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Geopolymer Concrete Using Scrap Steel Slag as Coarse Aggregate

Suganya. N[1], Thirugnanasambandam. S[2]
[1, 2]Department of Civil and Structural Engineerin, Annamalai University, Tamil Nadu, India

***Abstract:** This study is to evaluate the performance of scrap steel slag as coarse aggregate in low calcium fly ash based geopolymer concrete. Geopolymer concrete is an innovative material which is 100% cement-less. This experimental work was carried out to make it more sustainable by replacing the natural gravel coarse aggregate in geopolymer concrete by scrap steel slag, an industrial waste. Laboratory investigation was carried out and the conclusion is made based on mechanical – Compressive, Tensile, Flexural strength and Durability – Acid resistance, Sulphate resistance properties of concrete. It is found that steel slag performs similar to that of natural gravel coarse aggregate in concrete.*
***Keywords**: Low calcium fly ash, Geopolymer, Scrap steel slag, Mechanical properties, Durability properties.*

I. INTRODUCTION

Geopolymer concrete replaces cement binder in conventional concrete by alkali activated pozolanic material rich in silica and alumina. This innovative invention to replace cement in concrete is gaining importance in recent decades and is being put to field applications recently.

Replacement for cement is attentive because of the fact that concrete production involves release of huge amount of CO_2 into the atmosphere contributing largely to global warming.

Next to that, coarse aggregate which forms 60-70% of concrete leads to natural resource depletion, since natural gravel is used as coarse aggregate in conventional concrete. 8-12 million tons of natural aggregates are involved in concrete making annually. Globally, the amount of industrial waste products generated annually increases at a faster rate. In India around 960 MT of solid wastes are being generated every year out of mining and industrial activities.

To preserve this fast depleting natural resource, many research works are going on to replace the coarse aggregate in concrete. Scrap steel slag is selected in this study because the physical and chemical properties of steel slag are similar to that of natural gravel *(Suganya.N and Thirugnanasambandam. S)*[7].

Thus, this experimental study is carried out replacing the natural coarse aggregate in cement-less geopolymer concrete by scrap steel slag, an industrial waste.

II. LITERATURE REVIEW

1) *Sultan Tarawneh et al (2014)*[1] studied the effects of using steel slag aggregate on mechanical properties of concrete and reports that steel slag acts as accelerator at early age and 7 days strength of steel slag concrete is higher and at 28 days, the effect is reduced.
2) *Mohammed Nadeem, Arun Pofale (2012)*[2] investigated use of different types of steel slag as coarse in concrete and reports that steel slag absorbs lesser water than brick aggregate. Also the compressive strength of steel slag coarse aggregate concrete is similar to or better than that of conventional aggregate concrete. Heavy weight steel slag yield better compressive strength.
3) *N A Lloyd and B V Rangan (2010)*[3] presents a detailed report on making of geopolymer concrete, its short term and long term properties and suggests that geopolymer is well suitable for precast elements.
4) *B. Vijaya Rangan (2008)*[4] developed low calcium fly ash based geopolymer concrete and reports its material properties, mix design, fresh and hardened properties of concrete. Reports that geopolymer concrete is more durable and undergoes very low creep and shrinkage.
5) *Vinothini.P, Kumaravel. S and Girija. P(2015)*[5] studied the ambient curing of fly ash based geopolymer concrete with addition of GGBS. Reports that GGBS in geopolymer accelerates its setting time and aids curing at ambient temperature.
6) *Pradip Nath et al (2015)*[6] reports that fly ash based geopolymer shall be made under ambient curing by adding small percentage of GGBS, OPC or CH. Low to moderate strength concrete shall be achieved by this method.

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III.MATERIALS

A. Fly Ash

Class F type – low calcium fly ash conforming to ASTM C 618 obtained from lignite burning thermal power station was collected in dry state and used for making concrete. Specific gravity of fly ash was 2.39. Chemical composition of fly ash used is listed in table 1.

TABLE I

CHEMICAL COMPOSITION OF FLY ASH

S.No.	Component	Weight %
1	Si	66.63
2	Al	28.67
3	K	2.26
4	Mg	1.56
5	Ca	0.92

B. GGBS

Ground granulated blast furnace slag conforming to IS 12089-1987 with specific gravity 2.8 was used for the study. Chemical composition of GGBS used is listed in Table II

TABLE III

CHEMICAL COMPOSITION OF GGBS

S.No.	Component	Weight %
1	Si	42.2
2	Al	16.87
3	K	1.69
4	Mg	5.09
5	Ca	34.15

C. Gravel Coarse Aggregate

Crush gravel agregate conforming to IS 383 – 2016 of maximum size 20 mm was used for the study. Physical properties of coarse aggregate is listed in Table III.

