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Comparative Analysis of Geopolymer Concrete with Different Proportions of Fly ash and GGBS with Conventional Concrete Considering the Strength and Durability Parameters

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Abstract: ***The global demand of concrete for the construction of infrastructures is continuously increasing. The production of cement is highly intensive and it emits a lot of CO2 into the air which leads to the global warming. One of the effort to produce the environment friendly concrete is geopolymer concrete which emits less CO2.***

In the present study the feasibility of industrial by-products i.e.; Fly Ash (FA) and Ground Granulated Blast Furnace Slag (GGBS) powder as eco-friendly and sustainable is studied. So the main aim of this study is to analyse the performance of fly ash and GGBS based geopolymer concrete with conventional concrete which are compared with respect to strength and durability parameters for (7days and 28 days) curing period. In this study strength parameters includes compressive strength, split tensile strength and flexural strength and durability parameters includes acid attack test and rapid chloride permeability test. The two different proportions of (70% fly ash+ 30% ggbs) and (60% fly ash+ 40% ggbs) are used in geopolymer concrete. The Alkaline solutions used are sodium hydroxide (NaOH) and sodium silicate (Na2SiO3).

The study includes casting of geopolymer concrete and conventional concrete specimens and tested for (7 and 28 days) ages for both strength and durability. The results show that Geopolymer concrete gives good strength and durability compared to conventional concrete. Thus, the Geopolymer concrete can be considered to be an environmentally pollution free construction material.

Keywords***: fly ash, ggbs, compressive strength, split tensile strength, flexural strength, acid attack test, rapid chloride permeability test***

I. INTRODUCTION

Davidovits [1] first introduced the word Geopolymer in 1978 to present the wide scope of material characterisation by series or web of organic molecules. The chemical composition of the geopolymer material is similar to natural zeolitic materials, but the microstructure is amorphous. For the Any material that contains mostly silicon (Si) and aluminium (Al) in amorphous form is a possible source material for the manufacture of geopolymer. To impart a proper unbreakable binding forum this mechanization chiefly depends on the utilisation of industrial waste products ornatural materials. Metakaolin, low calcium ASTM Class F flyash, combination of metakaolin and fly ash, organic Al-Si minerals, combination of calcined and non-calcined minerals,combination of GGBS and metakaolin are investigated assource materials. Geopolymer are hardened material with three dimensional structures similar to aluminosilicate glass structures.

Cement is major ingredient of concrete. The cost of cement is increasing day by day due to its limited availability and large demand. At the same time the global warming is increasing day by day. Manufacturing of cement also releases carbon dioxide. In the present study an attempt been made on concrete and also an experimental investigation on the concrete using by replacing cement with Fly ash and GGBS to decrease the usage of cement as well as emission of concrete Experimental studies were performed on plain cement concrete and replacement of cement with Fly ash and ggbs is done. In this study the concrete mix were prepared by using fly ash, ggbs, sodium silicate, sodium hydroxide.

A comparative analysis has been carried out for concrete to the Geopolymer concrete in relation to their compressive strength, split tension strength, flexural strength, acid resistance and rcpt test.

The concrete made with fly ash and ggbs performed well in terms of compressive strength, split tension strength, flexural strength, acid attack test and rcpt test showed higher performance at the age of 7,28 days than conventional concrete.

The main aim of this study is –

1) To study the durability and strength parameters in accordance with the geopolymer concrete with varying amounts of ggbs and fly ash and comparing these parameters with conventional concrete.
2) To examine the performance of geopolymer concrete and conventional concrete under effects of and acid exposure condition and determine the resistance to acid exposure condition
3) To identify the potential use of fly ash and ggbs in the geopolymer concrete which will be environment friendly and economical and more effective than conventional concrete.
4) To determine the best proportion of fly ash and GGBS in geopolymer concrete which give approximately equal strength and durability with respect to conventional concrete.

II. MATERIALS USED

1) *Sand:* Locally available crushed sand is used as fine aggregate. The test carried out on fine aggregates are as follows:

Table 2.1: Test results of fine aggregate-

Properties	Average value
Specific Gravity	2.95
Fineness modulus	3.74

2) *Cement:* Locally available ordinary Portland cement (ACC -43 grade) is used for throughout casting of normal concrete specimens

Table 2.2: Test results of OPC-

Properties	Average value for OPC Used in percent investigation
Fineness	1.33%
Standard consistency	32%
Initial setting time	40 min
Final setting time	10 hour

3) *Coarse Aggregate:* A crushed ballast rock of 20mm size was used as coarse aggregate. The coarse aggregate is locally available. The following test were carried out on the coarse aggregate samples

Table 2.3: Test results of coarse aggregate-

Properties	Average Value
Specific Gravity	3.02
Crushing value	5.17%
Impact value	6.41%

4) *Fly ash:* Class-F fly ash was procured from "RMC plant" Kolhapur (Maharashtra) and is used as one of the primary raw materials.

