MECHANICAL PROPERTIES OF GEOPOLYMER CONCRETE USING GRANITE SLURRY AS SAND REPLACEMENT

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ABSTRACT

The present investigation aims at studying the mechanical properties of geopolymer concrete (GPC) using granite slurry (GS) as sand replacement. In this study, GS was replaced at different replacement levels (0%, 20%, 40% and 60%). Fly ash and ground granulated blast furnace slag (GGBS) were used at 50:50 ratio as geopolymer binders. Combination of sodium hydroxide (8M) and sodium silicate solution is used as an alkaline activator. Compressive strength and splitting tensile strength properties were studied after 7, 28 and 90 days of curing at ambient room temperature. From the results, it is revealed that the studied mechanical properties were increased with the increasing replacement level of GS up to 40% and decreasing trend of these properties were observed at 60% replacement level. It is concluded that optimum replacement level (40%) of GS can be used in place of sand and can save the natural resources.

KEYWORDS: *Geopolymer concrete, granite slurry, compressive strength, splitting tensile strength.*

I. INTRODUCTION

It is widely known that the production of Portland cement consumes considerable energy and at the same time contributes a large volume of CO_2 to the atmosphere [1]. The cement industry is held responsible for some of the CO_2 emissions, because the production of one ton of Portland cement emits approximately one ton of CO_2 into the atmosphere [2].However, Portland cement is still the main binder in concrete construction prompting a search for more environmentally friendly materials. Several efforts are in progress to supplement the use of Portland cement in concrete in order to address the global warming issues. These include the utilization of supplementary cementing materials such as fly ash, silica fume, granulated blast furnace slag, rice-husk ash and metakaolin [3,4], and the development of alternative binders to Portland cement.

One possible alternative is the use of alkali-activated binder using industrial by-products containing silicate materials. In 1978, Davidovits (1999) proposed that binders could be produced by a polymeric reaction of alkaline liquids with the silicon and the aluminium in source materials of geological origin or by-product materials such as fly ash, GGBS and rice husk ash [5]. He termed these binders as geopolymers. The most common industrial by-products used as binder materials are fly ash (FA) and ground granulated blast furnace slag (GGBS) [5].

1.1. Research Significance

In this investigation an attempt has made to study the mechanical properties of geopolymer concrete by replacing the fine aggregate using granite slurry at different levels (0%, 20%, 40% and 60%). This study is focused on the compressive strength and splitting tensile strength properties of GPC at different curing periods at ambient room temperature.

1.2. Outline of this paper

This paper includes material and test methods to find out strength properties such as compression, split tensile strength, results and discussions.

II. Materials And Methods

2.1. Fly ash

In this investigation, Class F (low calcium) fly ash produced from Rayalaseema Thermal Power Plant (RTPP), Muddanur, A.P is used as an additive according to ASTM C 618 [6]. As per IS-456(2000) [7], cement is replaced by 35% of fly ash by weight of cementitious material. The specific gravity of fly ash is 2.24.The chemical and physical properties are presented in the Table 2.1

2.2. Ground granulated blast furnace slag

GGBS collected from Astrra chemicals, chennai was used in the manufacturing of GPC. The specific gravity of GGBS is 2.86. The chemical and physical properties are presented in the Table 2.1

Table 2.1. Chemical and Physical Properties of Class F Fly Ash and GGBS

Particulars	Class "F" fly ash	ASTM C 618 Class "F" fly ash	GGBS
Chemical composition			
% Silica(SiO_2)	65.6		30.61
% Alumina(Al_2O_3)	28.0		16.24
% Iron Oxide(Fe_2O_3)	3.0	SiO_2+ Al_2O_3+ Fe_2O_3>70	0.584
% Lime(CaO)	1.0		34.48
% Magnesia(MgO)	1.0		6.79
% Titanium Oxide (TiO_2)	0.5		-
% Sulphur Trioxide (SO_3)	0.2	Max. 5.0	1.85
Loss on Ignition	0.29	Max. 6.0	2.1
Physical properties			
Specific gravity	2.24		2.86
Fineness (m^2/Kg)	360	Min.225 m^2/kg	400

2.3. Coarse aggregate

Crushed granite stones of size 20mm and 10mm are used as coarse aggregate. As per IS: 2386 (Part III)-1963 [8], the bulk specific gravity in oven dry condition and water absorption of the coarse aggregate are 2.58 and 0.3% respectively [8]. The fineness modulus of 20mm and 10mm coarse aggregates are 3.35 and 1.89.

