EXPERIMENTAL INVESTIGATION ON STRENGTH PARAMETERS OF GEOPOLYMER CONCRETE AND ANALYZING THE RESULTS USING X-RAY DIFFRACTION (XRD) METHOD

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Abstract
Cost of the construction is increasing day by day due to the increase in cost of materials and also the labour. Hence it is not affordable for a common man to fulfil his needs due to tremendous increase in cost of construction. Cost of geopolymer concrete blocks is much cheaper than the conventional blocks and also sustainable. Since in Geopolymer concrete there is no usage of Cement, it can also helps in controlling Carbon dioxide emission and thus proves environment friendly. Though the Geopolymer concrete has lower strength in early age compared to conventional concrete, its strength after 28 days is higher than the Conventional Concrete.
The overall purpose of this work is to reduce the cost of construction, and also to reduce environmental pollution. In the present work an attempt has been made to replace the cement completely by fly ash and GGBS with varying proportions and thereby reducing the cost of construction and also sustainability in construction can be achieved. An attempt has also been made to study the atomic structure of geopolymer concrete by means of X-Ray Diffraction (XRD) Analysis. To prove that Geopolymer Concrete is economically sustainable, Cost analysis also been carried out.

Keywords: Geopolymer Concrete; Fly-Ash; GGBS; X-Ray Diffraction Analysis; Cost analysis

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1. Introduction

Ordinary Portland cement production is the second generator of carbon dioxide, which pollutes the atmosphere. So, to avoid these global warming potentials, the other alternative materials for ordinary cement are GGBS, silica fume, rice husk ash, kaolin, metakaolin can be implemented in construction.

In this study Geopolymer produced with the combination of Fly-ash and GGBS in the proportions of 30:70, 40:60, 50:50 and 60:40. The study revealed that, the compressive strength of Geopolymer concrete is about 1.5 times more than that of the compressive strength with the conventional concrete, for the same mix

2. Experimental Study

2.a. Material Characterization

The various experimental investigations are carried out are tabulated in Table 1 and the results are compared the obtained results with the Permissible Limiting Values and satisfying the Indian Standard requirements.

Table 1: Material Characterization

Sl.No.	Material	Properties	Obtained Result	Permissible Limit as per Indian Standard
1	GGBS	Fineness Modulus	6%	<10%
		Specific Gravity	2.82	2.1-3.0
2	Fly-Ash	Fineness Modulus	4%	<10%
		Specific Gravity	2.227	2.1-3.0
3	Fine Aggregate (M-Sand)	Fineness Modulus	4.075	2.0-4.0
		Specific Gravity	2.56	2.53-2.67
4	Coarse Aggregate	Fineness Modulus	7.397	6.75-8.0
		Specific Gravity	2.64	2.3-3.1
		Specific Gravity	2.26	2.2-3.2
5	Cement	Fineness Modulus	6%	<10%
		Specific Gravity	3.10	3.01-3.19

2.b Quantity of Materials required for the preparation of Concrete

The geopolymer concrete with GGBS and fly ash as binding materials, M Sand as fine aggregate, 90% Natural coarse aggregate and 10% of E-Waste (PCB) as coarse aggregate was prepared and workability test on fresh geopolymer concrete and strength parameters on hardened geopolymer concrete were tested and the results are discussed below.

The various geopolymer concrete proportions used in the study are 30% Fly-Ash and 70% of GGBS, 40% Fly-Ash and 60% of GGBS, 50% Fly-Ash and 50% of GGBS. The Alkaline solutions used are sodium silicate and sodium hydroxide.

The assumptions made in the study based on literature review are listed below.

1) The ratio of sodium silicate to sodium hydroxide is 2.50
2) The ratio of alkaline solution to binder ratio is 0.40
3) The water to geopolymer solids ratio is 0.45

Table 2 shows the quantities of materials required for 1 cubic meter of conventional and geopolymer concrete.

