International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Experimental Study of Compressive Strength of 8m Geopolymer Mortar for Different Combinations of C-Ash with Ggbs(45µ)

C. K. Dhanalakshmi[1], H. M. Dayananda[2]

[1]Assistant Professor, Department of Civil Engineering, AIT, Chikkamagaluru
[2]Assistant Professor, Govt. Science College(Autonomous), Hassan

ABSTRACT

Concrete is the material which is abundantly used in the construction industry and the production of cement is one among the reason for global warming due to release of carbon dioxide, to minimize its effect on nature we must use industrial by-product as an alternative material.

Among industrial by-product, usage of fly ash is more. The geopolymer mortar made by the using fly-ash set slowly in ambient temperature and needs heat curing. To overcome this limitation, Ground Granulated Blast Furnace Slag (GGBS) powder is used as a cementious material which shows considerable gain in strength. In this paper, we investigated the properties of geopolymeric binder prepared using the Ground "Granulated Blast Furnace Slag" (GGBS) and coal ash without using conventional cement. The individual properties of the GM for 1:3 ratio, such as compressive strength test were determined as per relevant Indian standards. Cubes of size (70.6 x 70.6 x 70.6) mm were casted and cured in ambient condition for molarity 8M with different ratios and different temperatures.

After the experiments, compressive strength is increased for increasing number of days of curing. Also compressive strength decreased for increasing Na_2SiO_3/NaOH ratios and increasing oven curing temperatures.

Keywords: *Geoploymer mortar, GGBS, coal ash, 8M (Molarity)*

1. INTRODUCTION

Cement is a material used in construction industry as a binder from last few decades. Many hazardous gases were released in the manufacturing process of cement such as CO, CO_2, etc., in the atmosphere which are more precarious to the environment. Around 6.99% of greenhouse gas is emitted to the atmosphere in the production of cement. In general, 1 tonne production of cement requires 4.01GJ of energy which produces nearly 1 tonne of carbon dioxide to the atmosphere.

Fly ash (by-product of burning coal) is extensively available in a globe, which is used as an alternative for cement. When it utilized as a complete replacement of cement in the presence of H_2O and in surrounding temperature, fly ash reacts with the slaked lime during the hydration process of cement to form the H_2CaO_4Si gel. The development and usage of large volume fly ash cement, which enabled the complete alternative of cement up to 65% by mass is an eloquent improvement.

Geopolymers is an inorganic polymeric material used as binder, firstly developed by Joseph Davidovits in 1970. Geopolymerisation involves a chemical reaction between solid alumino-silicate oxides and alkali

metal silicate solutions under highly alkaline conditions yielding amorphous to semi-crystalline three-dimensional polymeric structures, which consist of Si-O-Al bonds.

The main intent is to remove the OPC in the mortar by using industrial waste. To study the basic properties of materials. To find out the compressive strength of geopolymer mortar with various combinations of coal ash with GGBS of 45µ for different curing periods of 3, 28 and 56 days.

2. MATERIALS USED

a. GROUND GRANULATED BLAST FURNACE SLAG (GGBS):

GGBS is a reusable material produced when the molten slag from melted iron core is crushed or milled rapidly and then ground into a powder. It has cementitious properties and it is used as a replacement for or additive cement for over 100 years. GGBS is purchased from a vendor, QUALITY POLYTECH, Mangalore. The Physical and Chemical properties of GGBS is as tabulated below. There is no Indian Standard on GGBS. The test results are compared with BS Specification. The GGBS belongs to IS: 12089:1987

2.1.1 PHYSICAL PROPERTIES OF GGBS

PROPERTIES	TEST RESULT
Colour	Off White
Specific gravity	2.94
Consistency	33%
% particles retained on 90µ sieve	Nil