2.4. Fine aggregate

2.4.1. Sand

Natural river sand is used as fine aggregate. As per IS: 2386 (Part III)-1963 [8], the bulk specific gravity in oven dry condition and water absorption of the sand are 2.62 and 1% respectively [8]. The fineness modulus of sand is 2.59.

2.4.2. Granite slurry

Granite slurry is used as secondary material of fine aggregate and which is collected from granite cutting industry. As per IS: 2386 (Part III)-1963 [8], the bulk specific gravity in oven dry condition and water absorption of the fine aggregate are 2.84 and 1.2% respectively [8].

The gradation of the fine aggregates was determined by sieve analysis as per IS code [9] and presented in the Table 2.2 & 2.3. The grading curve of the fine aggregate as per IS code [9] is shown in Fig. 2.1&2.2

Table 2.2. Sieve analysis of Fine aggregate (Sand)

S.No	Sieve No/ size	Weight retained (gm)	Percentage weight retained	Cumulative percentage weight retained	Cumulative percent passing	
					Fine aggregate	IS 383 (1970) – Zone II requirement
1	3/8" (10mm)	0	0	0	100	100
2	No.4 (4.75mm)	12	1.2	1.2	98.8	90-100
3	No.8 (2.36mm)	35	3.5	4.7	95.3	75-100
4	No.16 (1.18mm)	135	13.5	18.2	81.8	55-90
5	No.30 (600µm)	366	36.6	54.8	45.2	35-59
6	No.50 (300µm)	290	29.0	83.8	16.2	8-30
7	No.100 (150µm)	132	13.2	97.0	3.0	0-10

Table 2.3. Sieve analysis of granite slurry

S.No	Sieve No/ size	Weight retained (gm)	Percentage weight retained	Cumulative percentage weight retained	Cumulative percent passing	
					Fine aggregate	IS 383 (1970) – Zone II requirement
1	3/8" (10mm)	0	0	0	100	100
2	No.4 (4.75mm)	0	0	0	100	90-100
3	No.8 (2.36mm)	0	0	0	100	75-100
4	No.16 (1.18mm)	153	15.3	15.3	84.7	55-90
5	No.30 (600µm)	267	26.7	42.0	58	35-59
6	No.50 (300µm)	289	28.9	70.9	29.1	8-30
7	No.100 (150µm)	208	20.8	91.7	8.3	0-10