Table 2: Quantity of Materials Required for Various Geopolymer Concrete Mixes

MIX	Cement (KG)	Fly Ash (KG)	GGBS (KG)	M SAND (KG)	Natural CA (KG)	NaOH Pallets (KG)	Na_2SiO_3 Solution (Ltr)	Water (Ltr)
Conventional Concrete	450	-	-	651.85	1,008	-	-	198.52
30%FA+ 70% GGBS	-	148.15	296.30	651.85	1,008	26.37	136.60	214.82
40%FA+ 60% GGBS	-	207.41	272.60	651.85	1,008	26.67	138.37	216.30
50%FA+ 50% GGBS	-	266.67	237.04	651.85	1,008	26.97	140.15	222.22
60%FA+ 40% GGBS	-	325.93	210.53	651.85	1,008	27.26	142.22	224

2.c Workability Test

Table 3 and figure 1 represents the workability of conventional concrete and geopolymer concrete in their fresh state.

Table 3: Slump Test values

Mix No.	Binder Content	Slump (mm)
1.	Conventional Concrete	62
2.	30%Flyash+70%GGBS	52
3.	40%Flyash+60%GGBS	58
4.	50%Flyash+50%GGBS	66
5.	60%Flyash+40%GGBS	59

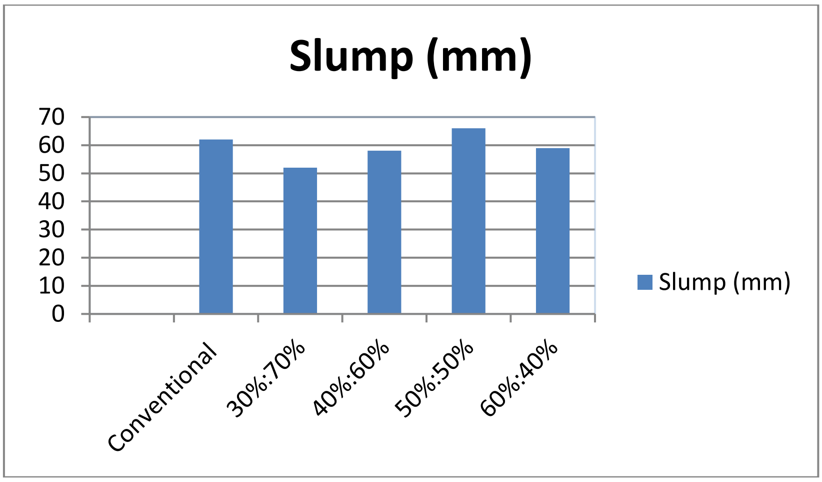

Fig. 1: Slump Test Results

2.d Compressive Strength Test Results

Table 4 shows the compressive strength test results for Conventional Concrete and also for Fly-Ash and GGBS based Geopolymer Concrete. The variation of Compressive strength test results after 7, 14 and 28 days curing are shown in figure 2. . It is found that, geopolymer concrete achieves higher compressive strength than conventional and by increasing the Fly-ash content compared to the quantity of GGBS, compressive strength enhances.

Table 4: Compressive Strength Test Results

Fly Ash in %	GGBS in %	7 days (Mpa)	14 days (Mpa)	28 days (Mpa)
Conventional Concrete		13.10	27.22	33.10
30	**70**	11.10	25.30	36.35
40	**60**	11.80	27.80	43.35
50	**50**	12.30	34.00	48.20
60	**40**	12.50	35.00	41.00