TABLE IIIII

PHYSICAL PROPERTIES OF GRAVEL AGGREGATE

S.No.	Parameter	Value
1	Bulk density	1380 kg/m^3
2	Specific gravity	2.66
3	Water absorption	1%
4	Fineness Modulus	6.23

D. Steel Slag Aggregate

Scrap steel slag obtained from steel re-rolling mill was crushed down using mechanical jaw type crusher and graded to a maximum size of 20 mm. Physical properties of steel slag are listed in Table IV.

TABLE IVV

PHYSICAL PROPERTIES OF STEEL SLAG AGGREGATE

S.No.	Parameter	Value
1	Bulk density	1260 kg/m^3
2	Specific gravity	2.18
3	Water absorption	1.5%
4	Fineness Modulus	6

E. Sand

River sand of maximum size 4.75 mm conforming to Zone II of IS 383-1970 was used as fine aggregate. Physical properties of sand are listed in Table V.

TABLE V
PHYSICAL PROPERTIES OF SAND

S.No.	Parameter	Value
1	Bulk density	1420kg/m^3
2	Specific gravity	2.6
3	Water absorption	0.5%
4	Fineness Modulus	2.7

F. Alkaline Solution

Alkaline solution used in activating the pozolanic binder is combination of sodium hydroxide and sodium silicate. Sodium hydroxide was obtained in pellet form and dissolved in distilled water to form 8M sodium hydroxide solution. (8x40=320g of sodium hydroxide pellets dissolved to form 1 litre solution. 40 – molecular weigth of sodium hydroxide, M-mole). Sodium silicate was obtained in solution form. Chemicals were obtained in extra pure form.

G. Superplasticizer

Naphthalene based superplasticizer Conplast SP430 with specific gravity 1.24 was used in the study.

IV. MIX DESIGN

M20 grade of concrete was taken for the purpose of this study. Geopolymer mix proportion was obtained on the basis of trial in the laboratory with binder to solution ratio of 0.45 and sodium silicate to sodium hydroxide ratio of 2.5. Mix proportion of ingredients is listed in Table VI.

TABLE VI
MIX DESIGN

S.No.	Ingredient	M I (kg/m^3)	M II(kg/m^3)
1	Fly Ash	218	218
2	GGBS	93	93
3	Activator solution	140	140
4	Sodium hydroxide	40	40
5	Sodium silicate	100	100
6	Fine aggregate	727	727
7	Coarse aggregate	1267 (Gravel)	1038 (Steel slag)
8	SP	6.22	6.22

V. EXPERIMENTAL WORK

A. Mixing

Conventional procedure was followed in mixing concrete. Sodium hydroxide solution was prepared a day before making concrete. Just before start of concrete mixing, sodium hydroxide and silicate solutions were mixed together. First all the dry ingredients were mixed well and then the solution was added to get a homogeneous mix. Sp was added at the last to gain required workability.

B. Casting

Standard concrete specimens – cube 150mm x 150mm x 150mm, cylinder 150mm dia and 300mm length, prism 100mm x 100mm x 500mm were cast. After 24 hours, the specimens were demoulded.

C. Curing

Ambient curing of concrete specimens was carried out. The specimens were left to laboratory temperature (32^{0}C ± 2^{0}C) for a period of 28 days and was put to testing.

D. Testing

Cubes were put to compressive strength (Fig.1) and cylinders were put to tensile strength (Fig.2) test under ACTM. Plain beams were studied for flexural strength under two point loading in flexure testing machine (Fig.3). Failure pattern in specimens are shown in Fig. 4, 5 and 6. Cubical specimens were subjected to acid attack with 1% H_2SO_4 and sulphate attack with 5% sodium sulphate for 30 days and checked for reduction in compressive strength. Standard procedures were followed.

Fig.1 Compression Test

Fig. 2 Tensile Test

Fig. 3 Flexure Test

Fig.4 Cube Crack Pattern

Fig. 5 Cylinder Crack Pattern

Fig. 6 Prism Crack Pattern

VI. RESULTS & DISCUSSION

Table VI reports mechanical strength at 28 days and Table VII reports durability values.

TABLE VI
MECHANICAL PROPERTIES

S.No.	Test Conducted	M I (MPa)	M II (MPa)
1	Compressive Strength	26.22	25.11
2	Tensile Strength	2.83	2.36
3	Flexural Strength	4.68	4.03

TABLE VII
DURABILITY PROPERTIES

S. No	Parameter	Result after 30 days immersion in 1% Sulphuric acid		Result after 30 days immersion in 5% Sodium sulphate	
		M I	M II	M I	M II
1	Compressive Strength (Mpa)	25.18	25	26.1	24.96
2	% reduction in strength	0.8	1	0.5	0.6

From the test results it is found that steel slag performs similar to that of conventional gravel aggregate. Though not significant a, a slight drop in strength values were found for steel slag aggregate. It was understood because of the reason that steel slag is relatively porous than gravel aggregate. Mechanical performance of the concrete is good and shows excellent durability properties.