Table 1 Physical Properties of GGBS

2.1.2 CHEMICAL PROPERTIES OF GGBS

SL. NO.	CHEMICAL COMPONENT	TEST RESULT	REQUIREMENT AS PER IS:12089-1987
1	CaO	37.34%	-
2	Al_2O_3	14.42%	-
3	Fe_2O_3	1.11%	-
4	SiO_2	37.73%	-
5	Magnesium Oxide(MgO)	8.71%	Max 17.0%
6	Manganese Oxide(MnO)	0.02%	Max 5.5%
7	Sulphide Sulphur	0.39%	Max 2.0%
8	Loss On Ignition	1.41%	-
9	Insoluble Residue	1.59%	Max 5%
10	Glass Content	92%	Min 85%
11	Chemical Moduli	-	-
A	$(CaO+MgO+1/3Al_2O_3)/(SiO_2+2/3Al_2O_3)$	1.07	>1.0

B	$(CaO+MgO+Al_2O_3)/SiO_2$	1.60	>1.0

Table 2 Chemical properties of GGBS

(SOURCE: JSW CEMENT Ltd, Test Certificate, GGBFS. Week no (03) 22-08-2016 to 29-08-2016)

b. FINE AGGREGATES

The locally available river sand is used as fine aggregate. The sand should be free from all organic and inorganic matters. As per IS 383-1976, the particle size distribution of sand shows that it is in zone-II.

2.3 COAL ASH

It is taken from brick industry, Bangalore

2.3.1 PHYSICAL PROPERTIES OF COAL ASH

Sl. No.	Characteristics	C-ash
1	Specific gravity	2.59
2	Standard consistency (%)	38.0
3	Setting time • Initial setting time (min) • Final setting time (min)	 205 340
4	Fineness • Wet sieving (75µ) in (%) • Dry sieving (150µ) in (%)	 9.0 4.0
5	Lime reactivity (N/mm^2)	1.37
6	Compressive strength of cement mortar (N/mm^2) • 3 days • 28 days • 56 days	 6.8 11.26 29.46

Table 3 Physical properties of coal ash

2.3.2 CHEMICAL PROPERTIES OF COAL ASH

Sl. No	Chemical constituents (as oxides) %	C-Ash
1	SiO_2	57.73
2	Al_2O_3	26.38
3	CaO	4.49
4	MgO	0.20
5	Fe_2O_3	3.79
6	SO_3	2.34
7	Na_2O	0.31

8	K_2O	0.77
9	Cl	0.051
10	L.O.I	3.01
11	Insoluble residue	80.98
12	Moisture	0.24
13	Free Lime	0.11

Table 4 Chemical properties of coal ash

2.4 ALKANINE ACTIVATOR

It is a combination of sodium hydroxide and sodium silicate solution. The sodium hydroxide in flakes form was used is a colour less substance with a purity of 98%. Sodium silicate in liquid form was used, colour of the liquid is white.

3. METHODOLOGY

3.1 MIX DESIGN OF GPM

The mix design of GPM are given below

a. Ratio of (GB+ CA) : Fine aggregate used = **1:3**
- (GB+ CA) used = 200g (for 100% GB)
- (GB+ CA) used = 160g + 40g (for 80% GB and 20% Coal ash)
- (GB+ CA) = 120g + 80g (for 60% GB and 40% Coal ash)
- (GB+ CA) = 80g + 120g (for 40% GB and 60% Coal ash)
- (GB+ CA) = 40g + 120g (for 20% GB and 80% Coal ash)
- (GB+ CA) = 160g + 40g (for 0% GB and 100% Coal ash)
- Fine aggregate = 600g

b. Alkaline liquid / (GB+ CA) ratio =**0.5**
- Alkaline liquid= 0.5 x (GB+ CA) = 0.5 x 200gm =**100 g**

c. Molarity of the solution =**8M**

d. Na_2SiO_3/NaOH = **1.5**

e. Alkaline liquid = Na_2SiO_3+NaOH solutions
- Na_2SiO_3 + NaOH =100
- Na_2SiO_3 solution = 60g
- NaOH solution = 40g

f. For NaOH solution of 8M,Quantity of NaOH solids = 8x40 = 320g of solids in 1000ml of water. Hence for 40gm of NaOH solution
- Quantity of NaOH solids = 9.7g
- Quantity of water = 30.3 ml

g. Oven curing period = **24hrs**

h. Curing temperature = **60^{o}C and 100^{0}C**

For 8M,

$\frac{Na_2SiO_3}{NaOH}$	1.5	2.0	2.5
NaOH pellets (g)	9.70	8.08	6.92
Water (ml)	30.30	25.25	21.64
Na_2SiO_3 (g)	60.00	66.67	71.43
NaOH solution (g)	40.00	33.33	28.57