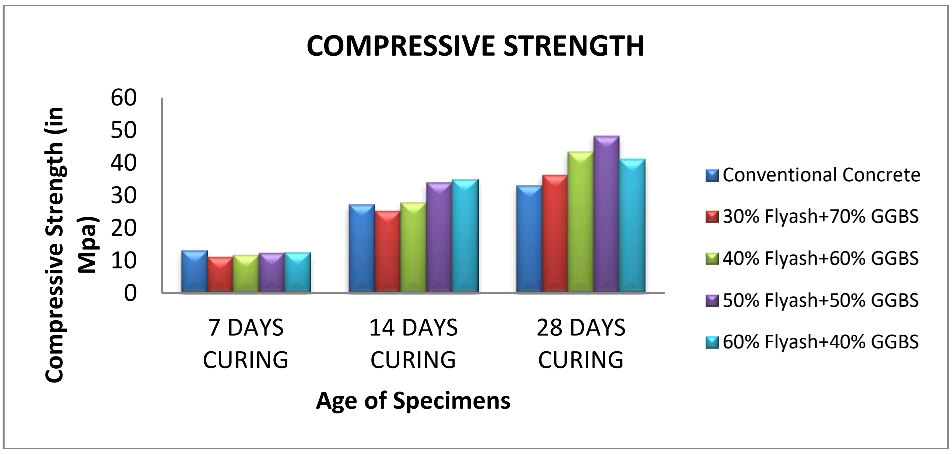

Fig.2: Compressive Strength Test Results

2.e Split Tensile Strength Test Result

Table 5 shows the split tensile strength test results for Conventional Concrete and also for Fly-Ash and GGBS based Geopolymer Concrete. The variation of Split Tensile strength test results after 7, 14 and 28 days curing are shown in figure 3. Geopolymer concrete achieves higher split tensile strength than conventional after 28 days of curing and by adding 50% of Fly-ash content and 50% of GGBS, Split tensile strength reaches highest value.

Table 5: Split Tensile Strength Test Results

Fly Ash in %	GGBS in %	7 days (Mpa)	14 days (Mpa)	28 days (Mpa)
Conventional Concrete		1.60	2.73	3.10
30	**70**	1.30	2.33	3.40
40	**60**	1.38	2.87	3.98
50	**50**	1.55	3.12	4.22
60	**40**	1.42	3.10	3.92

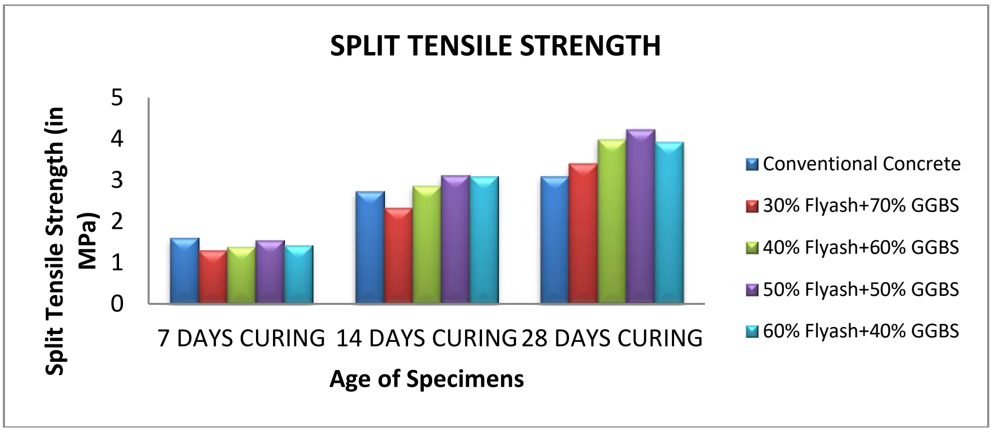

Fig.3: Split Tensile Strength Test Results

2.f Flexural Strength Test Result

Table 6 shows the flexural strength test results for Conventional Concrete and also for Fly-Ash and GGBS based Geopolymer Concrete. The variation of flexural strength test results after 7, 14 and 28 days curing are shown in figure 4. Geopolymer concrete by considering equal quantity of Fly-Ash and GGBS gives higher flexural strength compared to conventional concrete.

Table 6: Flexural Strength Test Results

Fly Ash in %	GGBS in %	7 days (Mpa)	14 days (Mpa)	28 days (Mpa)
Conventional Concrete		3.89	5.33	5.89
30	**70**	3.10	5.47	6.10
40	**60**	3.48	5.81	6.89
50	**50**	3.79	6.25	8.70
60	**40**	3.60	5.82	7.32

