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SUITABILITY OF CALCIUM CONTENT AT AMBIENT TEMPERATURE CURED FLY ASH AND GGBFS BASED GEOPOLYMER CONCRETE

Mishel C. Patel[1], Bansal R. Patel[2]

Post Graduate Student, Applied Mechanics Department, L.D. College of Engineering, Ahmedabad-380015, India[1]

Ph.D. Research Scholar, Applied Mechanics Department, L.D. College of Engineering, Ahmedabad-380015, India [2]

Abstract: The current study looks at how lime content affects the fresh and hardened properties of Fly Ash and GGBFS-based geopolymer concrete cured at ambient temperature. Two series of geopolymer concrete (GPC) were developed, each with a constant binder content of 350 kg/m^3 and an Alkaline-to-binder (a/b) ratio of 0.35. Fly Ash (FA) was sustained with GGBFS in the first series, with replacement amounts of 10%, 15%, 20%, 25%, and 30% by weight in each GPC series. Lime was not used in the initial concrete series assembly, but lime was added in the second series and lime combination created by replacing the GGBFS with lime at a constant 5 percent by weight. The best compressive strength produced geopolymer concrete from the first series, which comprises 70% fly ash and 30% GGBFS, was chosen as the lime substitute. Then a 5% weight substitution with GGBFS to lime is performed, for example, 70% FA, 25% GGBFS, and 5% lime. The slump test was used to evaluate the new qualities of the mixture. Furthermore, the mechanical performance of the lime-based geopolymer concrete was assessed using compressive strength, splitting tensile strength, and the Flexural strength test. Furthermore, statistical analysis was used to compare lime-based GPC to regular FA-based GPC and Ordinary cement concrete (OPC) in order to assess the significance of experimental characteristics such as lime levels. The experimental results showed that lime addition had a significant impact on both the fresh and hardened properties of GPC mixtures. Furthermore, the combination of GGBFS and lime significantly enhanced the mechanical properties of GPC, by close for the 7 days compressive strength but poor for the split tensile strength and flexural strength.

Keywords: Geopolymer Concrete (GPC), Fly Ash and GGBFS based Geopolymer Concrete, Lime Content in GPC

I. INTRODUCTION

The demand for cement is expanding dramatically as urbanisation continues. On the other hand, the cement sector is a major contributor to air pollution. According to reports, cement production accounts for 4% to 7% of total carbon dioxide emissions into the atmosphere, contributing to global warming. Each tonne of cement produced emits approximately one tonne of CO_2 into the environment. CO_2 provides around 65 percent of global warming among greenhouse gases. In GPC industrial wastes like fly ash, GGBFS, silica fume and rice husk are being used. So, as results use of GPC cuts CO_2 emissions by 80%. [1]. Fly ash and GGBS are rich in silicon and aluminium, which are polymerized by an alkali activating solution to form molecular chains and networks, resulting in a rigid binder. So, alumino-silicate based materials are the best alternatives of the cement.

'Geopolymer' developed by Davidovits [10] had geopolymeric aluminosilicate gel, performing the role of binder. He utilised silica (SiO_2) and alumina (Al_2O_3) in metakaolin to get inorganic polymeric system of alumino-silicates. Rangan and Hardijto [11] also exploited silica and alumina of fly ash to produce geopolymeric binder suitable for making structural grade concretes. Literature [11, 12**]** reveal that thermally cured geopolymer composites exhibit excellent mechanical properties, good thermal stability, better resistance to fire and acids. Geopolymer composites possess low shrinkage, low creep and excellent resistance to sulphate attack [08, 13]. Xiaolu Guo et. al. [14] synthesized class C fly ash based geopolymer pastes and realized a compressive strength of 63.4 MPa when cured at 750C for 8hours followed by curing at 230C for 28 days. Results of the investigation [15] on inorganic polymeric binder prepared from natural pozzolan reveal that any increase in both duration and temperature of curing increases the compressive strength. In India, the ambient temperature varies mostly in the range of 15-48°C. The acceptability of ambient temperature curing is high but the main drawbacks of adopting ambient temperature curing are that the Geopolymerization reaction needs higher temperature curing. The rate of geopolymerization reaction necessary influences the rate of gain of strength. Moreover, the heat curing mechanism itself is highly cumbersome and costly which necessitated the development of geopolymer concrete at ambient curing conditions [4].