Table 5 Mix design values for 8M

3.2 PREPARATION ALKALINE SOLUTION

- Take water of required quantity
- Add a required or calculated amount of NaOH pellets
- Stir well until it get complete dissolution
- After dissolution, add calculated amount of Na_2SiO_3 and stirr well
- Keep aside for 24 hours for solution preparation

3.3 PREPARATION OF GPM CUBES

- Take a binder of calculated amount and dry mix it well
- Add a sand of calculated amount and dry mix it well
- Add a solution of required amount and mix it well immediately after adding solution
- The mortar is filled in 70.6mm X 70.6mm X 70.6mm moulds in three equal layers and compacted
- Demould the cubes after 24 hours
- Keep the cubes in oven at different temperatures (60^oC and 100^0C) for 24 hours
- Remove the cubes from the oven after 24 hours and keep the cubes for ambient curing for the different curing periods of 3days, 28days and 56 days.

3.4 CURING

- Oven curing
- Ambient curing

After 24 hours of casting, all the cubes were demould from the moulds and place the cubes in oven at different temperatures i.e., 60^0C and 100^0C for a period of 24 hours. After oven curing, cubes were kept for ambient curing for different curing periods of 3days, 28days and 56days.

4. TEST CARRIED OUT ON MORTAR CUBE

4.1 COMPRESSIVE STRENGTH TEST

For compressive strength test, the specimen of a size 70.6mm x 70.6mm x 70.6mm are commonly used. These specimens are tested for a period of 3days, 28days and 56days.

To determine the compressive strength, place the specimen in the machine in such a manner that the load shall be applied to the opposite side of the cube cast. Apply the load gradually without shock till the specimen the fails and record the maximum load.

$$\textbf{Compressive strength} = \frac{\textbf{Load in N}}{\textbf{Area in mm}^2}$$


a) Placing of cubes in CTM b) Applying load

Figure 1 Compression testing


a) b) c)

Figure 2 Failure patterns

5. RESULT AND DISCUSSION

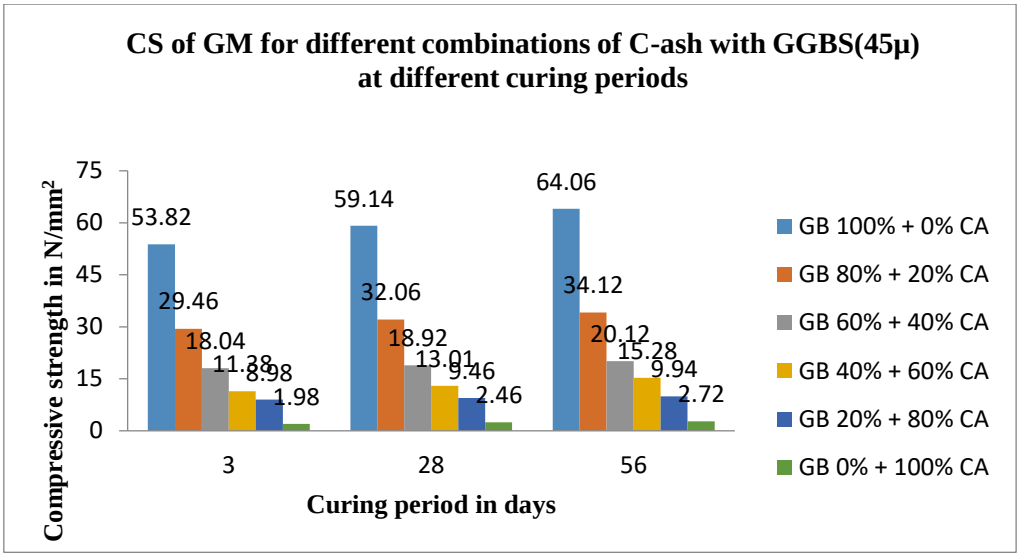
5.1 COMPRESSIVE STRENGTH

The compresive strength of GM for a different combination of C-ash with GGBS for different curing periods of 3, 28 and 56 days (45µ) was determined and results are tabulated in Table 7 to Table 10 and comparison of different combinations was shown in Graph 1 to Graph 4.