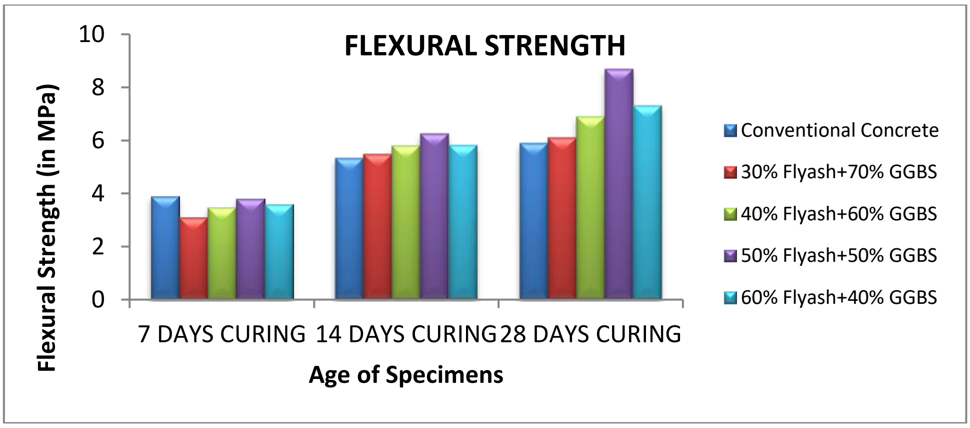

Fig.4: Flexural Strength Test Results

By comparing the results of all three strength parameters, it is proved that, the GPC having Fly-Ash content takes more time to set initially. So the early strength gain is low compared to the

Conventional concrete. But after 28 days of ambient curing, the GPC attains higher strength than the Conventional concrete.

X-ray powder diffraction (XRD) is a rapid analytical technique to study the atomic structure of the composite material.