Table 2.4: Chemical composition of fly ash-

Al2O3 (%)	Fe2O3 (%)	SiO2 (%)	MgO (%)	SO3 (%)	Na2O (%)	Chlorides (%)	CaO (%)
24	8.97	58.82	0.83	1.8	0.89	0.06	2.9

5) *GGBS:* GGBS was procured from "Malsa Factory", Kupawad (Maharashtra)

Table 2.5: Chemical composition of GGBS-

Glass (%)	SiO2 (%)	CaO (%)	Al2O 3 (%)	Fe2O 3 (%)	Sulphite sulphur (%)	Insoluble residue (%)	LOI (%)
92	37.73	37.34	14.42	1.11	0.39	1.59	1.41

6) *Alkaline Solution:* In this investigation, 10 molar concentration of sodiumhydroxide solution was selected based on the trial mix results to check for strength characteristics and durability characteristics of Geopolymer mix. For the present study the ratio of NaOH: Na_2SiO_3 is 2 The NaOH solution should be handled properly with special care and precautions as high exothermic reactions occur during the process which may affect the human skin and eyes.
7) *Hcl , NaCL, NaOH:* 1 percent concentrated hydrochloric acid was taken for the acid attack test and Nacl and NaOH was taken for the rapid chloride permeability test. These three solutions were used for the durability analysis.

III. METHODOLOGY

1) *Quantity Estimation Of Steel:* For project the balanced section of beam of length 900 mm, width 150 mm and depth of 150 mm is selected and top bars are two bars of 10 mm diameter bottom bars are two bars of 10 mm diameter and stirrups are 6 mm in diameter and 120 mm spacing Now, Length of Bar = length of beam – (2 X cover) = 900 - (2 X 30) = 840 mm Therefore, Top bar = 840mm Bottom bar = 840mm Length of stirrup = L = 2a + 2b + 2 (10 X ∅) = (2X90)+(2X90)+2(10X6) = 480mm No. of stirrups = (length – cover/ c/c distance)+ 1 = (840−30 / 120)+ 1 =7.75 = 8 no. of stirrup

Table 3.1: Quantity of steel required for one beam-

Sr. No.	description	Diameter in (mm)	Length of bar in (m)	No.	Total length in (m)	Unit weight	Total weight in kg
1	Top bar	10	0.84	2	1.68	0.617	1.036
2	Bottom bar	10	0.84	2	1.68	0.617	1.036
3	stirrup	6	0.48	8	3.84	0.222	0.852
						total	2.92=3 kg

In the present investigation total 18 nos of beam specimens are required in which 9 specimens are of geopolymer concrete and 9 specimens are of conventional concrete. So quanity of steel required for 18 beams-Top bars = 1.036 X 18 = 18.64 = 19kgs Bottom bars = 1.036 X 18 = 18.64 = 19kgs Stirrups = 0.852 X 18 = 15.336 = 16kgs

2) *Mix Design Of Conventional Concrete:* For the mix design of conventional concrete IS 10262 and IS 456-2000 guidelines and general procedure is followed in the present investigation

   After assuming the stipulation for proportioning the target mean strength, water cement ratio, water content, calculation of cement content, aggregate proportion between course and fine aggregate was found out. After mix calculation for one meter cube volume of concrete is carried out and mix design of conventional concrete (one meter cube) for the present investigation is shown in the table below:

Table 3.2: Mix design of conventional concrete-

Ingredients	Cement	water	Fine aggregate	Coarse aggregate (20mm)	Coarse aggregate (10mm)	Admixture	Water cement ratio
volume	315(kg/m³)	156.9(kg/m³)	822(kg/m³)	666(kg/m³)	444(kg/m³)	3.465(kg/m³)	0.5

3) *Mix Design Of Geopolymer Concrete:* As there are no code provisions for the mix design of geopolymer concrete from is code therefore the mix design of geopolymer concrete is obtained by trial and error basis method. The density of geopolymer concrete is assumed and rest of calculations are done on the basis of density of concrete, binder content, aggregate binder ratio. By assuming the density of geopolymer concrete the total aggregate content is assumed as 75% of density.