For 1.5, 8M, 60^0C

Sl. No.	Combinations	Compressive strength in N/mm^2 for different curing periods in days		
		3	28	56
1	GB100%+0%CA	53.82	59.14	64.06
2	GB80%+20%CA	29.46	32.06	34.12
3	GB60%+40%CA	18.04	18.92	20.12
4	GB40%+60%CA	11.38	13.01	15.28
5	GB20%+80%CA	8.98	9.46	9.94
6	GB0%+100%CA	1.98	2.46	2.72

Table 6 Compressive strength of GM for different combinations of C-ash with GGBS(45µ) at different curing periods

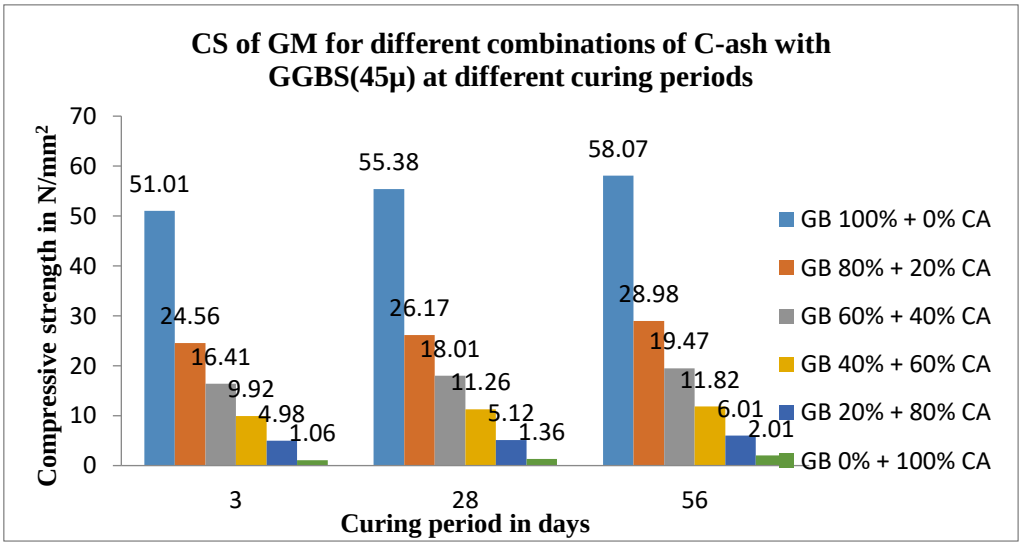


Graph 1 Compressive strength of GM for different combinations of C-ash with GGBS(45µ) at different curing periods

For 2, 8M, 60^{0}C

Sl. No.	Combinations	Compressive strength in N/mm^2 for different curing periods in days		
		3	28	56
1	GB100%+0%CA	51.01	55.28	58.07
2	GB80%+20%CA	24.56	26.17	28.98
3	GB60%+40%CA	16.41	18.01	19.47
4	GB40%+60%CA	9.92	11.26	11.82
5	GB20%+80%CA	4.98	5.12	6.01
6	GB0%+100%CA	1.06	1.36	2.01

Table 7 Compressive strength of GM for different combinations of C-ash with GGBS(45µ) at different curing periods

