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EXPERIMENTAL STUDIES ON GEOPOLYMER CONCRETE USING GGBFS AND MARBLE POWDER

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Abstract— Geopolymer concrete is an innovative construction material which has been made by the chemical action of inorganic molecules. It is commonly used construction material for replacement of the plain cement concrete. Geopolymer concrete are made with 0% amount of ordinary portland cement. In this experimental study are done for checking the mechanical strength properties of geopolymer concrete using GGBFS with different % replacement of Fly Ash (20%, 40%, 60%, 80%) and Marble Powder with different % replacement of Fine Aggregate (20%, 40%, 60%, 80%) on geopolymer concrete. In this project, the mix design is carried out for 12M concentration of sodium hydroxide. Alkaline activator solution ratio of 2.5 and alkaline liquid to fly ash ratio 0.56 is selected and conduct constant for this investigation. The specimen of size 150x150x150mm cubes, 150x300mm cylinders and 500x100x100mm beam were casted and the specimens of geo-polymer concrete are cured at ambient temperature for 3day 7days and 28days. The experiment are to be carried for the mechanical strength like a compressive strength, split tensile strength, flexural strength test on the concrete specimens and the test results are tabulated.

Keywords— Geopolymer Concrete, GGBFS, Marble Powder, Ambient Curing, Molarity, Mechanical Strengths.

I. INTRODUCTION

Geopolymer (Sodium silicate & hydroxide) is used for the material of binder for alternative of cement paste to making a concrete. The geopolymer alkaline activator is binding the fly ash, fine aggregates, course aggregates and other unreacted materials together to mode the geopolymer concrete. The manufacturing process of making the geopolymer concrete is carried out using the nominal concrete technology methods. The silicon and the aluminum in the fly ash are activated by a combination of sodium hydroxide & sodium silicate (alkaline liquid) solutions to form the geopolymer paste that binds the aggregates and other unreacted materials together to form concrete.
In the manufacturing process of geopolymer concrete are reduced CO_2 emissions as compare to cement and those benefits make them a good alternative to normal usable cement. The mechanical strength behavior of geo-polymer concrete is higher than normal concrete mix. Also the durability property of geo-polymer concrete is higher than the normal concrete mix made with cement. Compressive strength of geopolymer concrete is very high compared to the normal ordinary portland cement Concrete.

The superior properties of geopolymer concrete are

- Sets at room temperature
- Non toxic, bleed free
- Long working life before stiffening
- Impermeable
- This concrete is eco-friendly
- Higher resistance to heat and resist all inorganic solvents
- Higher compressive strength

II. OBJECTIVE OF RESEARCH

The objective of the present research is to study the effect of GGBFS and marble powder as a replacement of fly Ash (cement) and fine aggregate on geopolymer concrete and inspecting the mechanical properties of hardened concrete at 3 day, 7 day & 28 day. The specimens casting with geopolymer concrete will be cured at (ambient curing) normal room temperature. Advantages of geopolymer concrete include rapid strength gain, elimination of water curing, good mechanical and durability properties.
In this investigation we are attempting to make geopolymer concrete more sustainable by partially replacing the fine aggregate with marble powder which is a waste product generated in marble industries in addition to partially replacing fly ash with GGBFS.
This study is mainly aimed to achieve fly ash based geopolymer suitable for curing without elevated heat (oven curing), from the results of past literature study were noticed that to removed oven curing in geopolymer concrete is done by partial replacement of Fly Ash material with GGBFS.

III. MATERIAL AND THEIR PROPERTIES

All material used for this research work is listed below.

1) Fly ash- Fly ash is the main by product created from the combustion of coal in coal-fired power plants. These by product from plant are two classes of fly ash, 1) class F and 2) class C, both class of fly ash has its private unique properties. In this research work Class F fly ash of STALLIN ENERGY PVT. LTD. (Rajkot) is used and the physical properties of Class-F fly ash are within its range as per standard.

2) GGBFS- Ground granulated blast furnace slag (GGBFS) is a byproduct from the blast furnaces used to make iron. GGBFS of STALLIN ENERGY PVT. LTD. (Rajkot) is used and the chemical composition of GGBFS are shown in Table 1.