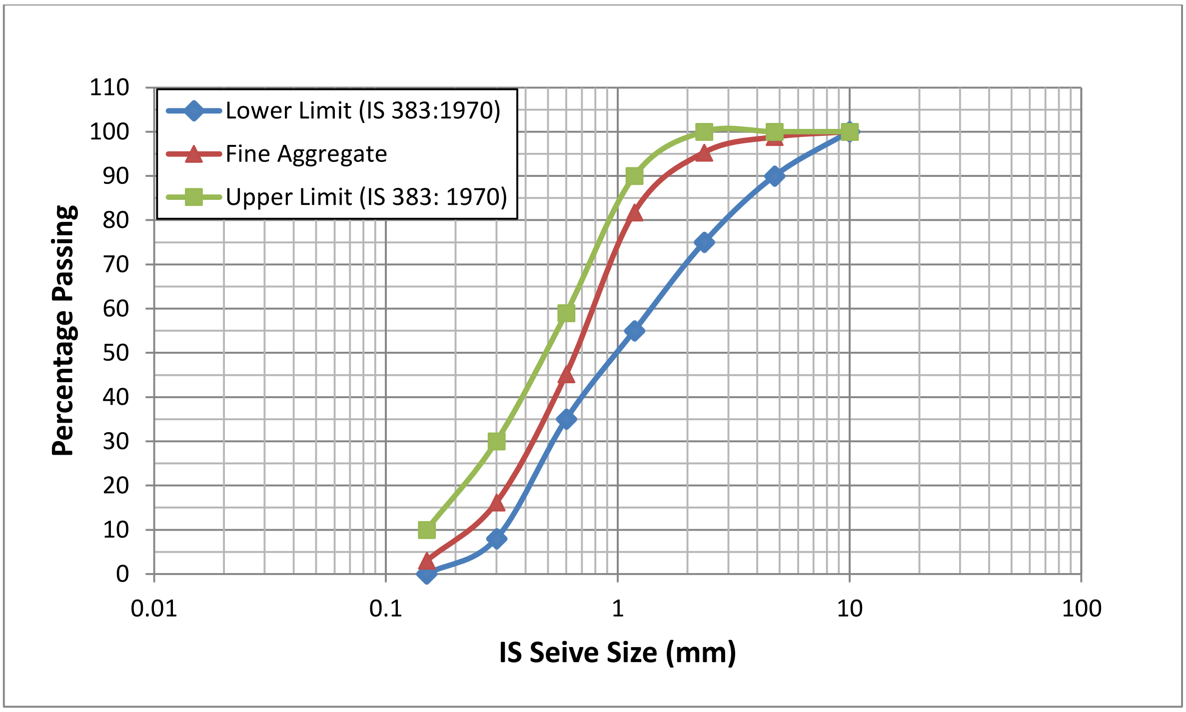

Fig. 2.1. Grading curve of fine aggregate(Sand)