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II. Need of Present Study

We know that we can adjust the strength of the OPC by altering the lime/calcium component. Calcium content has a significant impact on its strength. Chemical characteristics suggest that GGBFS has more calcium than fly ash. And we've noticed that increasing the GGBFS content in Geopolymer concrete improved its mechanical qualities significantly. Despite these findings, the lime hydration process generates heat, and we know that higher temperatures promote Geopolymerization. GGBFS is an industrial waste product of steel manufacture, and it may or may not be available in every region in sufficient quantities, whereas lime is readily available in practically every section of the country. So, if lime-added geopolymer concrete cured at room temperature provides the desired performance, it is quite promising for the future construction industry.
Previous studies focused on characteristics such as al/bi, the SS/SH ratio, and the quantities of various binding materials. There has also been study into lime-added geopolymer concrete, but only with fly ash and no GGBFS. As a result, there hasn't been much investigation into geopolymer concrete with lime addition.

III. Experimental Details

Materials Used in GPC:
Following are the basic ingredients of geopolymer concrete in investigation.
Cement, Fly ash , GGBFS (ground granulated blast furnace slag),lime, Alkaline solution, Water, Aggregates and Sand
Fly ash is purchased from local seller named Guru Corporation. Fly ash Type F is used for the experimental work with below characteristics.
GGBFS also acquired from the Guru Corporation with the Given below characteristics.

No.	Characteristics	Fly ash content (% wt.)	IS-3812 Specification
1	Silica	55-65	35 min. by mass
2	Aluminium oxide	22-25	70 min. by mass
3	Iron oxide	5-7	
4	Calcium	5-7	
5	Magnesium oxide	<1	5 max. by mass
6	Titanium oxide	<1	-
7	Phosphorus	<1	-
8	Sulphate	0.1	3 max. by mass
9	Alkali oxide	<1	1.5 max. by mass
10	Loss on ignition	1-1.5	5(max)

Table 3.1 properties of fly ash

no.	Chemical characteristics	Content (% wt.)
1.	Specific surface area (m2/kg)	338
2.	Sp. Gravity	2.82
3.	45 microns (residue %)	6.6
4.	Insoluble (residue %)	0.40
5.	Magnesia content %	7.90
6.	Sulphide (%)	0.55
7.	Sulphite	0.33
8.	Loss on ignition	0.33
9.	Manganese content (%)	0.12
10.	Chloride content (%)	0.007
11.	Glass content (%)	91
12.	Moisture content (%)	0.12

Table 3.2 Properties of GGBFS

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Alkaline solutions available in market are Sodium based, Potassium based, and Calcium based. Alkaline solutions are used in the research work are sodium-based solutions and are of commercial grade. 14 M sodium Hydroxide was used, and 99% pure sodium silicate liquid was used. Sodium silicate to sodium hydroxide ratio was kept (SS/SH) 2.

Geopolymer mix design is done as shown below:

Table 3.3 Material Quantity Calculation For 6 Cubes Of 15 X 15 X 15 Cm for Specimen Of Compressive Strength

Mix no.	Ratio	Fly ash(kg)	GGBFS (kg)	Sodium silicate(kg)	Sodium hydroxide (kg)	Fine aggregate (kg)	Coarse aggregate (kg)
F1	100-0	7.623	-	1.7798	0.8899	15.73	29.546
G1	90-10	6.93	0.778	1.7798	0.8899	15.73	29.546
G2	85-15	6.545	1.115	1.7798	0.8899	15.73	29.546
G3	80-20	6.16	1.54	1.7798	0.8899	15.73	29.546
G4	75-25	5.775	1.925	1.7798	0.8899	15.73	29.546
G5	70-30	5.39	2.31	1.7798	0.8899	15.73	29.546

Quantity of Lime Based GPC:

Table 3.4 Material Quantity Calculation For 6 Cubes Of 15 X 15 X 15 Cm for Specimen of Compressive Strength

Mix. No.	Ratio (FA-GGBFS-Lime)	Fly ash (Kg)	GGBFS(Kg)	Lime (Kg)
L1	70-25-05	5.39	1.925	0.385
L2	70-20-10	5.39	1.54	0.77
L3	70-15-15	5.39	1.155	1.155
L4	70-10-20	5.39	0.77	1.54
L5	70-05-25	5.39	0.385	1.925
G5	70-0-30	5.39	2.31	0

Mixing of Concrete:

All the ingredients are measured accurately and mixed in dry state. The dry concrete mix is then thoroughly and uniformly mixed till uniform and homogeneous mixing in dry mix is observed. Alkaline solution (sodium hydroxide + sodium silicate) is weighed accurately in plastic bucket and is poured in dry mix and mixed thoroughly for 4-5 minutes. Addition of extra water is done according to need.

IV. RESULTS AND DISCUSSION

Compression Test Results:

Compressive strength testing was performed at the end of the curing period, which was 7 days for Geopolymer concrete cubes and 28 days for Geopolymer concrete cubes. Specimens were examined for compressive strength using UTM according to IS 9013. (1978).

Table 4.1 Compressive Strength Results

Compressive strength			
Mix No.	Ratio	7 days (N/mm2)	28 days (N/mm2)
C1	100 (% Cement)	19	23.27

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F1	100-0 (FA-GGBFS)	31.47	41.47
G1	90-10	20.13	31.54
G2	85-15	14.37	26.5
G3	80-20	20.4	29.51
G4	75-25	26.23	42.12
G5	70-30	31.31	45.75
L1	70-25-05(FA-GGBFS-Lime)	40.77	48.96
L2	70-20-10	38.86	45.49
L3	70-15-15	36.29	42.19
L4	70-10-20	21.58	37.55
L5	70-05-25	14.717	32.66
L6	70-0-30	6.43	27.07

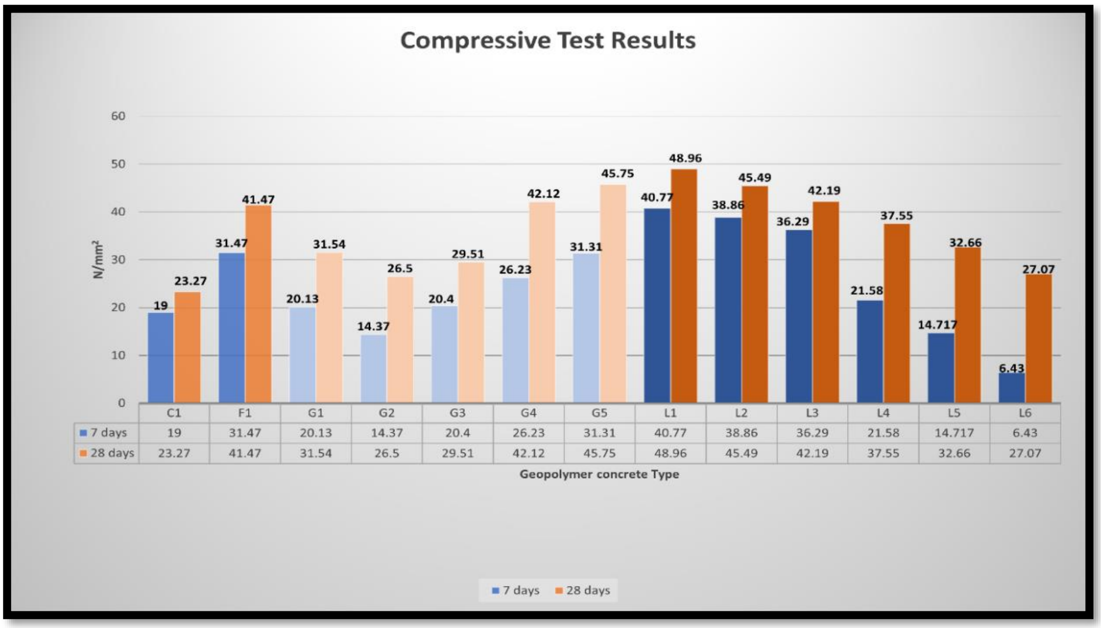

Fig 4.1 Compressive Test Results for 7 Days And 28 Days

Table 4.2 Compressive Test Results Comparison (Max.)