Then the alkaline liquid to fly ash + ggbs ratio is assumed as 0.55 in this investigation. Quantity of binder = 315 kg/m3 The ratio of fly ash: GGBS is 70%:30% i.e., Fly ash = 220.5 kg/m3 GGBS = 94.5 kg/m3 The ratio of fly ash: GGBS is 60%:40% i.e., Fly ash = 189 kg/m3 GGBS = 126 kg/m3 then quantity of alkaline liquid required is found out.The ratio of sodium silicate(Na_2SiO_3) solution-to-sodium hydroxide(NaOH) solution was adopted as 2. The sodium hydroxide solids (NaOH) is mixed with water to make a solution with a concentration of 10 Molar. Superplasticizer was added to maintain adequate workability.

Table 3.3: Quantity of geopolymer concrete for each specimen-

INGREDIENTS	QUANTITY (kg/m^3)								
	Beam			Cube			Cylinder		
GGBS	1.57	1.58	2.207	0.27	0.265	0.371	0.42	0.417	0.59
Fly ash	4.72	4.71	4.09	0.80	0.796	0.69	1.26	1.252	1.085
NaOH	1	1	1	0.168	0.168	0.168	0.265	0.265	0.265
Na_2SiO_3	2	2	2	0.337	0.337	0.337	0.53	0.53	0.53
Fine aggregate	14.26	14.26	14.26	2.401	2.401	2.401	3.77	3.77	3.77
Coarse aggregate	26.47	26.47	26.47	4.459	4.459	4.459	7.013	7.013	7.013
Total water	2.168	2.168	2.168	0.365	0.365	0.365	0.574	0.574	0.574
Extra water	0.08	0.08	0.08	0.013	0.013	0.013	0.02	0.02	0.02

4) *Test Methods:* The methodology of casting of geopolymer as well as conventional concrete is same. The coarse, fine aggregates, fly ash and GGBFS were first dry mixed for about 5 minutes and then the solution was added and it was mixed for about 4-5 minutes until it resulted in homogenous concrete mix.

   Immediately after mixing, the concrete was tested for its slump cone test and then concrete was poured into the moulds of beam specimens of size 150mm x 150mm x 900 mm, cube specimens of size 150 mm x 150mm x 150 mm, cylindrical specimens of height 300 mm and diameter 150 mm and RCPT test specimens of size 50mm x100mm in diameter in three layers, each layer being tamped 25 times and then vibrated in vibrating machine so that no voids are there. After demoulding Geopolymer specimens were given ambient curing at room temperature and concrete specimens were immersed in water.
5) *Final Mix:* After getting the results of trial mix the final mix of (70%fly ash +30%ggbs) and (60%fly ash +40%ggbs) are finalised and comparative analysis is carried out at 7and 28 days age of curing with 10 molar alkaline solution

IV. RESULTS AND DISCUSSION

Test conducted in the present investigation for comparative analysis are as follows–

Compressive strength test

Split tensile strength test

Flexural strength test

Acid attack test

Rapid chloride permeability test

1) *Compressive Strength Test:* Compressive test of concrete has been taken by testing cube of size 150x 150x150mm cube after 7 days and 28 days of normal curing and ambient room temperature curing and the results are recorded-

Table 4.1: compressive strength test results (7 and 28 days curing)-

Sr No.	Age In days	Conventional concrete		Geopolymer concrete (70% fly ash + 30%GGBS)		Geopolymer concrete (60% fly ash + 40%GGBS)	
		Compressive Strength of Three specimens	Average Compressive strength	Compressive Strength of Three specimens	Average Compressive strength	Compressive Strength of Three specimens	Average Compressive strength
1	7 days	6.7	6.7	18.71	17.91	19.75	19.53
2		6.8		17.52		19.52	
3		6.8		17.32		19.37	
4	28 days	29.02	30.60	50.26	49.79	58.4	64.76
5		30.22		50.02		65.5	
6		32.57		48.77		70.3	

At early 7 days the compressive strength of conventional concrete is 6.7N/mm2 which is lesser than the GPC 1(17.91N/mm2) and GPC 2 (19.53 N/mm2) and it is observed that at early 7 days age geopolymer concrete with high GGBS percentage achieves much more strength than conventional concrete. After 28 days age the compressive strength of GPC 1 is slightly equal to conventional concrete.