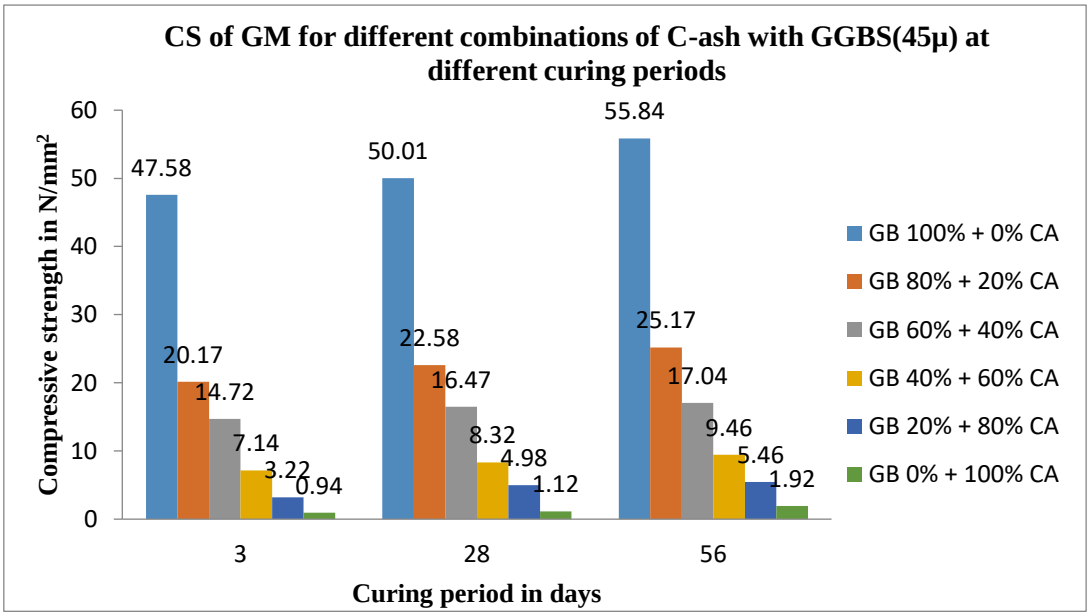


Graph 2 Compressive strength of GM for different combinations of C-ash with GGBS(45µ) at different curing periods

For 2.5, 8M, 60^{0}C Table 8

Sl. No.	Combinations	Compressive strength in N/mm^2 for different curing periods in days		
		3	28	56
1	GB100%+0%CA	53.82	59.14	64.06
2	GB80%+20%CA	29.46	32.06	34.52
3	GB60%+40%CA	18.04	18.92	20.12
4	GB40%+60%CA	11.38	13.01	15.28
5	GB20%+80%CA	8.98	9.46	9.94
6	GB0%+100%CA	1.98	2.46	2.72

Compressive strength of GM for different combinations of C-ash with GGBS(45µ) at different curing periods