TABLE 1
Chemical Composition of GGBFS

Characteristics	Properties (% wt)	Criteria for GGBFS (% wt)
Aluminium oxide	14.27	7-15
Calcium oxide	35.89	34-43
Sulphur	1.58	1.0-1.9
Magnesium oxide	8.06	7-10.5
Silica	35.47	27-38
Manganese oxide	0.34	0.15-0.76
Iron oxide	2.41	0.2-2.6

3) Coarse Aggregates- In this investigation the locally available aggregates from crusher 22.4mm sieve passing and 4.75mm sieve retained and conforming to IS 383 is used.

4) Fine Aggregates- In this investigation natural river sand is used as fine aggregate. Sand was obtained from local sources. Fine aggregate which is passing through IS 4.75mm sieve and retained on IS 150 micron sieve is considered for the experimental program.

5) Marble Powder- Marble powder is produced from the marble processing plants during the cutting, shaping and polishing. During this process, about 20-25% of the process marble is turn into the small grit & powder form. This locally available wastage material is used in this investigation. The properties of M.P. are shown in Table 2 & 3.

TABLE 2
Sieve Analysis of Marble Powder

OBSERVATION SHEET				
I.S. Sieve Size	**Weight Retained on Each Sieve (gm)**	**% Weight Retained on Each Sieve**	**Cumulative % Weight Retained on Each Sieve**	**% Passing**
4.75mm	0	0	0	0
2.36mm	23	2.3	2.3	97.7
1.18mm	226	22.6	24.9	75.1
600µ	722	72.2	97.1	2.9
300µ	11	1.1	98.2	1.8
150µ	10	1.0	99.2	0.8
Pan	8	0.8		
Total	1000	100	321.7	
Fineness Modulus for Marble Powder =		Cumulative % Weight Retained on Each Sieve / % Weight Retained on Each Sieve		3.22

TABLE 3
Physical Properties of Marble Powder

Properties	Results
Type	Crushed
Color	Almost White
Specific gravity	2.68
Fineness modulus	3.22
Bulk density	1522 kg/m^3
Particle size	150 micron to 4.75 mm

6) Sodium Silicate- Sodium silicate is also known as liquid glass or water glass, available in liquid (gel) form. In present investigation sodium silicate 3.0 (ratio between Na_2O to SiO_2) is used. The chemical properties and the physical properties of the silicates are given the manufacture is shown in below Table 4.

TABLE 4
Physical & Chemical Properties of Sodium Silicate

Description	**Silicate**
Na_2O %	21.1
SiO_2 %	63.5
K_2O %	0.18
Appearance	Liquid (gel form)
Color	Light yellow liquid
Molecular weight	184.04 g/mol
Specific gravity	1.6

7) Sodium Hydroxide- Generally the sodium hydroxides are available in solid state by means of pellets and flakes. In this investigation the sodium hydroxide pellets were used with 99% purity obtained from local suppliers. Whose physical and chemical properties are given by the manufacturer is shown in Table 5.

TABLE 5
Physical & Chemical Properties of Sodium Hydroxide

Description	**In %**
Purity (NAOH)	98%
Carbonate (NA_2CO_3)	0.24%
Chloride (Cl)	0.01%
Sulphate (SO_2)	0.002%
Copper (Cu)	0.2% (ppm)
Iron (Fe)	4.4% (ppm)
Specific gravity	1.44

8) Water- Potable water was used in this investigation for workability purpose only.

IV. MIX PROPORTIONS & METHODOLOGY

A. Mix Proportions

From the literature study I have noted that unlike conventional cement concretes geopolymer concrete are a new class of construction materials and therefore no standard mix design approaches are yet available for GPC. Geopolymer concrete involves more ingredients in its binder (like a, FA, GGBFS, Course aggregates, Fine aggregates, Sodium Silicate, Sodium Hydroxide and Water) whose proportion of mixing and final structure and relative chemical composition are under research. So that here the conventional method used in the making of normal concrete is adopted to prepare geopolymer concrete.

TABLE 6
Mix Proportion for 1 M^3 of Geopolymer Concrete (GP-2)

Serial No	**MATERIAL**	**QUANTITY (Kg/m^3)**
1	Fly ash	550
2	Fine aggregate	556
3	Coarse aggregate	930
4	Sodium silicate	240
5	Sodium hydroxide Solution	95.5
6	Extra water	15
Total Weight	Density	2386.5 kg/m^3

- Alkaline liquid to Fly ash ratio = 0.61 (Taken after revised trial mix results)
- Sodium silicate to sodium hydroxide ratio = 2.5

B. Replacement of Ingredients (% Wise Replacement Table)

TABLE 7
Mixing proportion of fly ash & GGBFS based GPC (% wise replacement table)