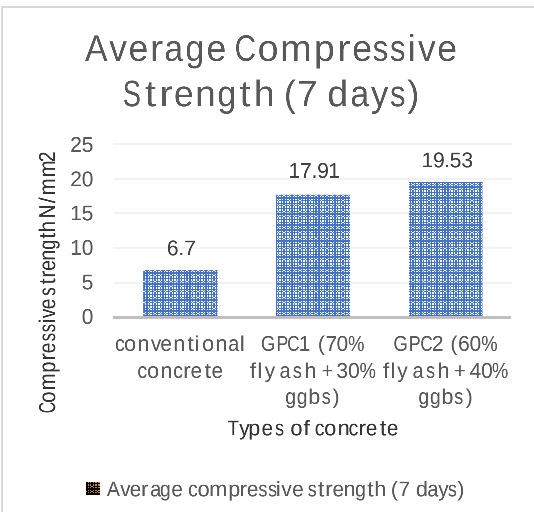

Figure 2.1: Average compressive strength (7 days)

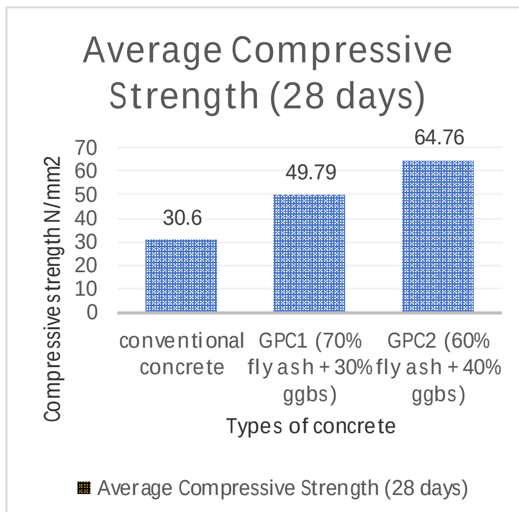

Figure 2.2: Average compressive strength (28 days)

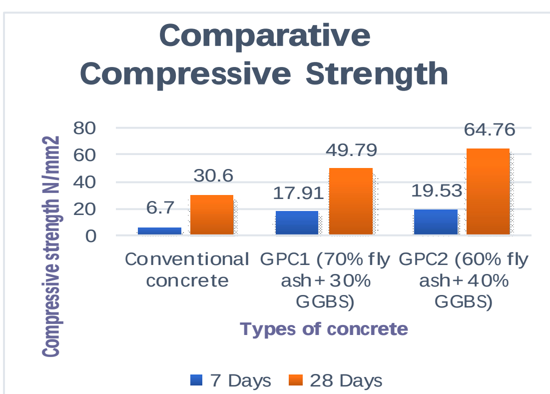

Figure 2.3: Comparative Compressive Strength (7 and 28 days)

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2) *Split Tensile Strength:* Split tensile strength test of concrete has been taken by testing cylinder of height 300mm and dimeter 150 mm after 7 and 28 days of normal curing and ambient room temperature curing and the results are recorded-

Table 4.2: Split tensile strength test results (7 and 28 days curing)-

Sr No.	Age In days	Conventional concrete		Geopolymer concrete (70% fly ash + 30%GGBS)		Geopolymer concrete (60% fly ash + 40%GGBS)	
		Split Tensile Strength of Three specimens	Average Split tensile strength	Split tensile Strength of Three specimens	Average Split tensile strength	Split tensile Strength of Three specimens	Average Split tensile strength
1	7 days	1.11	1.1	1.39	1.40	1.84	1.81
2		1.07		1.46		1.79	
3		1.12		1.37		1.82	
4	28 days	3.26	3.55	3.18	3.23	3.25	3.38
5		3.78		3.19		3.42	
6		3.63		3.34		3.48	

At the age of 7 days of curing split tensile strength of conventional concrete, GPC1, GPC2 are 1.1, 1.40 and 1.81 (N/mm2) which are approximately equal but slight variation is observed and at 28 days split tensile strength conventional, GPC1, GPC2 are 3.55,3.23 and 3.38 (N/mm2) which are approximately equal. At 7 days it is observed that GPC 1 and GPC 2 values of split tensile strength values are comparatively higher than conventional concrete but after 28 days these values are decreased than conventional concrete.