2.g X-Ray Diffraction (XRD) Analysis

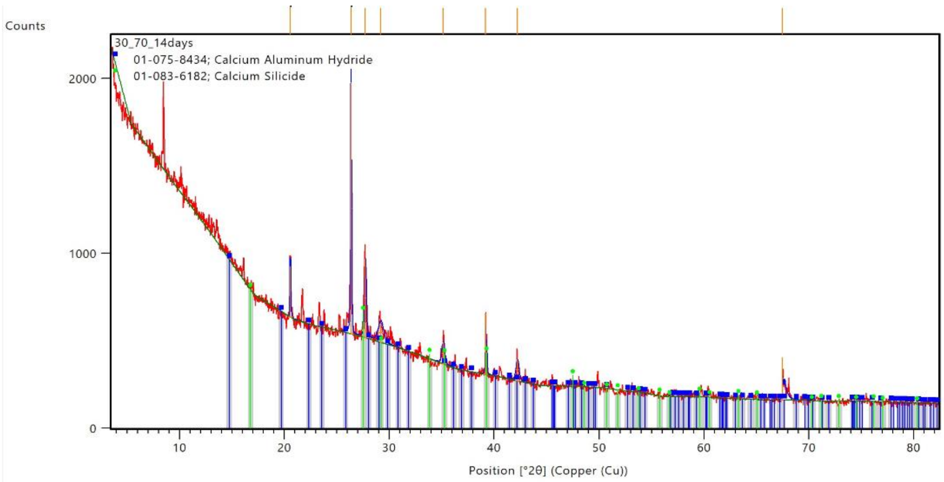

Fig.5: XRD Analysis on the specimens having 30% FA: 70% GGBS on 14th Day

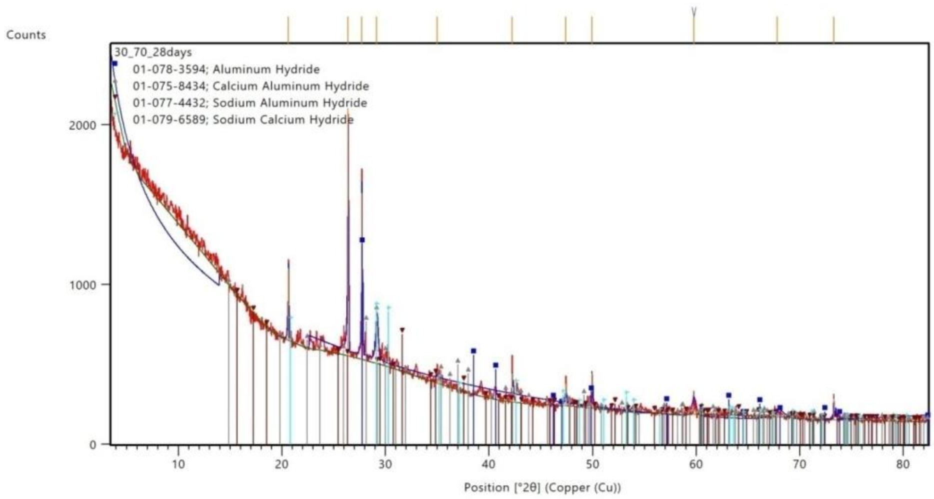

Fig.6: XRD Analysis on the specimens having 30% FA: 70% GGBS on 28th Day

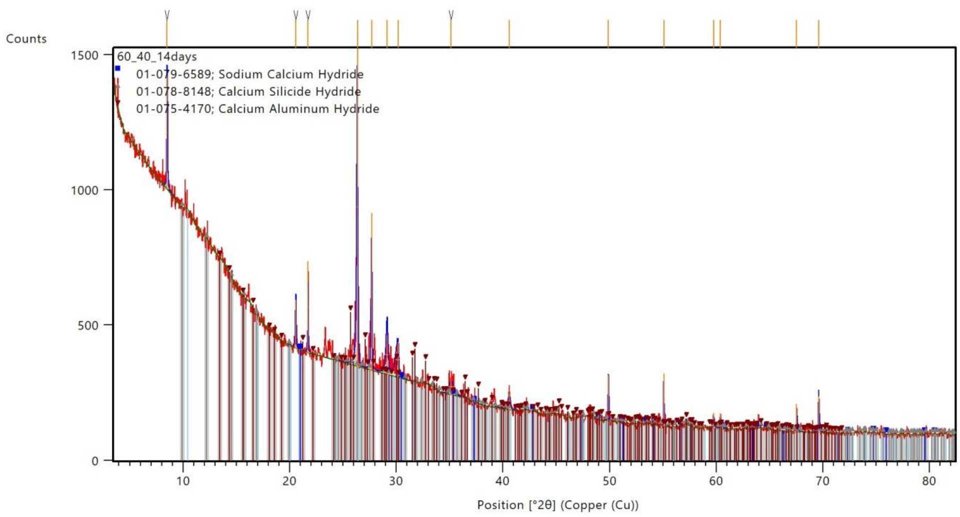

Fig.7: XRD Analysis on the specimens having 40% FA: 60% GGBS on 14th Day

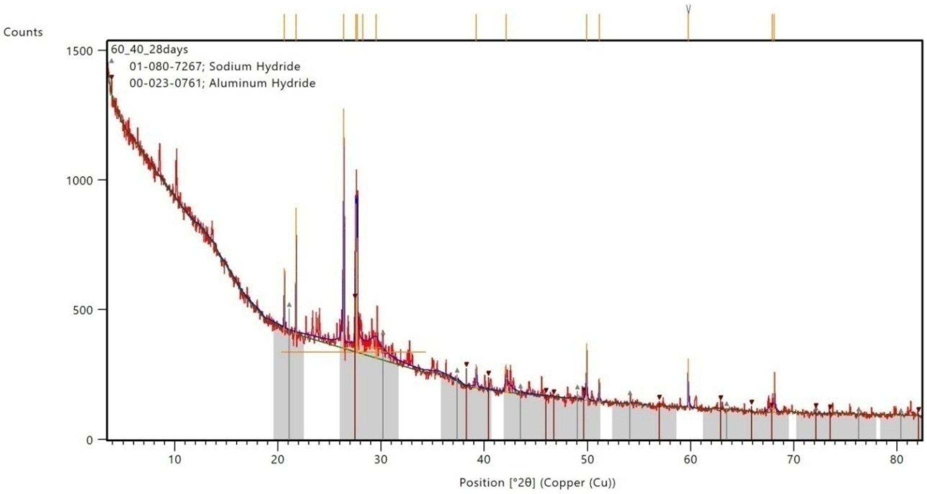

Fig.8: XRD Analysis on the specimens having 40% FA: 60% GGBS on 28th Day

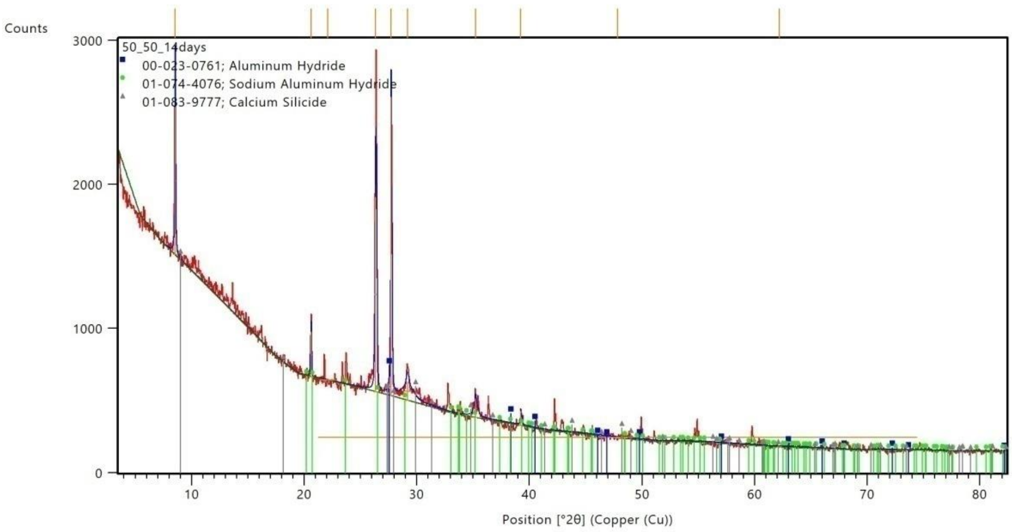

Fig.9: XRD Analysis on the specimens having 50% FA: 50% GGBS on 14th Day

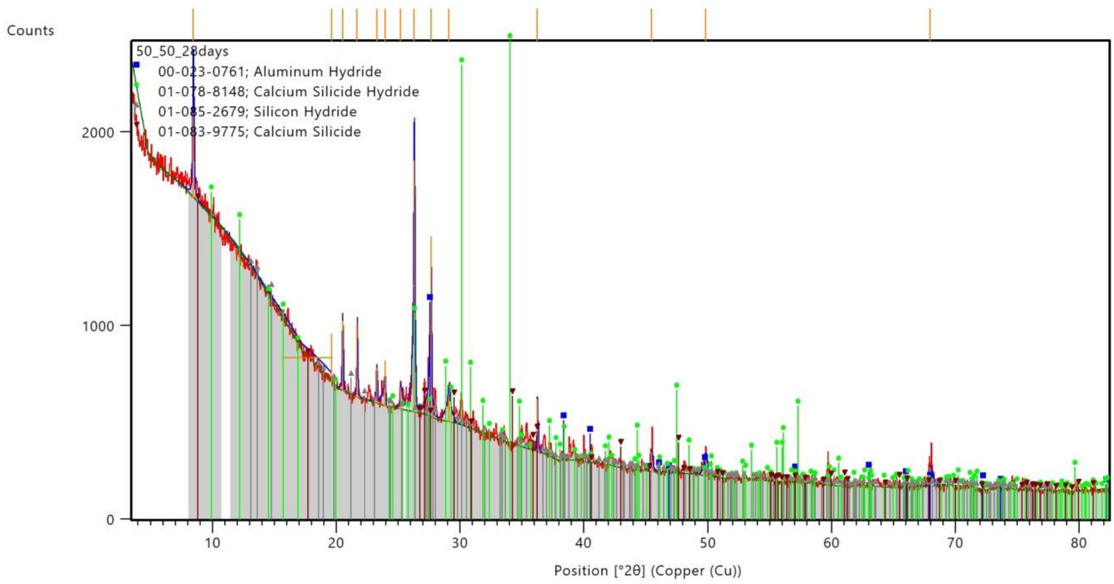

Fig.10: XRD Analysis on the specimens having 50% FA: 50% GGBS on 28th Day

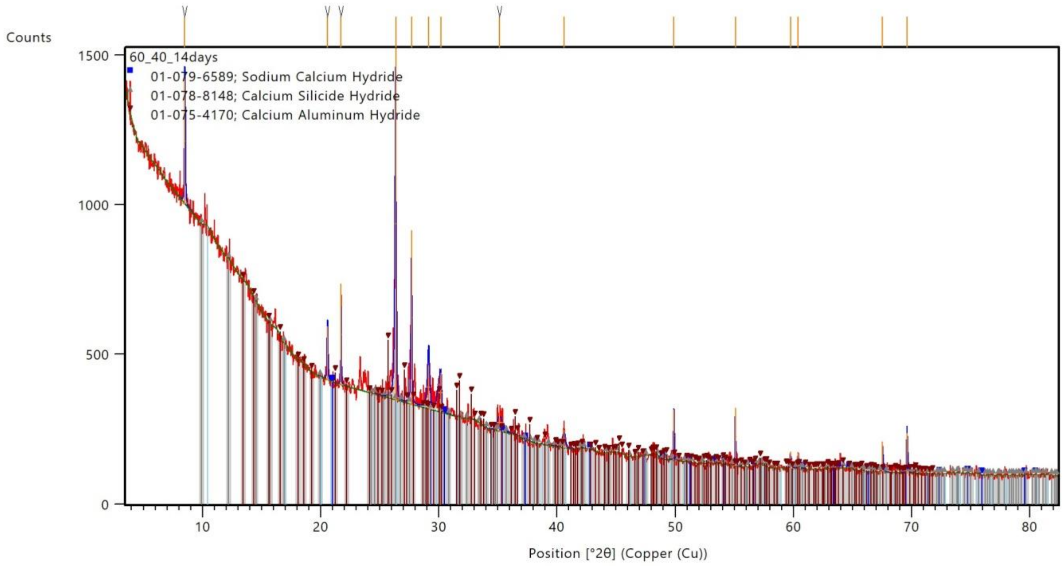

