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# Assessment of Mechanical Characteristics Of Fly Ash, Microsilica & Steel Fibre Based One Part Geopolymer Concrete

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**ABSTRACT:** Production of ordinary Portland cement (OPC) is a carbon-intensive process that generates significant amounts of carbon dioxide (CO<sub>2</sub>) gas from the combustion of fossil fuels and thermal decomposition of limestone. Overall, cement industries are responsible for around 7 % of global CO<sub>2</sub> emissions which poses a considerable threat to global climate change because of its greenhouse effects. The recent advent of geopolymer shows great potential to reduce carbon footprints by utilizing the industrial by-products, such as fly ash and ground granulated blast furnace slag (GGBS) and convert into a binding material. Generally, geopolymer binders are made using aluminosilicate compounds (fly ash and or GGBS) and an alkali activator (combination of sodium silicate and sodium hydroxide solution). Despite having superior engineering properties to conventional OPC concrete, geopolymer concrete has not been widely adopted in concrete industry so far. The safety hazards in mixing and handling geopolymer concrete posed by sodium hydroxide was one of the barriers to the adaptation of geopolymer concrete. Replacing liquid sodium hydroxide with less hazardous alkali materials, such as soda ash not only makes the geopolymer binder less hazardous and easier for mixing and handling process but also makes it more environmentally sustainable because of its lower embodied energy compared to sodium hydroxide. This study investigates the environmental sustainability of structural grade of geopolymer concrete and compares the results with GPC concrete of same strength grade. This study also investigates comparisons between geopolymer concrete tests and US GPC tests results

**KEYWORDS:** Geopolymer(GPC), Sustainable, Steel Fibres, Mechanical characteristics, Microsilica, Fly ash.

## I. INTRODUCTION

Concrete is the most widely used material next to water, and its production dates back to ancient Egyptian and Roman societies. The worldwide production of Portland cement contributes to 5–7% of global carbon dioxide (CO<sub>2</sub>) emission due to burning of fossil fuels during calcinations of limestone which is creating a serious environmental threat. Hence, cement does not satisfy the criteria of being a sustainable material and construction industries need substitute cementitious products to meet the demands of rapid infrastructure growth. Joseph Davidovits, a French scientist, coined the term ‘Geopolymer’ in 1978 and described the process of Geopolymerization that produced compounds having cementitious properties. To reduce cement consumption and thereby limiting the carbon footprint is paramount. To this end, to replace cement in concrete production, industrial byproducts such as fly ash, ground granulated blastfurnace slag (GGBS), fumed silica can be used. Adding these supplementary cementitious materials can reduce reducing the emission of carbon dioxide into the atm.

## II. RELATED WORK

Kolli.Ramujee (2017),[1] their study, the regression model analysis was carried out to study the relationship between the Compressive strength and Split tensile strength and It was found that the mechanical behaviour of GPC is similar to that of ordinary Portland cement (OPC) concrete. In this experimental work, fly ash is used as the source material to make geopolymer paste as the binder, to produce concrete. The role and influence of aggregates are considered to be same as in the Portland cement concrete. The mass of combined aggregates may be taken to be between 75% and 80% of the mass of the Geopolymer concrete. The mix proportions for Geopolymer concretes of three grades namely G20, G40 & G60 were arrived based on the trial mixes carried out by the author in the laboratory and for control mix the corresponding grades were taken in equivalent mix proportions of Geopolymer concrete. Based