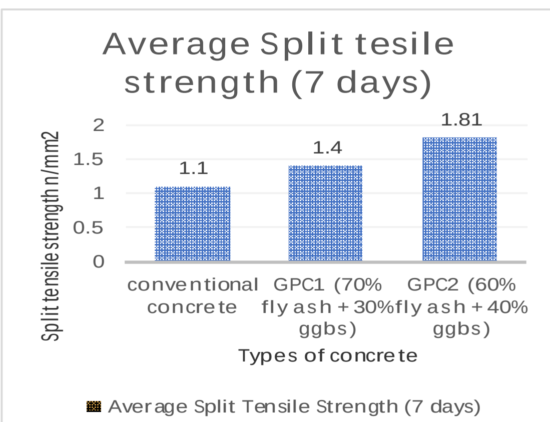

Figure 3.1: Average Split tensile strength (7 days)

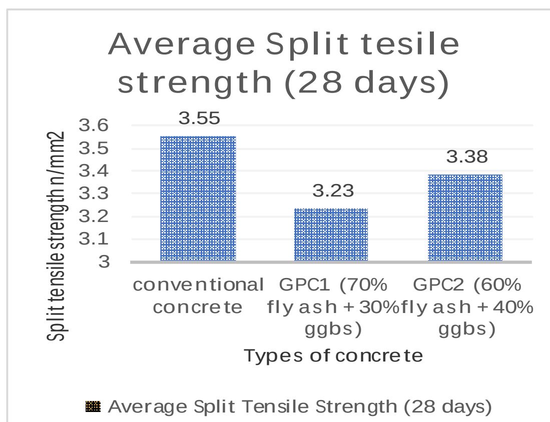

Figure 3.2: Average Split tensile strength (28 days)

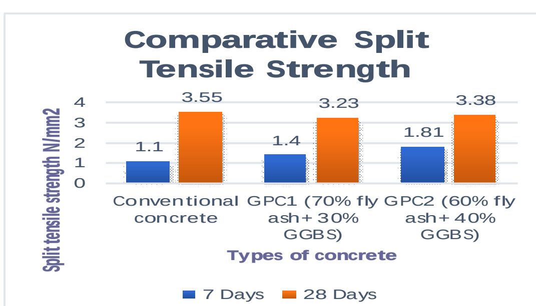

Figure 3.3: Comparative Split tensile strength (7 and 28 days)

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3) *Flexural Strength Test:* Flexural strength test of concrete has been taken by testing balanced section of beam of size 900mm x 150mm x 150mm with reinforcement at top and bottom after 7 days and 28 days of normal curing and ambient room temperature curing and the results are recorded-

Table 4.3: Flexural strength test results (7 and 28 days curing)-

Sr No.	Age In days	Conventional concrete		Geopolymer concrete (70% fly ash + 30%GGBS)		Geopolymer concrete (60% fly ash + 40%GGBS)	
		Flexural Strength of Three specimens	Average Flexural strength	Flexural Strength of Three specimens	Average Flexural strength	Flexural Strength of Three specimens	Average Flexural strength
1	7 days	6.51	6.60	8.5	8.7	9.5	9.63
2		6.38		9.1		9.6	
3		6.92		8.7		9.8	
4	28 days	9.7	9.47	12.23	11.54	12.30	13.08
5		9.5		11.15		13.24	
6		9.23		11.24		13.70	

Due to use of reinforcement in the balanced section of beam the flexural strength of beam is higher than the normal standard concrete beams (without reinforcement) used for flexural strength test. At the age of 7 days the flexural strength of GPC 1 and GPC2 (8.7, 11.54 N/mm2) respectively are comparatively higher than conventional concrete (6.60 N/mm2) and similarly at 28 days of curing flexural strength of GPC1 and GPC2 (11.54, 53.08 N/mm2) is comparatively higher than conventional concrete (9.47 N/mm2)

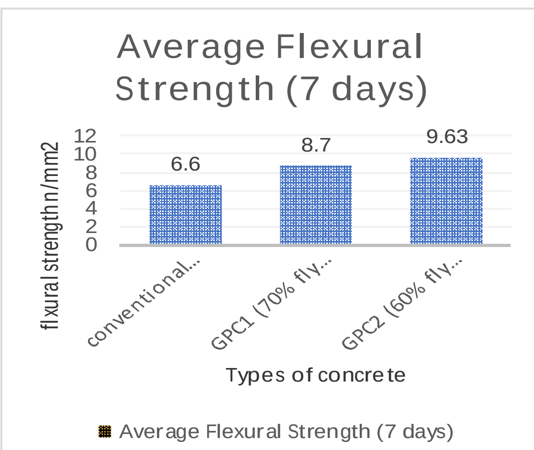

Figure 4.1: Average Flexural strength (7 days)