Fig.11: XRD Analysis on the specimens having 60% FA: 40% GGBS on 14th Day

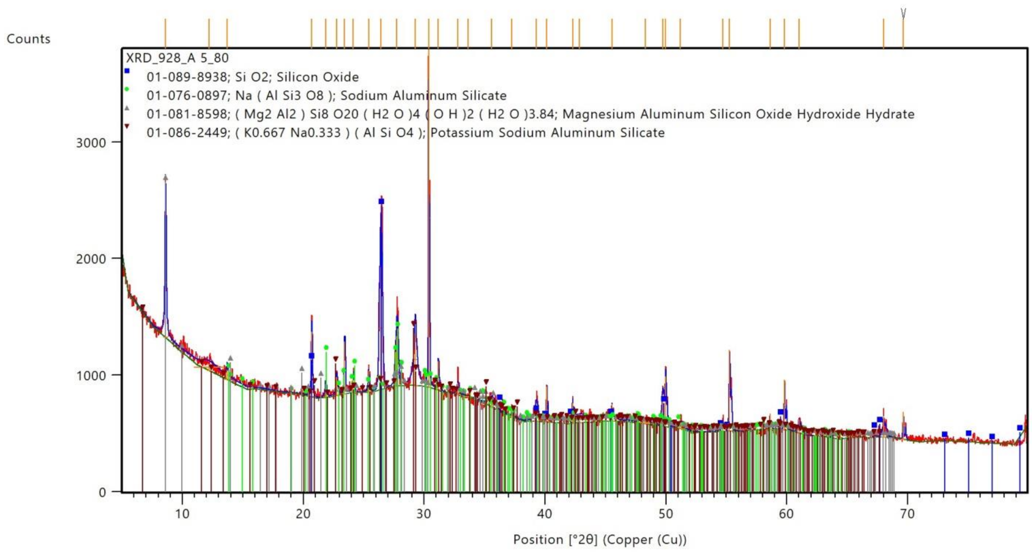

Fig.12: XRD Analysis on the specimens having 60% FA: 40% GGBS on 28th Day

XRD tests were conducted at 14 and 28 days with respect to the age of samples and the results were combined in graphs shown in Figure 5 to figure 12.

In addition to the bonding conditions of various samples, study has been extended to study the elemental composition in different samples and that is represented in Table 7.

Table 7: Elemental Composition of Geopolymer Concrete with Various Proportions

MIX DESIGNATION	AGE OF SPECIMEN	ELEMENTAL COMPOSITION
30 FA: 70 GGBS	14 Days	Calcium Aluminium Hydride
		Calcium Silicide
	28 Days	Aluminium Hydride
		Calcium Aluminium Hydride
		Sodium Aluminium Hydride
		Sodium Calcium Hydride
40 FA: 60 GGBS	14 Days	Sodium Calcium Hydride
		Calcium Silicide Hydride
		Calcium Aluminium Hydride

	28 Days	Sodium Hydride
		Aluminium Hydride
50 FA: 50 GGBS	14 Days	Aluminium Hydride
		Sodium Aluminium Hydride
		Calcium Silicide
	28 Days	Aluminium Hydride
		Calcium Silicide Hydride
		Silicon Hydride
		Calcium Silicide
60 FA: 40 GGBS	14 Days	Sodium Calcium Hydride
		Calcium Silicide Hydride
		Calcium Aluminium Hydride
	28 Days	Silicon Oxide
		Sodium Aluminium Silicate
		Magnesium Aluminium Silicon Oxide Hydroxide Hydrate
		Potassium Sodium Aluminium Silicate

Discussion on Result

By comparing all the 4 proportions of geopolymer concrete, Calcium silicide is the common elemental composition at 14th day.