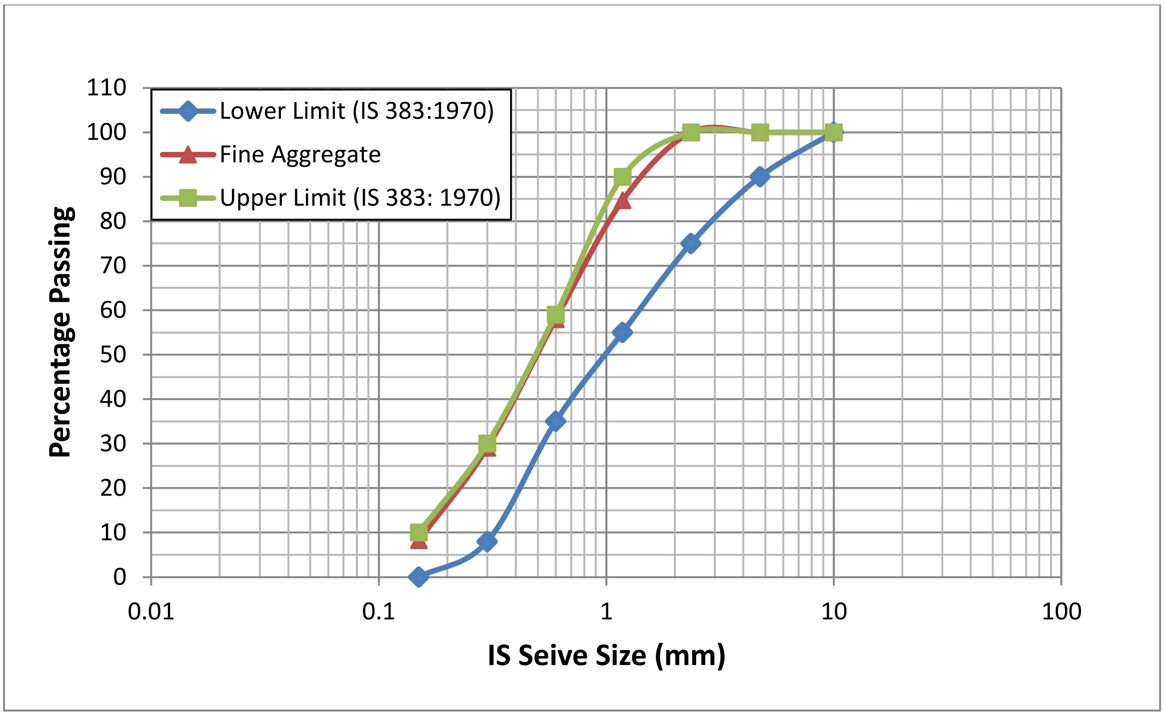

Fig. 2.2. Grading curve of granite slurry

2.5 Alkaline Liquid

The alkaline liquid used was a combination of sodium silicate solution and sodium hydroxide solution [10]. The sodium silicate solution (Na2O= 13.7%, SiO2=29.4%, and water=55.9% by mass) and sodium hydroxide (NaOH) in flakes or pellets from with 97%-98% purity and it was purchased from a Astrra chemicals, Chennai.

2.6. Mixture Proportions

Based on the limited past research on GPC (Hardjito & Rangan, 2005), the following proportions were selected for the constituents of the mixtures[5].In the design of geopolymer concrete mix, coarse and fine aggregates together were taken as 77% of entire mixture by mass[11]. Fine aggregate was taken as 30% of the total aggregates. The density of geopolymer concrete is taken similar to that of OPC as 2400 kg/m^3 (Rangan, 2008) [5]. The Class F fly ash and GGBS were taken as 50-50% and the Molarity of sodium hydroxide solution was kept at 8M. The details of mix design and its proportions for different mixes of GPC are given in Table 2.4.

Table 2.4. GPC Mix Proportions

Materials		Mass (kg/m³)			
		100% Sand	20% GS + 80% Sand	40% GS + 60% Sand	60% GS + 40% Sand
Coarse aggregate	20 mm	774	774	774	774
	10 mm	516	516	516	516
Fine aggregate	Sand	549	439.2	329.4	219.6
	GS	0	109.8	219.6	329.4
Fly ash (Class F)		204.5	204.5	204.5	204.5
GGBS		204.5	204.5	204.5	204.5
Sodium silicate solution		102	102	102	102
Sodium hydroxide solution		41 (8M)	41 (8M)	41 (8M)	41 (8M)
Extra water		55	55	55	55
Alkaline solution/ (FA+GGBS) (by weight)		0.35	0.35	0.35	0.35
Water/ geopolymer solids (by weight)		0.29	0.29	0.29	0.29

2.7. Preparation of test specimen

The sodium hydroxide flakes or pellets were dissolved in water to make a solution with a desired concentration at least one day prior to use [12]. The mixture of fly ash, GGBS and the aggregates were first mixed together about three to four minutes. After that the sodium hydroxide and the sodium silicate solutions were mixed together with super plasticizer and the extra water and then added to the dry materials and mixed for about few minutes. After mixing the fresh concrete was cast into the mould. The specimens were compacted with three layers of placing and tamping using a rod [12]. This was followed by an additional vibration of 10 seconds using a vibrating table. After that the specimens were stored for 24 hours, then demoulded and kept in open until the day of testing.

2.8. Test methods

The mechanical properties of the geopolymer concrete are evaluated by using Compressive strength test and split tensile test. The Compressive strength test [13,14] and Split tensile test [15,16] of all specimens were evaluated by using respective codes. These samples were tested at 7, 28 and 90 days of curing at ambient room temperature.

III. RESULTS AND DISCUSSION

3.1. Compressive strength

Compressive strength values of GPC mixes (100% Sand, 20% GS+ 80% Sand, 40% GS + 60% Sand, 60% GS + 40% Sand) at different curing periods are shown in Table 3.1 and Fig. 3.1.