Description	Normal G.P.C.	Test with Replaced GGBFS				Test with Replaced Marble Powder				Test with GGBFS & M.P.	
	GP-2	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2
Fly Ash	100%	80%	60%	40%	20%	100%	100%	100%	100%	50%	20%
GGBFS	0%	20%	40%	60%	80%	0%	0%	0%	0%	50%	80%
Coarse aggregate	100%	Constant through all experiment									
Fine aggregate	100%	100 %	100%	100%	100%	80%	60%	40%	20%	50%	40%
Marble powder	0%	0%	0%	0%	0%	20%	40%	60%	80%	50%	60%
Sodium silicate	100%	Liquid form of sodium silicate is constant through all experiment									
Sodium hydroxide	100%	12 molarity sodium Hydroxide is constant through all experiment									
Water	100%	As per requirement of workability condition									

C. Experimental Procedure

Dissolving NAoH > Preparing Alkaline Solutions > Weighting and Mixing Ingredients > Casting of Concrete > Ambient (Sun Light) Curing > Testing of Specimens

Figure 1
Experimental Work Photographs

V. RESULTS AND DISCUSSIONS

A. Revised Trial Mix Design Results of GPC (GP-2)

TABLE 8
Trial Mix Results (GP-2)

Material	Age of curing	Dimension of cube	Strength	Average strength
GP-2,1	28 day	150*150*150 mm	21.86	
GP-2,2	28 day	150*150*150 mm	22.65	21.43(N/mm^2)
GP-2,3	28 day	150*150*150 mm	19.78	

B. Test for Molarity Variation on GPC (GP-2)

TABLE 9
Test Results for Molarity Variation

Material	Molarity	Slump Value (mm)	Age of curing	Average Compressive strength (N/mm^2)
GP-2, 8M	**8M**	124	7 day	11.82
GP-2, 8M	**8M**		28 day	14.22
GP-2, 12M	**12M**	106	7 day	18.62
GP-2, 12M	**12M**		28 day	21.28
GP-2, 16M	**16M**	83	7 day	22.80
GP-2, 16M	**16M**		28 day	26.13

C. Compressive Test

Compressive strength test results at the age of 3, 7 & 28 days for replacing percentage wise GGBFS and Marble Powder for different mix (in N/mm^2) is given in below table and chart. From the test results, it was observed that the maximum compressive strength with replacing GGBFS was obtained for GP-A4 (80% GGBFS) and replacing Marble Powder was obtained for GP-B3 (60% M.P). From this test adopt new mix with best replacing of material 80% GGBFS & 60% M.P. and tested on it.

TABLE 10
Compressive Strength Test Results

MIX TYPE	REPLACEMENT IN %	SLUMP VALUE (in mm)	COMPRESSIVE STRENGTH (N/mm^2)		
			3 Day	7 Day	28 Day
GP-2	F100-G0 S100-M0	106	11.42	18.62	21.28
GP-A1	F80-G20	121	19.77	24.17	28.13
GP-A2	F60-G40	138	27.56	30.93	36.62
GP-A3	F40-G60	147	31.86	37.11	43.46
GP-A4	F20-G80	162	38.49	42.67	48.31
GP-B1	S80-M20	113	12.49	20.71	21.58
GP-B2	S60-M40	121	13.90	19.25	22.20
GP-B3	S40-M60	100	14.50	20.71	23.12
GP-B4	S20-M80	108	12.96	19.48	21.88
GP-C1	G50-M50	145	30.93	38.58	42.13
GP-C2	G80-M60	154	37.11	43.47	49.82