Compressive strength		
	7 DAYS(N/mm^2)	28 DAYS(N/mm^2)
CEMENT	19	23.27
Fly ash	31.47	41.47
Geopolymer (70-30)	31.31	45.75
Geo + lime (70-25-5)	40.77	48.96

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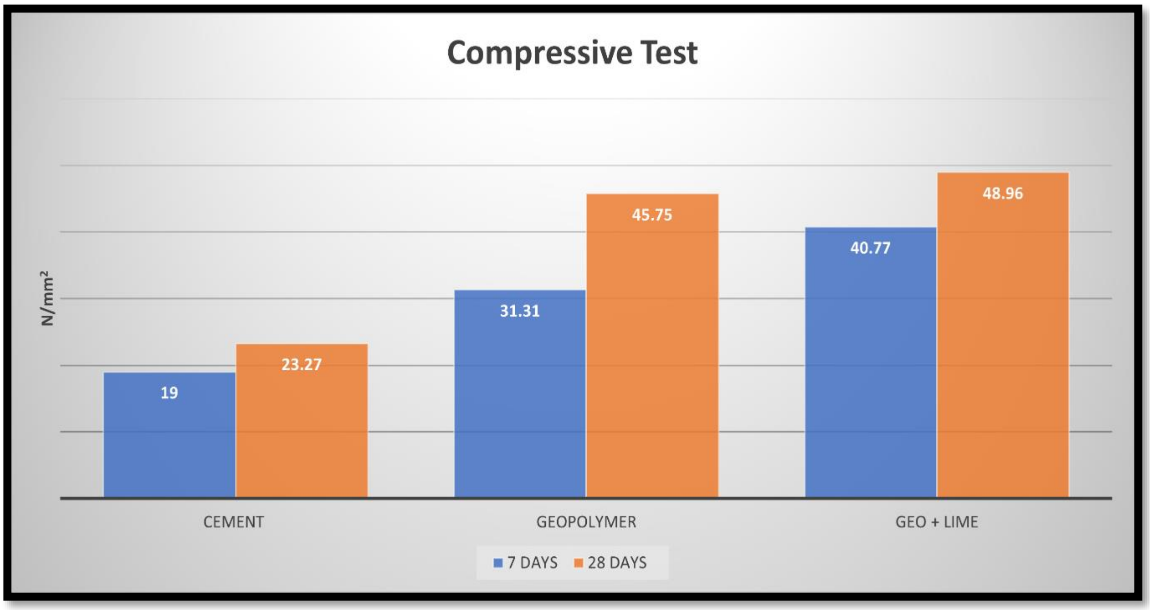

Fig. 4.2 Maximum Compressive Test Results for Different GPC

For each combination, the results are graphed in Fig. 4.2. The best compressive strength test results were obtained in mix L1, which was 40.77 N/mm2 for 7 days and 48.96 N/mm2 for 28 days, with the materials proportions of 70% FA, 25% GGBFS, and 5% Lime by weight. It has been discovered that the early strength growth in ambient cured geopolymer concrete is greater than that of ordinary Portland cement. And, in the case of lime-based ambient cured geopolymer concrete, the majority of the strength was gained in the first 7 days, after which there was little increase.

Furthermore, Geopolymer concrete increases strength by 39.31 percent and 49.13 percent after 7 days and 28 days, respectively. Whereas lime-based ambient cured geopolymer concrete increases strength by 53.39 percent and 52.47 percent above OPC after 7 days and 28 days, respectively.

Based on the table, we can conclude that increasing the GGBFS and likewise increasing the lime % in GPC reduces workability significantly. We also conclude that adding lime to the GGBFS up to 5% and 10% boosted the compressive strength effectively and increased the rate of strength gain in the early phases of construction.