Table 3.1. Mechanical properties of GPC (Compressive strength)

Mechanical property	Age (days)	Mix type			
		100% SAND	20% GS + 80% SAND	40% GS + 60% SAND	60% GS + 40% SAND
Compressive strength, *f'*c (MPa)	7	29.08	31.97	33.97	22.39
	28	45.87	48.07	51.14	33.63
	90	53.53	57.02	59.93	38.55

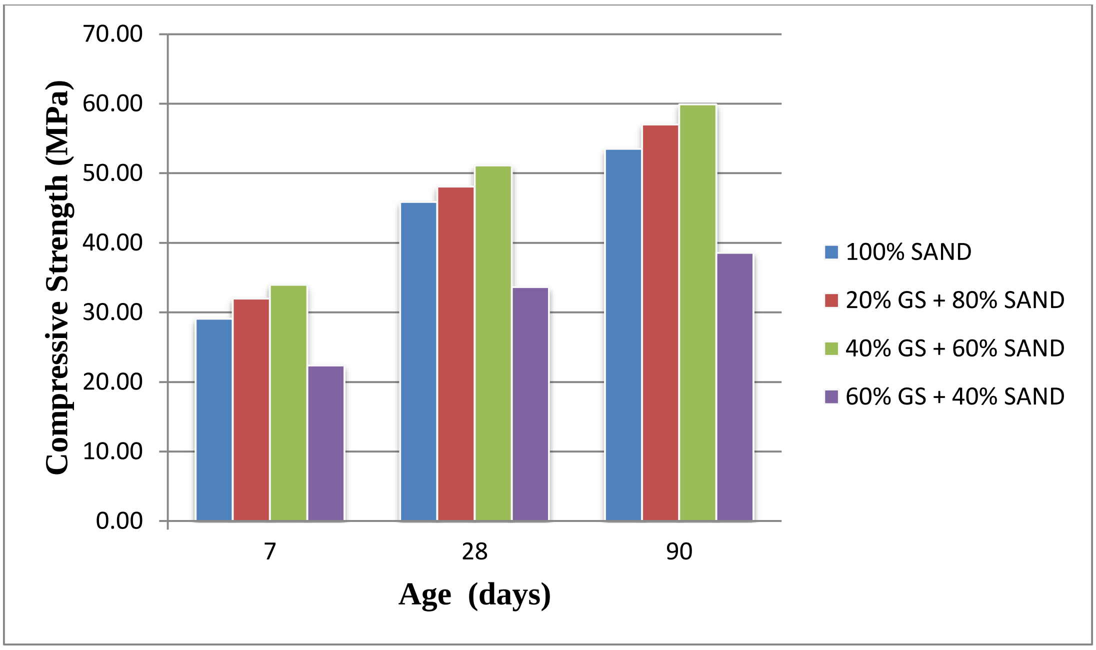

Fig 3.1. Compressive strength versus Age

From the results, it is observed that compressive strength values of GPC mixes were increased with the increasing replacement levels of GS from 20% to 40% at all ages as in the case of 20%GS+80%SAND and 40%GS+80%SAND. But these values were decreased at the 60% replacement level of GS as shown in Fig.3.1.

3.2. Split tensile strength

Split tensile strength values of GPC mixes (100% Sand, 20% GS+ 80% Sand, 40% GS + 60% Sand, 60% GS + 40% Sand) at different curing periods are shown in Table 3.2 and Fig. 3.2.