on the applicability evaluation empirical reactions to GPC and the regression analysis on experimental data and mechanical properties of GPC [2] Jena, et al. (2019), their study stated that fresh density of all the specimens of different mixes was higher than that of the hardened concrete. This is only due to excess water available in the specimen. The hardened densities of GPS5, GPS10 and GPS15 are 0.9%, 3.15% and 4.5% lower than that of GPS0. The fresh densities of GPS5, GPS10 and GPS15 are 1.4%, 2.6% and 4.8% lower than the GPS0. Slump value of GPS5 was decreased 33% than that of the control mix at constant water-to-binder ratio. Further, the slump value of GPS10 and GPS15 was increased 14% and 47%, respectively due to the addition of extra water of 10 kg/m<sup>3</sup>. Split tensile and flexural strength of GPS5 were 30% and 33.7% higher than that of the control mix, respectively. [3] Mandal, et al. (2019), aimed to enhance strength and durability performance of fly ash based process modified geopolymer concrete. An 8M NaOH solution was mixed with Na<sub>2</sub>SiO<sub>3</sub> in the proportion of 1:1.75 (by weight) to prepare the activator fluid for both process modified GPC and conventional heat cured GPC. The low calcium fly ash based process modified geopolymer concrete cured at ambient temperature after casting shows improved mechanical strength and durability than conventional heat cured GPC and OPC concrete. [4] Hassan, et al. (2019), aimed to Use of geopolymer concrete for a cleaner and sustainable environment – A review of mechanical properties and microstructure. and stated that, the past researches on GPC show that it can be suitable for the structural applications, with a workable slump, and comparable grade of strength to ordinary Portland cement concrete. The development of a standard code for GPC is still in the experimental stage. the development of the mix proportion of GPC is more difficult due to a range of parameters being involved in the matrix of geopolymer concrete [5] Rao, et al. (2020), studied Ground granulated blast furnace slag (GGBFS) was blended with fly ash (FA) to form binder content (B) and combined at different ratios with a solution of various alkaline activators (ALA) to make Geopolymer concrete (GPC). The ALA solution consisted of a mixture of sodium silicate (Na<sub>2</sub>SiO<sub>3</sub>) and sodium hydroxide (NaOH), with a stable NaOH concentration of 12 M and 14 M (Molarities) and a Na<sub>2</sub>SiO<sub>3</sub>/NaOH mass ratio from 2.5 to 3.5. The GPC mixes were prepared with different ALA/B ratios (0.3, 0.35 and 0.40). All of the mixes were cured under ambient conditions. To analyses, the impact of the ALA/B ratio on the GPC, the compressive, flexural strength and splitting tensile strengths of hardened GPC were investigated at the ages of 7, 28 and 90 days. The experimental results showed that varying the ALA/B ratio had an influence on the compressive strength of GPC. The Compressive strength was higher at an ALA/B ratio of 0.4 than at both higher and lower ratios. At this optimum ALA/B ratio, the compressive strength of up to 64.13 N/mm<sup>2</sup> was recorded at 90 days. [6] Murugan et al. (2020), aimed to understand the effect of alccofine as ternary binder in Geopolymer concrete at low molarities of NaOH based alkaline solution under ambient temperature curing. They are also focused on to enhanced the mechanical properties of GPC by comparing of OPC they were considered following factors in their mix design of GPC Alkaline to binder 0.4, water to binder by under 0.18 and Na<sub>2</sub>SiO<sub>3</sub> NaOH 2.5, and alkaline solution should be prepared at least 24 hour before mixing in the concrete molarities of NaOH are 0.5, 1, 2 and 3 in all the placement levels of fly ash with all alccofine i.e.5%, 10% and 15 %.

### III. PROPOSED ALGORITHM

Mix design:

1. Parameters consider for mix propositioning of geopolymer concrete for the development of fly ash base Geopolymer concrete make design method detailed investigation have been carried out and following parameters where selected on the basis of a capability and compressive strength.
2. Preparation of polymer concrete mixes preparation of Geo polymer concrete is similar to that of cement concrete course aggregate sand and fly ash where mix indrasted then add prepared mixture solution of sodium hydroxide and sodium silicate along with extra water based on water to geopolymer binder ratio and mix thoroughly 3- 4 minutes so as to give homogeneous mix it was found that the fresh fly ash based concrete was viscous, cohesive and dark in colour

- **SIEVEANALYSIS INSAND Required apparatus**

**Observations and Calculations-**

WEIGHT OF SAMPLE (GM): -



**Table-1: Measurements for Sieve analysis Test**

ISSieveSize	Wt.ofSample retained(gm)	Individual%wt. Retained(gm)	Cumulative %wt. Retained	%Passing
4.75mm	2025	19.87	99.3	0.6
2.36mm	70	70	3.5	96.5
1.18mm	98	168	8.4	91.6
600mic	6560	1153.5	57.68	42.33
300mic	726.5	1880	94	6
150mic	95	1975	98.75	1.25
PanTot	25	2000	100	0

**4.3 DETERMINATION OF WATER ABSORPTION OF COARSE AGGREGATE**

Observations and calculations–

**Table -2: Measurements for water absorption of Coarse aggregate Test**

Sr.no	Particular	Coarse Aggregate Sample (Gm)		
		1	2	3
1	Weight of surface saturated dry sample in water w1	1560	1555	1570.3
2	Weight of surface saturated dry sample in air w2	2440.7	2432.5	2440
3	Weight of oven dry sample aggregate in air w3	2439.4	2430	2434.6
4	Specific gravity of coarse aggregate	2.76	2.77	2.79
5	Water absorption of coarse aggregate	0.05	0.10	0.22

**Result–**

Average water absorption of coarse aggregate of 12.5mm is 0.12%.

average specific gravity of coarse aggregate of coarse aggregate of 12.5mm is 2.76.

