Mechanical Properties of Geopolymer Concrete Incorporating Copper Slag as Fine Aggregate

B. Mounika[1] C. Sreenivasulu[2] J. Guru Jawahar[3] K. Narasimhulu[4]
[1]PG Student [2]Assistant Professor [3,4]Professor
[1,2,3,4]Department of Civil Engineering
[1,2,3,4]Annamacharya Institute of Technology & Sciences, Andhra Pradesh India

Abstract— The present paper mainly focused on mechanical properties of geopolymer concrete (GPC) incorporating copper slag (CS) as fine aggregate. In this study, CS was replaced at different replacement levels (0%, 10%, 20%, 30% and 40%). Fly ash and ground granulated blast furnace slag were used as geopolymer binders. Combination of NaOH and Na2Sio3 solution were used as activating solution. Mechanical properties viz., compressive strength, split tensile strength and modulus of elasticity were found after 7, 28 and 90 days respectively. From the results, it is concluded that the improvement in mechanical properties up to 40% CS replacement was observed.

Key words: Geopolymer Concrete, Copper Slag, Compressive Strength, Split Tensile Strength, Modulus of Elasticity

I. INTRODUCTION

Concrete is the most widely used material in construction worldwide in terms of volume and has a large impact on the environment. Manufacturing of Portland cement is one of the most important materials of construction and is responsible for significant amount of emissions of co2 which is the main greenhouse gas, causing global warming. Efforts are being made in the construction industry to address these by utilizing alternative materials and developing supplementary binders in concrete. The application of geo polymer concrete is one such alternative. The geo polymer technology is proposed by Davidovits and gives considerable propose for application in concrete industry as an alternative binder to the Portland cement. This process results in two benefits. i.e. reducing CO2 releases from production of OPC and effective utilization of industrial waste by-products such as fly ash, slag etc. By minimizing the use of OPC. In terms of reducing the global warming, the geo polymer technology can reduce the CO2 emission in to the atmosphere, caused by cement and aggregate industries is about 80%. In this geo polymer technology, the source material is rich in silicon (Si) and Aluminium (Al) is reacted with a highly alkaline solution through the process of geo polymerization to produce the binding material. The polymerization process involves a substantially fast chemical reaction under high alkaline condition on Si-Al minerals that result in a three-dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds. Depending on the raw materials and the processing conditions, geo polymers can exhibit a wide variety of properties and characteristics, including high compressive strength, adequate flexural strength, acid resistance, fire resistance and also provides low thermal conductivity. This paper presents the compressive strength, split tensile strength and modulus of elasticity of geo polymer concrete (GPC) incorporating fly Ash and GGBS at equal ratio for M45 grade, cured at ambient temperature.

II. EXPERIMENTAL STUDY

The experimental investigation was focused on the effect of various proportions of copper slag on GPC. Mix proportion was designed using Rangans method. Fly ash and GGBS are used as the replacement of cement. Sand and CS were used as fine aggregate and CS chemical composition are listed in

Composition	% by mass
SiO_2	43.20
Al_2O_3	12.60
Fe_2O_3	1.30
CaO	40.20
Na_2O_3	0.90
K_2O	0.60
TiO_2	-
MgO	1.45
GNO_3	-

Table 1: Super plasticizer of SP-430 was used to improve the workability of mixtures.

Crushed granite stones of the size 20 mm and 10 mm were used as coarse aggregate and the river sand was used as fine aggregate. The bulk specific gravity in oven dry condition and the water absorption of the coarse aggregate 20 mm and 10mm were 2.58 and 0.3% respectively. The bulk specific gravity in oven dry condition and water absorption of the sand were 2.62 and 1% respectively and also the fineness modulus is 2.59.

III. MIX DESIGN

In this study, mechanical properties of geopolymer concrete (GPC) incorporating copper slag(CS) as fine aggregate with the replacement levels of 0%, 10%, 20%, 30% and 40% of copper slag was studied. The design mix proportions of GPC values are shown in Table 2.

Constituents	Content of concrete per m^3
GGBS	242
Fly ash	242
20 mm aggregate	914
10mm aggregate	610
SS Solution	121
SH Solution	48
Super plasticizer	3.386

Table 2: GPC mix proportions per m^3

The changing values of sand and copper slag according to different proportions are shown in Table 3.

Constituents	Proportions per m^3				
	0%	10%	20%	30%	40%
Sand	648.5	583.6	518.8	453.95	390
Copper slag	0	64.85	129.7	194.55	260

Table 3: Mix proportions of sand and CS

IV. MIXING, CASTING AND CURING

The GGBS, fly ash, copper slag, sand and the aggregates were dry mixed together in a pan mixer for about 3 minutes. The alkaline solution was then added to the dry mixture of GPC and the mixing was further continued for about 4 minutes to manufacture the fresh concrete as shown in Fig. 1.

Fig. 1: Fresh concrete

Immediately after mixing the fresh concrete was cast into the cubes (15cmx15cmx15cm) and cylinders (15cm x15cm x30cm) to find the results for compressive strength, split tensile strength and modulus of elasticity. Then these specimens are cured at ambient temperature and tested at certain curing periods i.e. 7, 28 and 90 days.