Table 3.2 Mechanical properties of GPC (Split tensile strength)

Mechanical property	Age (days)	Mix type			
		100% SAND	20% GS + 80% SAND	40% GS + 60% SAND	60% GS + 40% SAND
Splitting tensile strength, fct (MPa)	7	1.89	1.91	2.06	1.27
	28	2.89	3.03	3.31	1.65
	90	3.01	3.16	3.44	1.89

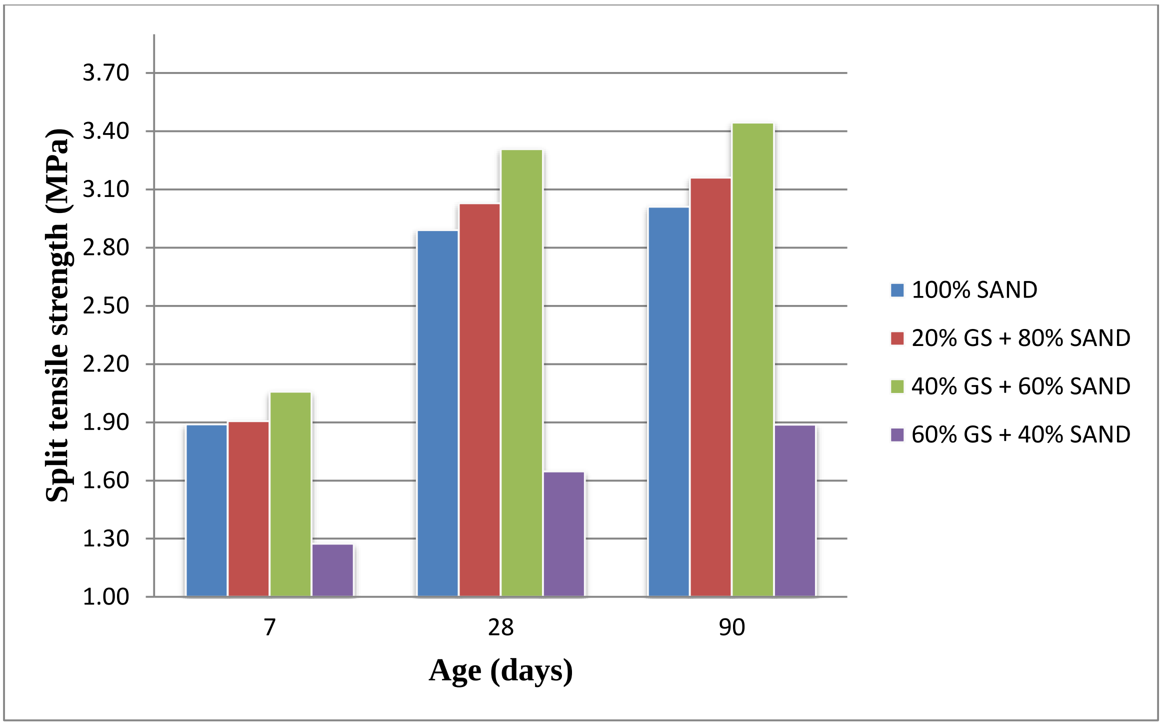

Fig 3.2. Split tensile strength versus Age

From the results, it is observed that splitting tensile strength values of GPC mixes were increased with the increasing replacement levels of GS from 20% to 40% at all ages as in the case of 20%GS+80%SAND and 40%GS+80%SAND. This is due to the increase in compressive strength. But these values were decreased at the 60% replacement level of GS as shown in Fig. 3.2.

IV. Conclusions

Based on the results presented in this investigation the following important conclusions may be observed.

1. It is observed that an increasing trend has been observed in compressive strength of GPC mixes up to 40% replacement level of GS.
2. It is observed that an increasing trend has been observed in splitting tensile strength of GPC mixes up to 40% replacement level of GS.
3. Both the mechanical properties have got falling trend at 60% of replacement level of GS.
4. It is concluded that 40% replacement level of GS can be considered as optimum replacement level of GS.

V. Scope for Future Works

From the available literatures on Geopolymer concrete and based on the findings in this research, following works are suggested for further research.

1. Study on the addition of various concentration of molarity on Geopolymer concrete and their effect on enhancement of strengths.
2. Achieving ultra high strength of Geopolymer concrete by the addition of silica fume, quartz sand and quartz powder.
3. Investigate on the effect of varying percentage of industrial by products like palm oil fuel ash, bottom ash, rice husk ash on strength properties of Geopolymer concrete.

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