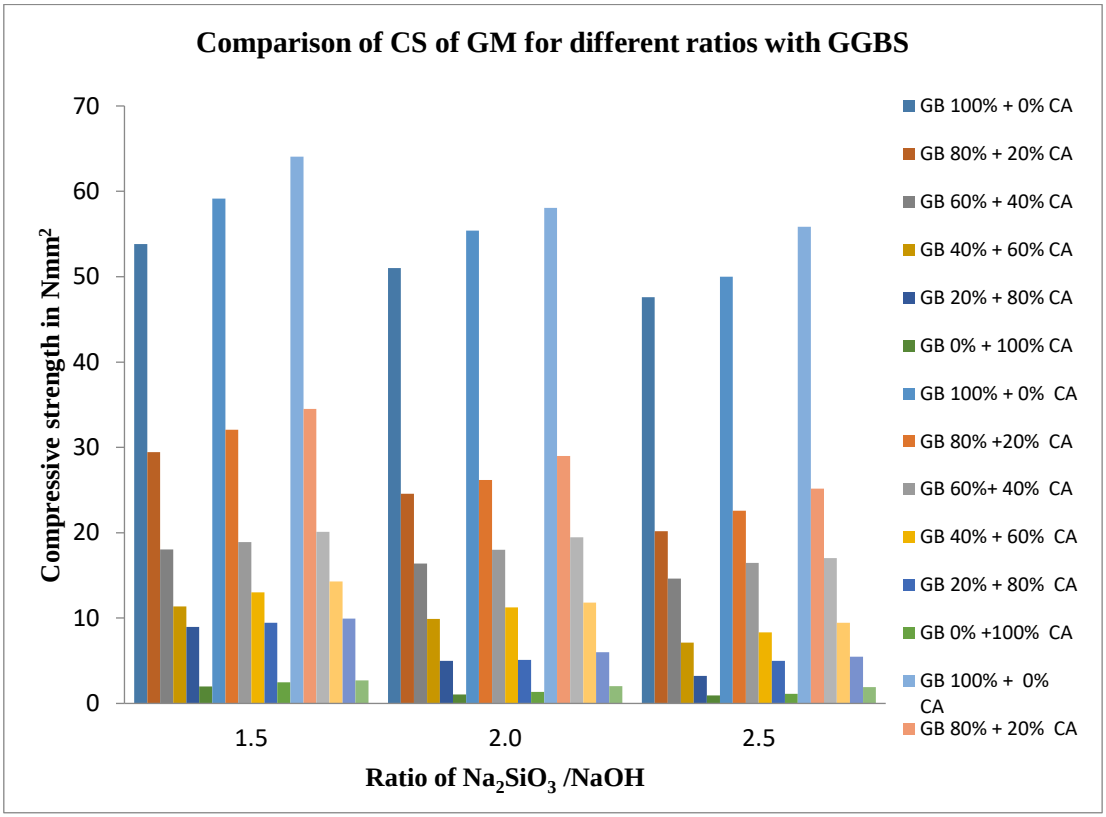


Graph 3 Compressive strength of GM for different combinations of C-ash with GGBS(45µ) at different curing periods

Sl. No.	Combinations	Compressive strength in N/mm^2 for different curing periods in days		
		3	28	56
1	GB100%+0%CA	47.58	50.01	55.84
2	GB80%+20%CA	20.17	22.58	25.17
3	GB60%+40%CA	14.72	16.47	17.04
4	GB40%+60%CA	7.14	8.32	9.46
5	GB20%+80%CA	3.22	4.98	5.46
6	GB0%+100%CA	0.94	1.12	1.92

1	GB100%+0%CA	51.01	55.28	58.07
2	GB80%+20%CA	24.56	26.17	28.98
3	GB60%+40%CA	16.41	18.01	19.47
4	GB40%+60%CA	9.92	11.26	11.82
5	GB20%+80%CA	4.98	5.12	6.01
6	GB0%+100%CA	1.06	1.36	2.01
1	GB100%+0%CA	47.58	50.01	55.84
2	GB80%+20%CA	20.17	22.58	25.17
3	GB60%+40%CA	14.72	16.47	17.04
4	GB40%+60%CA	7.14	8.32	9.46
5	GB20%+80%CA	3.22	4.98	5.46
6	GB0%+100%CA	0.94	1.12	1.92

Table 9 Comparison of Compressive strength of GM for different combinations of C-ash with GGBS(45µ) at different ratios



Graph 4 Comparison of Compressive strength of GM for different combinations of C-ash with GGBS(45µ) at different ratios

NOTES

- The compressive strength is increased as the curing period increases.
- The ash content in GM increases the strength will be decreases.
- The ratio of Na_2SiO_3 /NaOH increases, the strength will decrease due to the greater amount of soluble silica in sodium silicate solution retards the geopolymerization reaction

- For increasing the polymerisation process, the cubes were kept in oven which helps to get more strength than ambient curing.
- While performing compression test, the cracks were found near the edges due to less reaction near the edges.
- In all the combination of C-ash with GGBS, the cracks are vertical.
- As the molarity increases the compressive strength increases due to high NaOH concentration accelerate the chemical dissolution it depresses the CH (carbon-hydron) formation during binder formation.
- The Na_2SiO_3 /NaOH ratio of 1.5 shows maximum compressive strength values. It has been observed that the compressive strength increases with decrease in NaOH molarity.
- The maximum strength was found at 60^0C beyond that there was no significant strength gain was observed.