Split Tensile Test Results:

Split tensile tests were performed on cylinders 15 cm in diameter and 30 cm in height. The bar chart in fig. 3.3 depicts the results graphically. As can be seen, the split tensile strength was lower when compared to ordinary Portland cement. Tensile strength in Fly ash and GGBFS-based ambient cured concrete was reduced by 10.41 percent and 15.72 percent for 7 days and 28 days, respectively, according to the table. Furthermore, the split tensile strength of the Lime-based GPC was reduced by 0.27 percent and 0.35 percent after 7 days and 28 days, respectively, which is negligible.

Table 4.3 Split Tensile Test Results

	7 Days	28 Days
	(KN/mm^2)	(KN/mm^2)
Cement	1.51294	1.98357
Geopolymer	1.37024	1.55486
Geo + Lime	1.30738	1.45975

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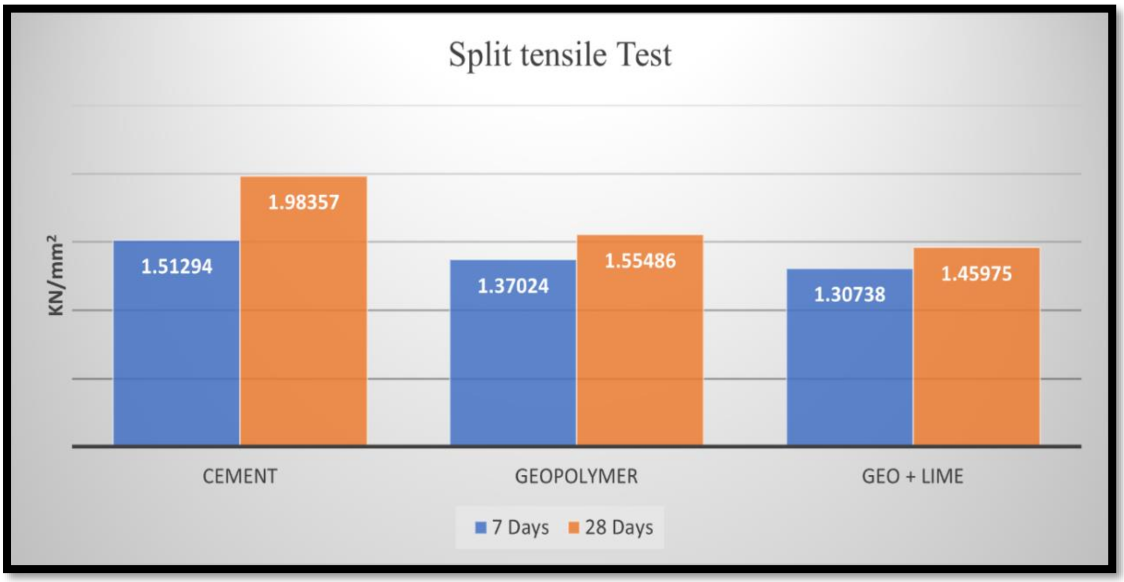

Fig. 4.3 Split Tensile Strength Tests Results

Flexural Test Results:
Flexural Strength indicates one of the measures of tensile strength of concrete. Flexural Strength test is conducted on beam specimens As GPC early strength gain capacity 7 days flexural strength was also tested. As given below,