VII. CONCLUSION

From this experimental study, it is concluded that scrap steel slag can be used as coarse aggregate in geopolymer concrete. The strength behaviour is similar to that of conventional gravel concrete. Further long term research work is recommended to put scrap steel slag as coarse aggregate in structural applications.

VIII. ACKNOWLEDGMENT

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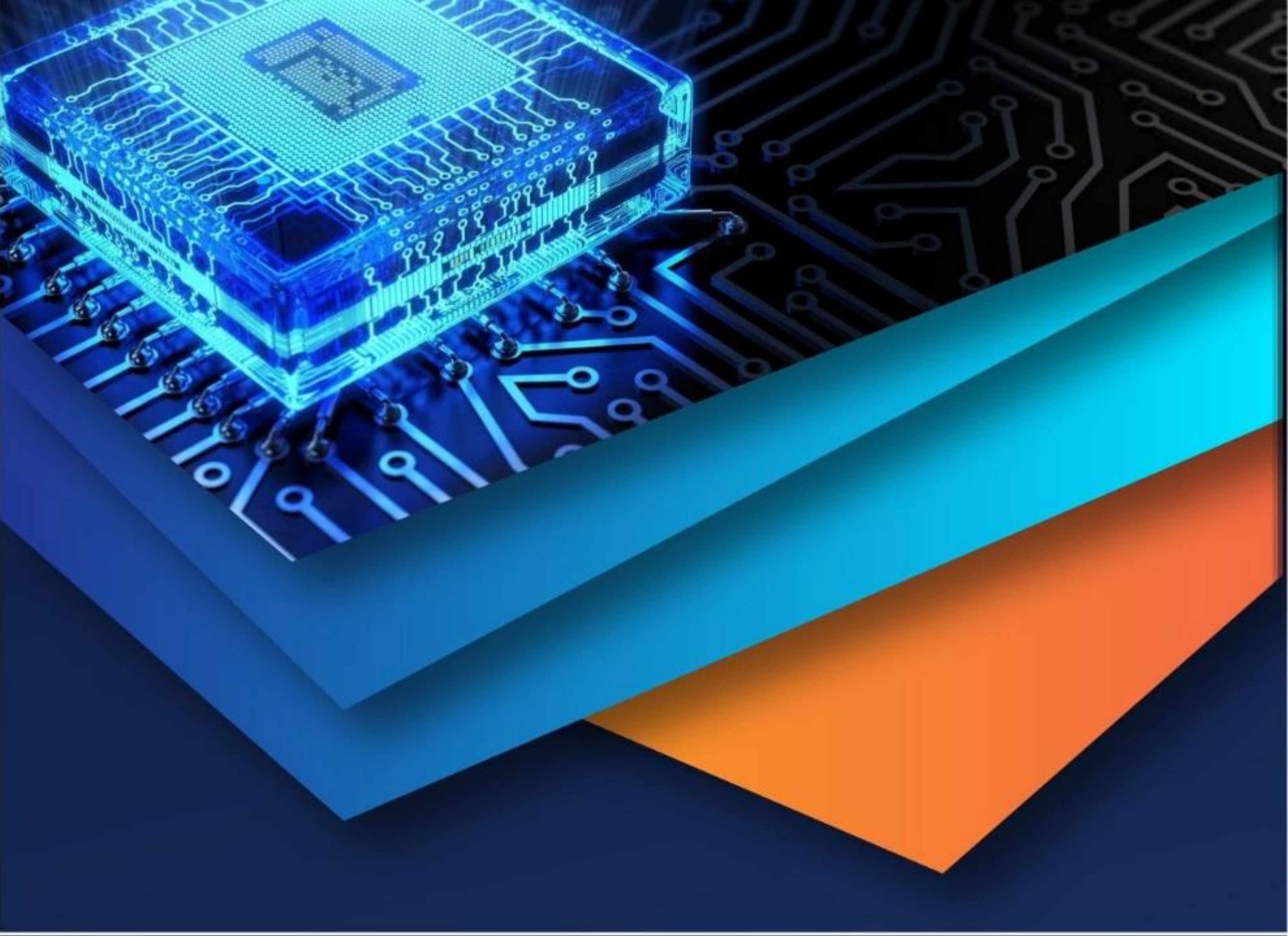

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