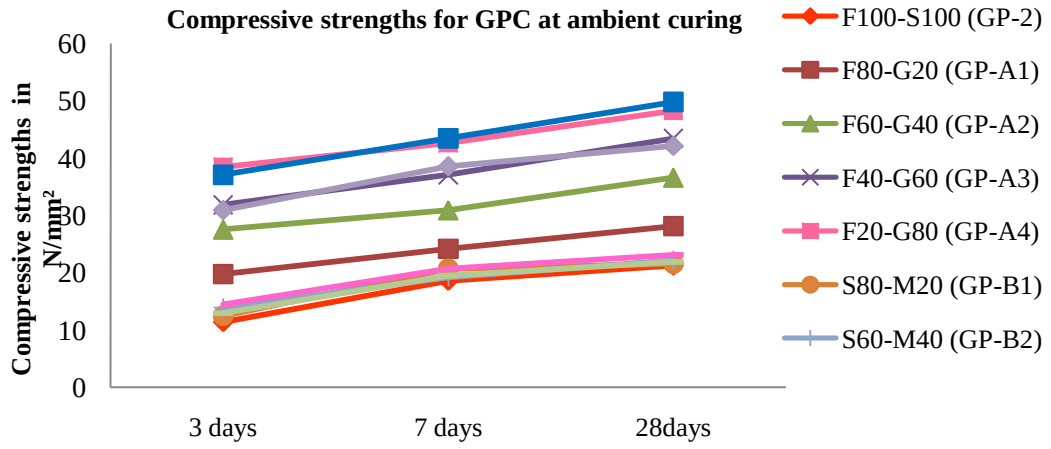

Chart 1
Compressive Strength

D. Compressive Strength Comparison for Best Replacement of Material

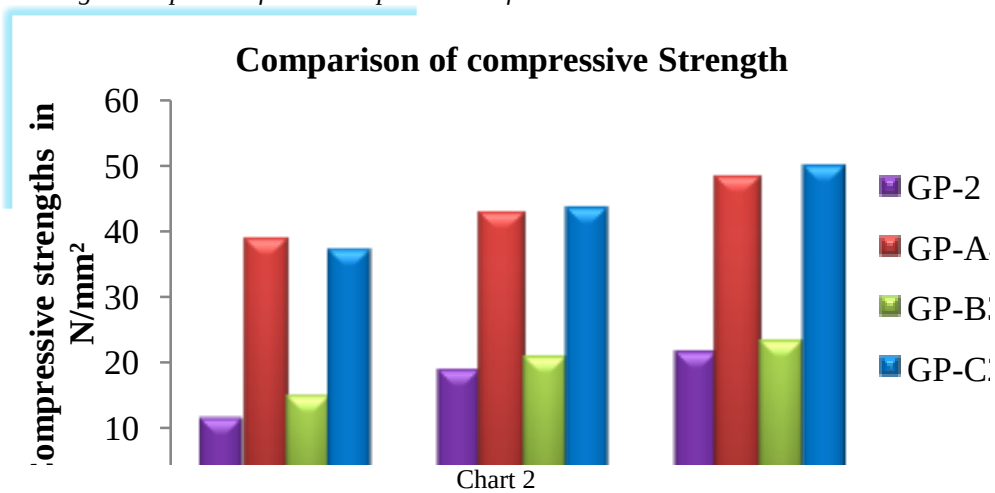

Chart 2
Compressive Strength Comparison

E. Split Tensile Test

Split tensile strength test results at the age of 3, 7 & 28 days for replacing percentage wise GGBFS and Marble Powder for different mix (in N/mm^2) is given in below table and chart. From the test results, it was observed that the maximum compressive strength with replacing GGBFS was obtained for GP-A4 (80% GGBFS) and replacing Marble Powder was obtained for GP-B2 (40% M.P).

TABLE 11
Split Tensile Strength Test Results

MIX TYPE	REPLACEMENT IN %	SLUMP VALUE (in mm)	SPLIT TENSILE STRENGTH (N/mm^2)		
			3 Day	7 Day	28 Day
GP-2	F100-G0 S100-M0	106	1.50	1.64	1.95
GP-A1	F80-G20	121	2.02	2.17	2.64
GP-A2	F60-G40	138	2.41	2.53	3.17
GP-A3	F40-G60	147	3.09	3.41	3.80
GP-A4	F20-G80	162	3.34	3.83	4.27
GP-B1	S80-M20	113	1.54	1.82	2.05
GP-B2	S60-M40	121	2.04	2.26	2.79
GP-B3	S40-M60	100	1.92	2.06	2.58
GP-B4	S20-M80	108	1.71	1.98	2.24
GP-C1	G50-M50	145	2.68	2.93	3.27
GP-C2	G80-M60	154	3.09	3.78	4.19