6. CONCLUSION

- The compressive strength increases from 29.46 N/mm^2 to 32.06 N/mm^2 i.e., 8.10% at 28 days for a combination of GB80% +20%CA.
- The compressive strength increases from 32.06N/mm^2 to 34.52N/mm^2 i.e., 7.12% at 56 days for a combination of GB80%+20%CA.
- The compressive strength decreases from 34.52 N/mm^2 to 28.98 N/mm^2 i.e., 16.04% for the ratio of Na_2SiO_3 to NaOH is 2 as compared to 1.5
- The compressive strength decreases from 28.98 N/mm^2 to 25.17 N/mm^2 i.e., 13.14% for the ratio of Na_2SiO_3 to NaOH is 2.5 as compared to 2.

7. ACKNOWLEDGEMENT

The authors sincerely express gratitude to the Adichunchanagiri Institute of Technology, Chikkamagaluru, GEC, Hassan(Affiliated to VTU, Belgaum), Government Science College, Hassan(Autonomous; Affiliated to Hassan University), Karnataka, INDIA, for needful research support

8. CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

9. REFERENCES

1. Janardhanan Thaarrini, Venkatasubramani Ramaswamy, “Feasibility Studies on Compressive Strength of Ground Coal Ash Geopolymer Mortar”, Periodica Polytechnica Civil Engineering, DOI:10.3311/PPci.7696, 59(3), 2015, pp.373-379.
2. Suresh Thokchom, Partha ghosh, Somnath ghosh. “Effect of Na_2O Content on durability of geoplymer Mortars in Sulphuric Acid”, International Journal of Civil and Environmental Engineering, Vol:3, No:3,2009, pp.193-198.
3. V.Sreevidya, R.Anuradha, D.Dinakar, R.Venkatasubramani, “Acid Resistance of Flyash based Geopolymer Mortar under ambient curing and Heat curing”, International Journal of Engineering Science and Technology, ISSN:0975-5462,Vol:4, No:02, February 2012,pp.681-684.

4. A.Z.Warid Wazien, Mohd Mustafa Al Bakri Abdullah, Rafiza Abd.Razak,M.A.Z.Mohd Remy Rozainy, and Muhammad Faheem Mohd tahir. "Strength and Density of Geopolymer Mortar Cured at Ambient Temperature for Use as Repair Material", IOP Conf. Series: Materials Science and Engineering 133012042, DOI:10.1088/1757-899X/133/1/012042 ,2016, .1-8.
5. Suresh Thokchom, Partha Ghosh and Somnath Ghosh, "Effect of Water Absorption, Porosity and Sorptivity on Durability of Geopolymer Mortars",ARPN Journal of Engineering and Applied Sciences,ISSN:1819-6608,Vol.4,No.7,September 2009,pp.28-32.
6. Banda Rohit Rajan, K.Ramujee, "Strength and Development of Fly ash and GGBS Based Geopolymer Mortar",International Journal of Recent Advances in Engineering and Technology,ISSN:2347-2812,Vol.3,Issue-1,2015,pp.42-45.
7. V.Sree Vidya, R.Anuradha, Tini Thomas and Venktasubramani, "Durability Studies on Fly Ash Based Geopolymer Mortar Under in Ambient Curing Condition",Asian Journal of Chemistry, DOI: 10.14233/ajchem.2013.13423, Vol.25,No.5,November 2012.
8. Subhash V.Patankar, Yuwaraj M. Ghugal and Sanjay S.Jamkar, "Effect of Concentration of Sodium Hydroxiode and Degree of Heat Curing on Fly Ash Based Geopolymer Mortar", Indian Journal of Material Science, DOI.Org/10.1155/2014/938789, Vol-2014, Artical ID 938789, pp.1-6.
9. Kolli Ramujee, "Strength and Setting Times of F-Type Fly Ash Based Geopolymer Mortar", International Journal of Earth Sciences and Engineering, ISSN 0974-5904, Vol.09, No.03, June-2016, pp.360-365.
10. IS 1727-1967 for methods of test for pozzolanic materials.
11. IS 12089-1987 Specification for granulated slag for the manufacture of Portland slag cement.
12. IS 383-1970 Specification for Coarse and Fine aggregate from natural source for concrete.