V. RESULTS AND DISCUSSION

A. *Compressive strength*

Compression test is the important test conducted on hardened concrete. We found the characteristic properties of concrete that are qualitatively related to strength. In our investigation the test is carried out on cubical shaped specimens, In this test the load is acted continuously in the gradual manner on the specimen up to the ultimate capacity of the specimen of different proportions and on different curing periods like 7, 28 and 90 days. The testing of the specimen is done as shown in the Fig 2. The results of the test were labeled in Table 4 and graph is drawn for corresponding values in Fig 3.

Fig. 2: Compressive testing machine

Property	Age	0% CS	10% CS	20% CS	30% CS	40% CS
Compressive Strength	7	29.08	36.06	38.41	41.73	45.56
	28	53.53	61.19	65.61	67.81	75.85
	90	60.24	68.72	72.98	74.58	83.47

Table 4. Compressive strength test

By observing the table readings we can say that, with the increase of the proportion of copper slag the compressive strength of concrete cube increases gradually.

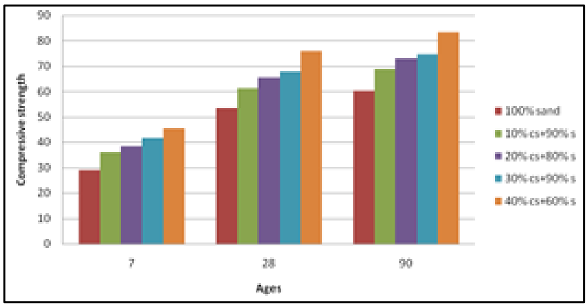

Fig. 3: Compressive strength Vs Age

B. *Split Tensile Strength*

Split tensile strength is conducted on the cylinders to find bearing capacity of the Geo polymer cylinders of different proportions at different curing periods by applying the gradual load. In this investigation we use the cylinders of dimensions 0.3m x 0.15m x 0.15m with the GPC of the mix design prepared. The testing process is carried out as shown in the Fig 4. The result of the split tensile strength is noted in the Table 5 and graph is drawn for corresponding values in Fig 5.

Fig. 4: Split tensile strength test

Property	Age	0% CS	10% CS	20% CS	30% CS	40% CS
Split tensile Strength	7	22.68	28.13	29.96	32.55	35.53
	28	41.75	47.72	51.18	52.89	59.16
	90	46.99	53.60	56.92	58.17	65.11

Table 5: Split tensile strength test

By observing the table readings we can say that, with the increase of the proportion of copper slag the split tensile strength of concrete cube increases gradually.

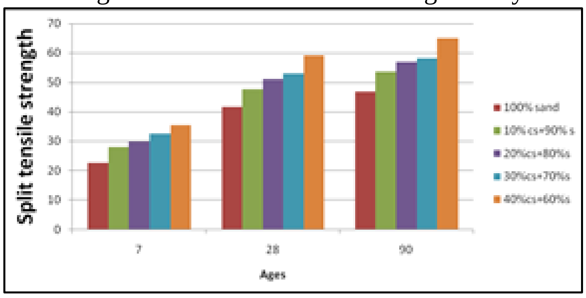

Fig. 5: Slipt tensile strength Vs Age

C. *Modulus of Elasticity*

Modulus of elasticity was conducted on the cylinders of dimensions 0.3m x0.15m x 0.15m. The specimens are placed in the testing machine and applied load gradually. Each specimen was loaded until an average stress of (C+5) kg/cm2 is reached. Here, C is the one-third of the average equivalent cube compressive strength. The equivalent cube strength has been determined by multiplying the cylinder strength by 5/4. Strains at the regular interval of loads till proportional limit, have been measured. Stress-strain curve has been plotted. In our investigation we conducted test at three different curing periods of different temperature as shown in Fig 6. The test results are noted in the Table 6 and the graph is drawn for the corresponding values in Fig 7.

Fig. 6: Testing of cylinders for modulus of elasticity

Property	Age	0% CS	10% CS	20% CS	30% CS	40% CS
Modulus of elasticity	7	22.82	25.41	26.23	27.34	28.57
	28	30.96	33.10	34.28	34.85	36.86
	90	32.85	35.08	36.15	36.55	38.67

Table 6. Modulus of elasticity test

From the table the experimental values of the modulus of elasticity for the specimens at different proportions on the different ages are gradually increasing continuously. This is because of the filling of voids by using the fine material copper slag.

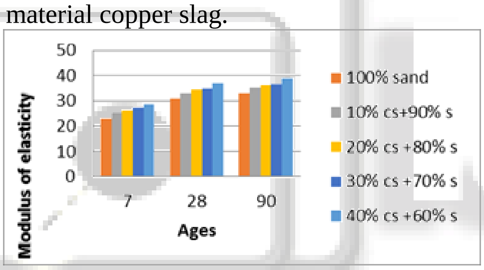

Fig. 7: Modulus of elasticity Vs Age

VI. CONCLUSIONS

Based on the investigation, the following conclusions have been drawn.

1) There was a significant increase in the compressive strength with increase in percentage of CS from 0% to 40% in different curing periods.
2) When percentage of CS increased from 0% to 40%, splitting tensile strength and modulus of elasticity have been enhanced.
3) The improvement in mechanical properties up to 40% CS replacement is mainly due to the fine material of CS which fills the voids and increases the compressive strength of the concrete which in turn increases the other mechanical properties.

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