**DETERMINATION OF IMPACT VALUE OF AGGREGATE**

Observations and Calculations–

**Table -3: Determination of Impact value**

Sr. No.	Particular	Samples (Gm)		
		1	2	3
1	Wt. of oven dry sample (W1)	660	630	630
2	Wt. of fraction passing through IS.2.36mm sieve (W2)	10	30	20



3	Wt. of fraction retained on IS 2.36mm Sieve (W3)	650	600	610
4	Aggregate impact value of coarse aggregate (%) [W2/W1x100]	1.51	4.76	3.17

The average Aggregate impact value of coarse aggregate is 3.14%

**IV. SIMULATION RESULTS**

**WORKABILITY TEST (SLUMP CONE TEST)**

WORKABILITY OF CONCRETE IS A BROAD AND SUBJECTIVE TERM DESCRIBING HOW EASILY FRESHLY MIXED CONCRETE CAN BE MIXED, PLACED, CONSOLIDATED, AND FINISHED WITH MINIMAL LOSS OF

OBSERVATIONS AND CALCULATIONS -

**TABLE -4: WORKABILITY**

FLY ASH	NORMAL GPC	ULTRA SAFE GPC	SLUMP
50%	✓		120
50%		✓	90
50%		✓	95
70%	✓		120
70%		✓	105
70%		✓	95
80%	✓		120
80%		✓	100
80%		✓	100
95%	✓		120
95%		✓	90
95%		✓	90
100%	✓		120

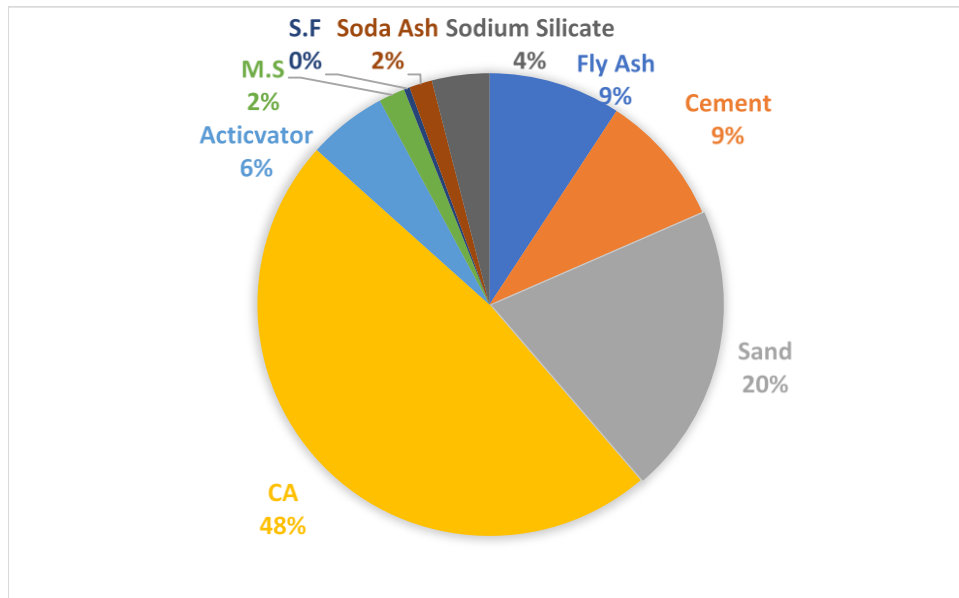


- COMPRESSIVESTRENGTHTEST

Table-5:Average Compressive Strength

Sr. No	Fly Ash	NaOH	Na2CO3	Soda Ash	Normal GPC	Ultra Safe GPC	Prop1	Prop2	Compressive Strength in MPA		
									7 Days	14 Days	28 Days
1	50%	Yes			Yes				21.33	28.23	28.53
2	50%		Yes			Yes	Yes		21.69	28.44	28.74
3	50%			Yes		Yes		Yes	22.44	28.56	28.89
4	70%		Yes		Yes				6.66	7.998	8.88
5	70%			Yes		Yes	Yes		6.666	7.2	8.91
6	70%			Yes		Yes		Yes	9.768	12.438	13.56
7	80%	Yes			Yes				13.328	13.44	15.639
8	80%			Yes		Yes	Yes		10.5	10.74	11.76
9	80%			Yes		Yes		Yes	11.4	11.607	12.57
10	95%	Yes			Yes				3	3.63	4.08
11	95%			Yes		Yes	Yes		3.6	4.08	4.74
12	95%			Yes		Yes		Yes	4.2	10.5	10.836
13	100%	Yes			Yes				0.3	0.3	0.3

## 6. Compressive strength Results ( Pie Chart)



Quantities For 3 Cubes of 50% Flyash

Above pie chart shows detailed about 50% fly ash cubes specimen.

## V. CONCLUSION

1. The collective results of the study of various experiments Shows that the stress imposed on 50% flyash concrete cube was (the value for prop 1 and prop 2) almost to 100% as satisfactory results and therefore more detailed study can be carried to improve its strength and other mechanical properties
2. Using US-GPC with replacement to Cement at 50% gives the satisfactory results with highest possible strength comparing to on field 30% replacement with actual trials of 95%, 80%, 70%, 50% replacement of cement in this project.
3. Sodium Carbonate powder was replaced with Soda Ash because it has Crystalizing molecules in its structure causing solution to get solid a day prior to casting.
4. Sodium Carbonate cannot be used even before 15 mins of casting because it has high heat of hydration when mixed with sodium which causes absorption of more water than its water content limit.

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