moderates penetrability or more 4000 _c is high vulnerability. for cs 50, the chloride penetrations showed most extreme values of 493.seventy five. be that as it may, as with regards to astm c1202, every one of the qualities will comes under 'low' rate of chloride entrance. the variety in chloride entering for concrete blends with copper slag and elastic tires is given in work area 2.

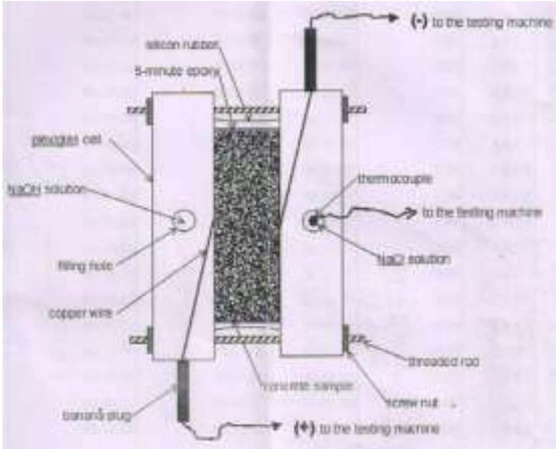



**Figure - 5.0** Schematic diagram of RCPT [ASTM C 1202- 94]


**Figure - 6.0** RCPT test setup.

**Table - 6.0** Recommended Values from ASTM C1202

| Charge Passed (Coulombs) | Chloride ion Penetrability |
|---|---|
| >4000 | High |
| 2001-4000 | Moderate |
| 1001-2000 | Low |
| 100-1000 | Very Low |
| <100 | Negligible |

**Table - 7.0** Rapid Chloride Permeability Test Results

| Percentage Replacement of Fly Ash by GGBS | Mix | Charge passed (coulombs) | Average charge passed (coulombs) Q | Chloride permeability rating |
|---|---|---|---|---|
| G0F100 | Mix-1 | 1300 | 1156.17 | Low |
| | Mix-2 | 1185 | | |
| | Mix-3 | 983.5 | | |
| G40F60 | Mix-1 | 864 | 771.30 | Very Low |
| | Mix-2 | 788.4 | | |
| | Mix-3 | 661.5 | | |

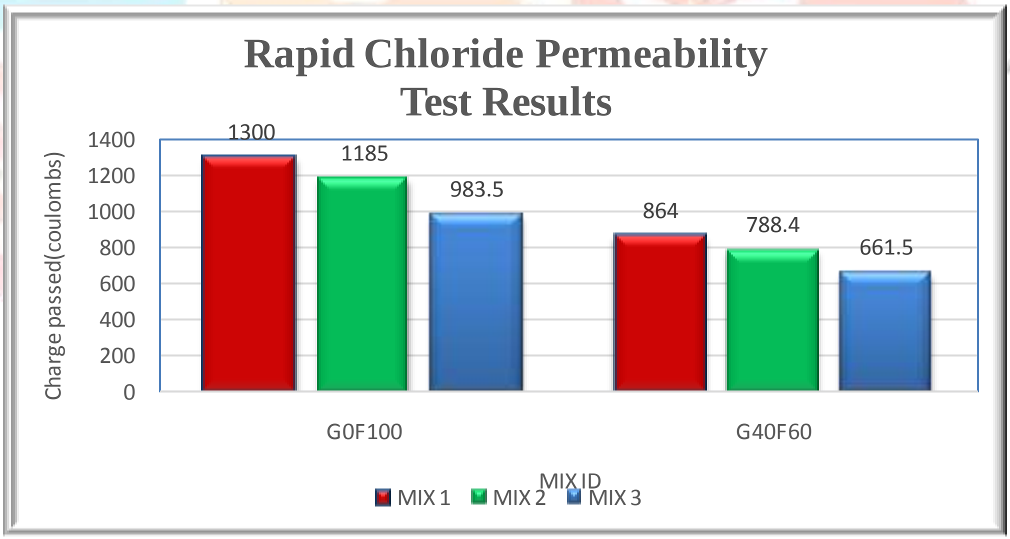



**Chart 4.0** RCPT of geopolymer Concrete

**VI. CONCLUSION:**

Based on the results obtained in the experimental investigation, the following conclusions are drawn.

- When the ratio of alkaline solution (Na2SiO3/NaOH) increased then the strength of concrete also increase and maximum strength gain for 2.5 is 66.48 Mpa.
- Geopolymer concrete shows higher Sorptivity than cement concrete.
- The geopolymer concrete gained strength within 24 hours at ambient temperature without water curing.
- The strength of geopolymer concrete was increased with increase in percentage of GGBS in a mix.
- As the Geopolymer concrete has less permeability, less porous , and has less void ratio which results in high durability of the Geopolymer concrete, thus Geopolymer concrete has high durability aspect than the conventional concrete.

## VII. REFERENCES


- Suresh G Patil, Manojkumar, " Factors influencing compressive strength of geoplymer concrete" , IJRET, Eissn 2319-1163, Page no 372-375, Nov-2013.
- P.GanapatiNaidu,A.S.S.N.Prasad,P.V.V.Satayanarayana(2012)"A Study On Strength Properties Of Geopolymer Concrete With Addition Of G.G.B.S" International Journal of Engineering Research and Development Volume 2, Issue 4 PP. 19-28.
- S.SundarKumar,J.Vasugi,H.Bharatkumar(2013)Development and Determination of Mechanical Properties of Fly Ash And Slag Blended Geo Polymer Concrete" International Journal of Scientific & Engineering Research, Volume 4, Issue 8.
- Prof.PratapKrishnarao(2013)"Design of Geopolymer Concrete" International Journal of Innovation Research in Science, Engineering and Technology (IJIRSET) Volume 2 Issue 5.
- P. Abhilash, C. Sashidhar, I.V.Ramana Reddy (2016), "Strength properties of Fly ash and GGBS based Geo-polymer Concrete" International Journal of ChemTech Research, Vol.9, No.03 pp 350-356, ISSN: 0974-4290
- Prasanna, B. Lakshminarayanan, M. Arun Kumar, J.R Dinesh Kumaran (2016) , "Flyash based geopolymer concrete using GGBS" International Conference on Current Research in Engineering Science and Technology ,E-ISSN :2348 – 8352.