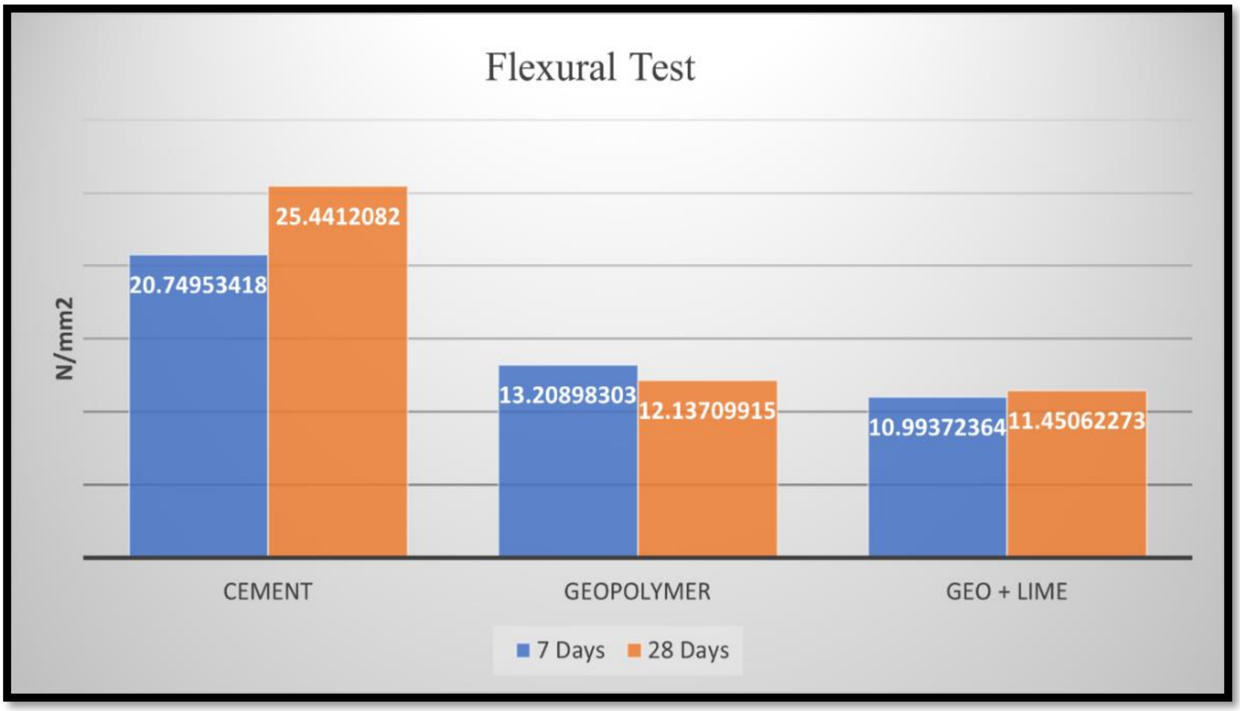

Fig. 4.4 Bar Chart for Flexural Tests Results

Table 4.4 Flexural Strength Tests Results for 7 Days and 28 Days

Split Tensile Test Results		
	7 Days	28 Days
	(N/mm^2)	(N/mm^2)
Cement	20.74953	25.44121
Geopolymer	13.20898	12.1371
Geo + Lime	10.99372	11.45062

Tables 3.4 illustrate the experimental outcomes for 7 and 28 days, respectively. The flexural strength of FA and GGBFS-based GPC is significantly lower than that of OPC, and it was further lowered as partial replacement GGBFS to lime-based GPC. Flexural strength was reduced by 57 percent and 109.61 percent for the FA and GGBFS-based GPCs, respectively. In the lime-based GPC, the flexural strength was reduced by 88.80 percent and 122.18 percent after 7 days and 28 days, respectively. So, whether regular GPC or lime-based GPC flexural strength has been significantly lowered, it is still significantly less than OPC flexural strength.

V. CONCLUSION

Based on the results of the experiments, the following conclusions can be drawn:

- GGBFS improved the properties of FA and GGBFS-based geopolymer concrete. The compressive strength is rapidly increasing as the GGBFS by weight percentage increases. However, it has been shown that increasing the amount of Ground Granulated Blast Furnace Slag (GGBFS) increases strength while sacrificing workability.
- However, it has been shown that increasing the amount of Ground Granulated Blast Furnace Slag (GGBFS) increases strength while sacrificing workability. Geopolymer concrete has been discovered to be exceedingly sticky, dark grey in colour, and denser than OPC.
- When comparing split tensile strength to OPC, there is no significant difference. Although there isn't much of an increase in Flexural Strength, GPC could be a fantastic option in the near future.
- After adding lime to Geopolymer concrete as a partial substitute for GGBFS, the workability and harshness of the concrete are reduced, but the compressive strength is much boosted.
- The compressive strength has risen by 5% to 10% when GGBFS is replaced with lime. Further lime addition reduced compressive strength. However, lime based Geopolymer concrete has the ability to build strength at an early stage and has a very promising future.
- However, lime added geopolymer concrete has no significant modifications in its split tensile strength capability, but it has further decreased its flexural strength capacity.