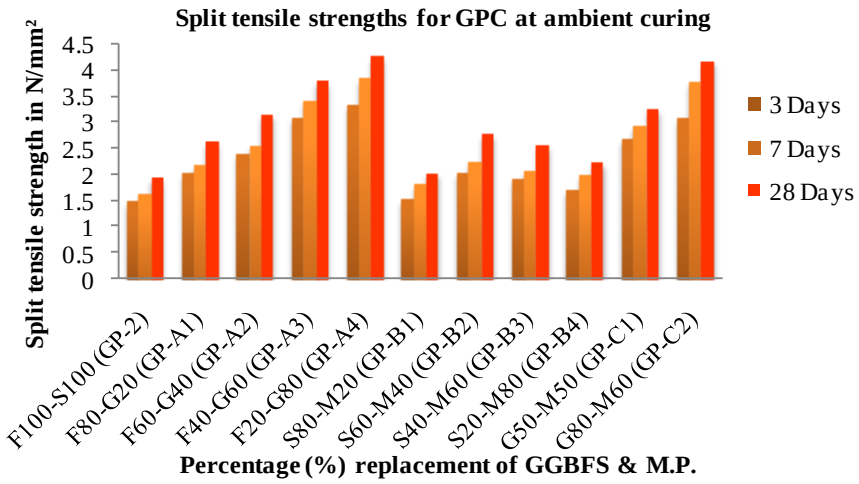

Chart 3
Split Tensile Strength

F. Flexural Test

Flexural strength test results at the age of 3, 7 & 28 days for replacing percentage wise GGBFS and Marble Powder for different mix (in N/mm^2) is given in below table and chart. From the test results, it was observed that when the percentage of GGBFS increased, the flexural strength of geopolymer concrete also increased. The maximum compressive strength with replacing GGBFS was obtained for GP-A3 (60% GGBFS) and replacing Marble Powder was obtained for GP-B3 (60% M.P).

TABLE 12
Flexural Strength Test Results

MIX TYPE	REPLACEMENT IN %	SLUMP VALUE (in mm)	FLEXURAL STRENGTH (N/mm^2)		
			3 Day	7 Day	28 Day
GP-2	F100-G0, S100-M0	106	0	0.90	1.27
GP-A1	F80-G20	121	1.86	2.28	2.86
GP-A2	F60-G40	138	2.45	2.88	3.34
GP-A3	F40-G60	147	3.16	3.71	4.19
GP-A4	F20-G80	162	3.03	3.64	3.93
GP-B1	S80-M20	113	0.98	1.21	1.87
GP-B2	S60-M40	121	1.25	1.67	2.17
GP-B3	S40-M60	100	1.39	1.86	2.35
GP-B4	S20-M80	108	1.42	1.74	2.20
GP-C1	G50-M50	145	2.35	2.74	3.29
GP-C2	G80-M60	154	2.82	3.27	3.52

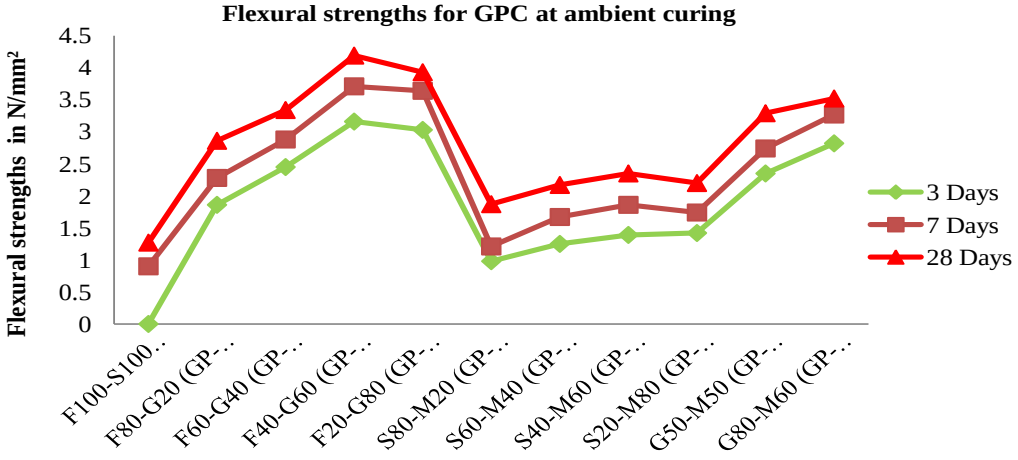

Chart 4
Flexural Strength

G. Slump Test

Slump test result of various different mix with replacing GGBFS and marble powder for GPC are in range of 106mm to 162mm. The values of slump increased with increased the percentage of GGBFS, means that the workability of concrete increased with increased GGBFS percentage replacement. The replacement of fine aggregate with marble powder does not affect more in workability of concrete.