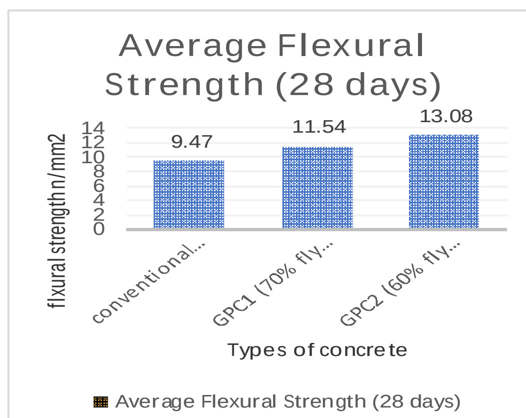

Figure 4.2: Average Flexural strength (28 days)

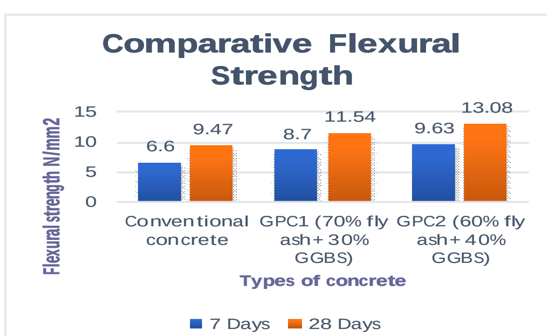

Figure 4.3: Average Flexural strength (7 and 28 days)

4) *Acid Attack Test:* Acid Exposure Hydrochloric acid (HCL) of 1% concentration was considered to be representative of aggressive sewer environments and 1% Hydrochloric acid (HCL) solution used to investigate the acid resistance. Concrete cube 150 × 150 × 150 mm samples were immersed in 1% Hydrochloric acid solution for 60days and percentage weight loss after acid attack immersion is recorded.

Table 4.4: Average weight loss due to acid attack

Sr.no	Type of concrete	Avg. wt. before acid attack	Avg. wt. after acid attack	Loss in kg.	Percentage loss
1	conventional	8.448	8.420	0.028	1%
2	GPC 1	8.375	8.353	0.022	0.26 %
3	GPC 2	8.343	8.325	0.018	0.18 %

After 60 days immersion in acid attack it was observed that the percentage weight loss of geopolymer concrete cube is comparatively lesser than conventional concrete and had more acid resistance than conventional concrete.

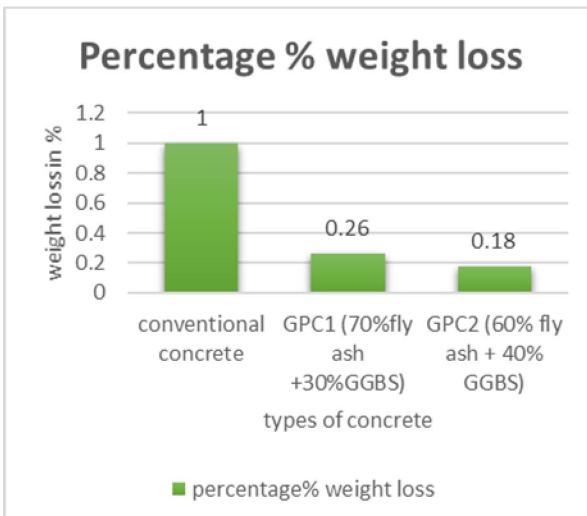

Figure 5.1: Percentage weight loss due to acid attack

5) *Rapid Chloride Permeability Test:* Concrete with the thickness 50mm and diameter 90-100mm is used as a test specimen. Charge passed in coulombs through RCPT test specimens are recorded. And it was observed that charge passed in coulombs is approximately equal.

Table 4.5: RCPT test results

Types of concrete	Charge passed in coulombs
Conventional concrete	2837
Geopolymer concrete (70% fly ash + 30% ggbs)	2915
Geopolymer concrete (60% fly ash + 40% ggbs)	2875

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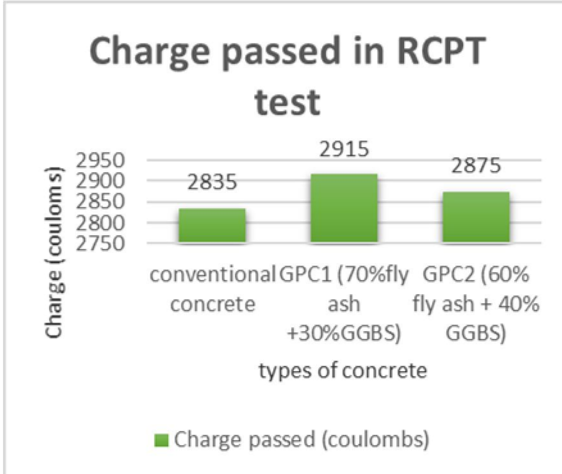