VI. FUTURE SCOPE

Infrastructure development is accelerating. It has a considerable impact on the amount of available construction space. To manage global warming, humanity must seek alternative materials to cement in terms of carbon dioxide reduction. In the future, GGBS could be used instead of cement to manufacture geopolymer concrete. In addition, when considering partial replacement in the construction of geopolymer concrete, lime concentration is an important issue. Further research is required in the future because the GGBFS has an advantage because to the ease of availability of lime.

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REFERENCES

[1]. Wallah, S.E., Hardjito, D.S.D.M.J., R.B.V.,2005. Performance of fly ash-based geopolymer concrete under sulphate and acid exposure’. Geopolymer Proc 153-156.

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DOI: 10.17148/IARJSET.2022.9476

[2]. Duxson, P., et al., 2007b. Geopolymer technology: the current state of the art, Journal of Material Science. 42, 2917 - 2933.

[3]. Fareed, Fadhil, Nasir, M., 2011. Compressive strength and workability characteristics of low-calcium fly ash-based self-compacting geopolymer concrete. International Journal of Civil, Environ. Struct. Constr. Archit.

[4]. Pradip Nath , Pradip kumar sarkar (2014), " Effect of GGBFS on setting time, workability and early strength properties of fly ash geopolymer concrete cured in ambient condition" construction and building materials, 66 (2014) 163 – 171.

[5]. B. Singh., ishwarya g., m. Gupta and s.k. Bhattacharyya. (2015), "geopolymer concrete: a review of some recent developments", construction and building materials, vol.85, pp.78– 90.

[6]. LI Hui and XU Delong, "The Future Resources for Eco-building Materials: II. Fly ash and coal waste". Journal of Wuhan University of Technology, 2009. vol. 24, No.4.FLEXChip Signal Processor (MC68175/D), Motorola, 1996.

[7]. Djwantoro Hardjito, Steenie E. Wallah, Dody M. J. Sumajouw and B. Vijaya Rangan, "Fly ash based Geopolymer Concrete", Australian Journal of Structural Engineering, 2005, Vol. 6, No.1, pp

[8]. Djwantoro Hardjito, Steenie E. Wallah, Dody M. J. Sumajouw and B. Vijaya Rangan, "Fly ash based Geopolymer Concrete", Australian Journal of Structural Engineering, 2005, Vol. 6, No.1, pp.

[9]. Manjunatha G. S., Radhakrishna, Varuna Koti & Venugopala K, "Strength and Durability Performance of Open Air Cured Alkali Activated Concrete", Journal of Civil Engineering Technology and Research Volume 2, Number 1 (2014), pp.147-157

[10]. Davidovits. J, "Ancient and modern concretes: what is the real difference?" Concrete International: Design and Construction, 1987, Vol.9, No. 12, pp.23-35.

[11]. Hardjito, D. and Rangan, B.V. "Development and Properties of low Calcium Fly ash based Geopolymer Concrete-Research Report GC1", 2005, Curtin University of Technology, Australia.

[12]. Radhakrishna, "Development of Methods for Re-proportioning of Fly ash-based Composites", Doctoral Thesis, 2009, Visvesvaraya Technological University, India.

[13]. LI Hui and XU Delong, "The Future Resources for Eco-building Materials: II. Fly ash and coal waste". Journal of Wuhan University of Technology, 2009. vol. 24, No.4.

[14]. Xiaolu Guo, Huisheng Shi and Warren A. Dick, "Compressive strength and microstructural characteristics of class C fly ash geopolymer. " Cement and Concrete Composites, 2010, 32,Vpp. 142- 147.