Calcium silicide imparts the early strength in the concrete by producing the heat during hydration process. Calcium silicide also helps to increase the density and thereby imparts good strength and enhances the durability.

Aluminium hydride is present in all the samples both at 14th and 28th day, primarily helps in producing Ettringite and thereby promotes the setting of geopolymer concrete.

2.h Cost Analysis

The table 8 has showed the cost factor of Conventional concrete and Geopolymer concrete is compared by calculating the costs of materials used for both type of concrete.

Table 8: Cost Analysis

Specification	For 1m³ Conventional Concrete		For 1m³ Geopolymer Concrete	
	Material Consumption	Cost (Rs)	Material Consumption	Cost (Rs)
Cement	0.31	3,780.00	0	0.00
Fly ash	0	0.00	0.15	765.00
GGBS	0	0.00	0.17	880.00
Natural sand	0.34	425.00	0	0.00
M-sand	0	0.00	0.35	135.00
Natural CA	0.35	438.00	0.35	438.00
NaOH Pallets	0	0.00	0.36	680.00
Na_2SiO_3	0	0.00	0.57	1450.00
Transport	---	400.00	---	400.00
Total		**5,043.00**		**4,748.00**

Cost of Conventional concrete 1m^3=**5,043.00₹**

Cost of Geopolymer concrete 1m^3=**4,748.60₹**

3. Conclusion

1. The geopolymer concrete with 50% fly-ash and 50% GGBS shows the high flowability when conduct the workability test using slump test procedure.
2. Due to the presence of high fly-ash content in 50:50 Fly-ash:GGBS proportion compared to the other geopolymer concrete specimens, the heat evolution during the hydration process is low and the rate of hydration is also slower. So, there is no high strength gain in early age, but as the time passes, the strength is higher than the conventional concrete and also compared to the geopolymer concrete with 30:70 and 40:60 Fly-ash: GGBS proportion.
3. The XRD analysis revealed the periodicity of atomic arrangements in various samples. Since the atomic arrangement of 50:50 ratio is frequently periodic and attained the peak intensity, hence observations on the graphs shows that 50:50 fly-ash: GGBS ratio has good bonding strength and therefore the geopolymer concrete achieved the better strength parameters.
4. The cost of conventional concrete for 1 m3 is Rs.5,043 and cost of GPC for 1m3 is Rs.4,748. By comparing the cost factor to each other, it

can be concluded that the cost of GPC is 7% lesser than that of the Conventional concrete, which is desirable.

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References

1. A.Maria Rajesh, M.Adams Joe, Roy Mammen "*study of the strength geopolymer concrete with alkaline solution of varying molarity*", IOSR Journal of Engineering, ISSN (e): 2250-3021, ISSN (p): 2278-8719 Vol. 04, Issue 06, June. 2014.
2. S.Subburaj, S.Ravikumar, V.ajith "*Strength and Durability characteristics of Geopolymer concrete using GGBS and RHA",* ISSN (Print) : 2321-5747, Volume-2, Issue-4,2014.
3. K. Chandra Padmakar B. Sarath Chandra Kumar "*An experimental study on metakaolin and GGBS based geopolymer concrete",* International Journal of Civil Engineering and Technology**,** Volume 8, Issue 1, pp. 544–557, January 2017.
4. Basil Al-Shatr et.al, *" Relationship between amorphous silica in source materials and compressive strength of geopolymer concrete",* 2018.
5. Abhishek C. Ayachit, Pranav B. Nikam, "*Mix design of fly-ash based geopolymer concrete,* International Journal of Scientific and Research Publications, Volume 6, Issue 2, 381 ISSN 2250-3153, , February 2016.