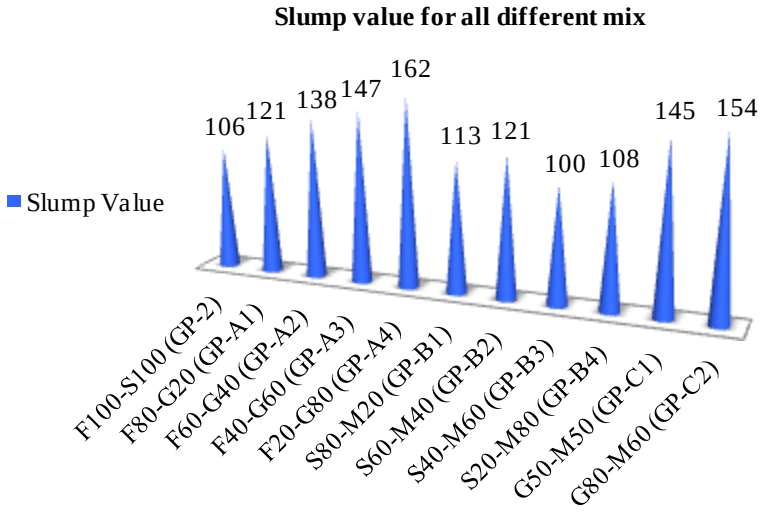

Chart 5
Slump Value for Different Mix

VI. CONCLUSIONS

- ❖ In this Experimental study, the following conclusions are made for GPC…
- ✓ From above research work it can be concluded that fly ash based geopolymer replacing with GGBFS is found to be a suitable binder for low to moderate strength concrete production at ambient curing condition and it eliminates the requisite of heat curing.
- ✓ It is observed that increase in GGBFS content in geopolymer concrete will increases the degree of workability.
- ✓ By increasing the GGBFS content in geopolymer concrete will increases in compressive strength, split tensile strength and flexural strength also no need to compulsory adding of super plasticizer.
- ✓ Compressive strength of GP-A4 (80% replacement GGBFS) concrete shows maximum strength.
- ✓ By increasing the Marble Powder content in geopolymer concrete will slightly increases in compressive strength up to certain limit then after strength is decrease.
- ✓ Compressive strength of GP-B3 (60% replacement Marble powder) concrete shows maximum strength.
- ✓ In compressive strength, optimum result is obtained by using GGBFS content of 80% and Marble powder content of 60%, this combination of replacing both material are advisable for getting best compressive strength.
- ✓ Molarity of sodium hydroxide (viz. 8M, 12M, 16M) is increases as the compression strength increases.
- ✓ As the Sodium Silicate to Sodium hydroxide ratio (viz. 2.0, 2.5, 3.0) increases compressive strength of geo-polymer concrete increases.
- ✓ It is observed that, nearly 70% of the strength is achieved in 7 days at ambient curing.
- ✓ The GGBFS based geopolymer concrete specimens surface is more smoothen that of ordinary portland cement concrete.

REFERENCES

[1] Concrete Technology Theory and Practice, M. S. Shetty, (S. Chand)
[2] Manual: Hand Book of Material Testing – IRICE
[3] Concrete Technology Book
[4] Research Paper :-
- ➢ Geopolymer Concrete-A Review, By: M. I. Abdul Aleem, P. D. Arumairaj.
- ➢ An Experimental Study On Geopolymer Concrete With The Partial Replacement Of Coarse Aggregate With Laterite, By: Aswathy Kurian, Mr. Binu M Issac, Mrs. Soumya Anand.
- ➢ An Experimental Investigation On Strength Parameters Of Fly Ash Based Geopolymer Concrete With Ggbs, By: P.Vignesh, K.Vivek.
- ➢ Experimental Study On Geo-Polymer Concrete Incorporating GGBS, By: V. Supraja, M. Kanta Rao.
- ➢ Effect Of GGBFS On Setting, Workability And Early Strength Properties Of Fly Ash Geopolymer Concrete Cured In Ambient Condition, By: Pradip Nath, Prabir Kumar Sarker.
- ➢ Many other Research paper studied for References.

[5] Internet website data using (Searching for Journal & Research Related)
[6] www.asce.lib
[7] www.ascelibrary.org
[8] www.sciencedirect.com
[9] IS CODE 10262 (2009) : Guideline for concrete mix design proportioning
[10] IS CODE 456 (2000) : Plain and Reinforced Concrete