Figure 6.1: Charge passed in RCPT test-

V. CONCLUSION

The experimental investigation carried out for comparative analysis of geopolymer concrete with different proportions of fly ash and GGBS with conventional concrete and concluded that:

1) At early 7days of curing the compressive strength of geopolymer concrete is more than conventional concrete but after 28 days of curing the compressive strength becomes slightly more than conventional concrete. Compressive strength of geopolymer concrete with 70% fly ash and 30% GGBS gives approximately slightly more value than conventional concrete.
2) As we increase the proportion of GGBS content in geopolymer concrete then it gives high early strength value so the proportion of GGBS content to be provided in geopolymer concrete should be adequate.
3) As we increase the proportion of sodium hydroxide in geopolymer concrete the strength is going to increase.
4) Workability of geopolymer concrete directly depend on aggregate binder ratio.
5) Split tensile strength of conventional concrete and geopolymer concrete are almost gives equal values.
6) Flexural strength of conventional concrete is less than geopolymer concrete. Conventional concrete fails in flexure earlier than geopolymer concrete. Hence geopolymer concrete is more durable than conventional concrete.
7) In exposure of acid attack for 60 days the average weight loss of conventional concrete is more than geopolymer concrete hence it is concluded that the geopolymer concrete has better resistance to acid exposure condition than conventional concrete.
8) From RCPT test it is concluded that the charge passed to concrete specimen is almost equal for conventional as well as geopolymer concrete.
9) Geopolymer concrete with 70% fly ash 30% GGBS is best proportion as a replacement of cement which gives acceptable strength and durability approximately equal to conventional concrete

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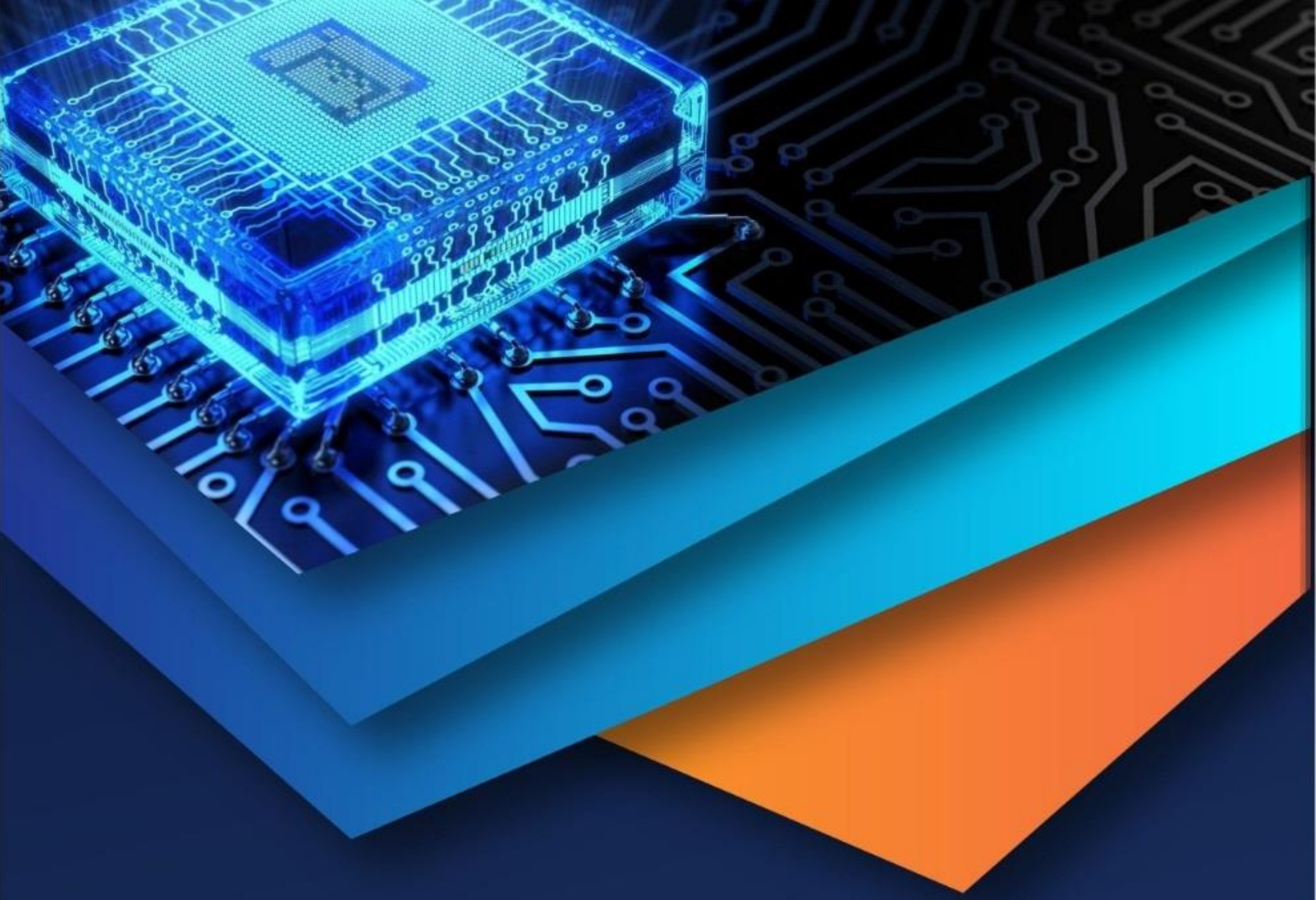
REFERENCES

[1] Davidovits. J. “Geopolymer Chemistry and Application”,ISBN-978251482050,Saint-QuenitinFrance, 2008.

[2] "Durability Performance of Geopolymer Concrete under Sulphate and Acid Exposure" P. Somiyadevi1, A. Aruna2Assistant Professor1, PG Student2(April 2012) (IJESC journal)
[3] "A Comparative Study on Strength and Durability Aspects of fly ash- GGBS based Geopolymer Concrete over" by Miss. Sapna Rathod, Mr. Girish (December 2011) (IJERT journal)
[4] "Effect of Aggressive Chemical Environment on Durability of Green Geopolymer Concrete" by Neetu Singh, Sameer Vyas, R.P.Pathak, Pankaj Sharma, N.V.Mahure, S.L. Gupta (October 2013) (IJEIT journal)
[5] "Comparative Study on Geopolymer and Conventional Concrete Beams Subjected to Flexural loading" Harsha B R 1, Mr.Shashi Kiran.S2(Feburary 2018) (IRJET journal)
[6] "Comparative Analysis of Compressive Strength of Concrete by Replacing of Cement by Fly Ash with Conventional Concrete" by Swati Chandra1, Ramendra Singh2 (June 2019) (IJSR journal)
[7] "Comparison of Geopolymer Fly Ash and OPC to the Strength of Concrete" A. M. Mustafa Al Bakri1, H. Kamarudin, M. Binhussain, I. Khairul Nizar, A. R. Rafiza1, and Y. Zarina1 (December 2013) (Journal of Computational and Theoretical Nanoscience)
[8] "Conventional Concrete Over Geo Polymer Concrete Using GGBS" A.Pavani, J.Rakesh, P.Gopichand, P.Suvarnaraju (April 2016) (IJEAS journal)
[9] "Comparison of Mechanical Strengths and Resistance to Acidic Conditions, Permeability and Resistance to Elevated Temperatures of Geopolymer Concrete and Conventional Concrete" by Amir Bahador Moradikhou 1, Majid Safehian 2 (15 may 2021) (ARCE Journal)
[10] "MECHANICAL PROPERTIES OF FLY ASH AND GGBS BLENDED GEO POLYMER CONCRETE USING DIFFERENT FINE AGGREGATES" P. Ukesh Praveen1, Dr. J. Guru Jawahar2, K. Sai Abhinav3, C. Sashidhar4 (june 2016) (IRJET Journal)
[11] "Strength & Development of Fly ash and GGBS Based Geopolymer Mortar" 1Banda Rohit Rajan, 2KRamujee (2015) (IJRAET journal)
[12] "Strength and Durability Test of Fly Ash and GGBS Based Geopolymer Concrete" Ajay Kumar Singh (august 2016) (IJERA journal)
[13] "Resistance of geopolymer mortar to acid and chloride attacks" Huang Ji Zhuang, Hai Yan Zhang (December 2017) (ELSEVIER journal)
[14] STUDY ON STRENGTH AND DURABILITY PARAMETERS OF GEO POLYMER CONCRETE WITH GGBS FOR 12M AND 14M ALKALI ACTIVATORS by Md. Ishaq Jaffery, Y. Himath Kumar(august 2014)(ARPN journal)
[15] "Performance of Fly Ash and GGBS Based Geopolymer Concrete in Acid Environment" J. Guru Jawahar1, D. Lavanya1, C. Sashidhar2 (august 2016) (IJRSI journal)



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IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

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