

# An Experimental Study on Geopolymer Concrete with Partial Replacement of Coarse Aggregate by Steel Slag

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**ABSTRACT:** This study is to evaluate the performance of steel slag as coarse aggregate in low calcium fly-ashbased geopolymer concrete. Geopolymer concrete (GPC) is 100 % cement less. This experimental work was carried out to make GPC by replacing the natural coarse aggregate in geopolymer concrete with steel slag. Laboratory tests were carried out and the conclusion was made based on the results from mechanical properties such as Compressive, Tensile, Flexural strength, Rebound hammer and Ultrasonic Pulse Velocity test of geopolymer concrete. It is found that steel slag performance is similar to that of natural coarse aggregate in geopolymer concrete.

**KEYWORDS:** Low calcium fly ash, GGBS, Geopolymer concrete, steel slag, Mechanical properties.

## I.INTRODUCTION

In recent years, green concrete has draws serious attention of researchers and investigators because a concept of thinking environment “Environmentally Ecofriendly”. The contribution of OPC production worldwide to greenhouse gas emissions is estimated to be approximately 1.35 billion tones/annum. It is essential to replace the cement by alternative materials such as available in waste product from industries.

Geopolymers are formed when various alumina and silica containing materials react under highly alkaline conditions and forms a three-dimensional network of Si-O-Al-O bonds. Electric arc furnace steel slag is an industrial by product obtained from steel manufacturing industry during melting of steel scrap from the impurities and fluxing agents. Electric arc furnace steel slag is obtained by cooling the electric arc furnace steel liquid slag in air at production site. The composition of slag varies upon the type of furnace and charge, the desire grade of steel purity and the furnace operation conditions. In production of steel process about 15% of slag/ton of steel gets produced. Slag containing components are calcium silicates, Ca-Al-ferrites and molten oxides of calcium, iron, magnesium and manganese.

## II.LITERATURE REVIEW

1. O. M. Omar, A. M. Heniegal Geopolymer is an inorganic polymer that contains silicon-oxygen-aluminum (Si-O-Al) frame-work. The geo polymerization requires presence of an alkali and alkali metal salt for dis-solution of silica and alumina. In the presence of alkali hydroxide and silicate solution, polymerization takes place when aluminosilicates dissolves and free SiO<sub>4</sub> and AlO<sub>4</sub> compounds are formed in solution. These compounds are alternatively connected, which gives geopolymers. The effect of ambient curing on the early and final compressive strengths were investigated on fly ash based geopolymer concrete. The long-term mechanical properties of fly ash based geopolymer concrete were carried up to 1 year of age.
2. Deepth, Rajeevan (2018) results of experimental investigations conducted, that the steel slag can be used as a partial replacement for coarse aggregate. It is found that 30% replacement of coarse aggregate by steel slag gives maximum result in strength that normal concrete and the decrease 40%. The compressive strength is quantified for varying percentage and grades of concrete by replacement of coarse aggregate with steel slag.
3. Dr. K.P. Dattatreya and Dr. K.P. Shivanandha (2016). Presented the experimental investigation carried out to evaluate the effects of concrete by replacing the normal coarse aggregate by steel slag on properties of concrete. In this study concrete of M20, M30, M40, M50 grades were considered for W/C ratio of 0.55, 0.45, 0.37, 0.32 respectively for the replacement of coarse aggregate 30%, 60% and 100% by steel slag. In comparing with M20, M30 and M40, M50 grade of concrete, M50 attains maximum strength compared to all grade of concrete.

## III.GEOPOLYMERS

Geopolymers consists of a polymeric Si-O-Al framework, similar to zeolites. The main difference to zeolite is

geopolymers are amorphous instead of crystalline.

The reaction produces SiO<sub>4</sub> and AlO<sub>4</sub>, tetrahedral frameworks linked by shared oxygen as poly(sialates) or poly(sialate-siloxo) depending on the SiO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub> ratio in the system. The connection via long range covalent bonds. Thus geopolymer structure is perceived as dense amorphous phase consisting of semi-crystalline 3-D alumino-silicate microstructure.

Commercially produced geopolymers may be used for fire, heat-resistant coatings and adhesives, in medical applications, in manufacturing the high temperature ceramics, as a new binders for fire resistant fibre composites, in toxic and radioactive waste encapsulation and as new cements for concrete.

#### IV.MATERIALS

##### 4.1. 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 from Mettur Thermal Power Station (MTP), Salem, Tamil Nadu and used for making concrete. Specific gravity of fly ash is about 2.27. Chemical composition of fly ash used is listed in table 4.1.

S. No	Component	Weight%
1	SiO <sub>2</sub>	61.30
2	Al <sub>2</sub> O <sub>3</sub>	29.40
3	K <sub>2</sub> O <sub>3</sub>	1.20
4	MgO	0.75
5	CaO	1.21
6	Fe <sub>2</sub> O <sub>3</sub>	3.27
7	SO <sub>3</sub>	0.003
8	TiO <sub>2</sub>	0.01
9	Na <sub>2</sub> O	0.73
10	Cl	0.04
11	LOI	0.67

**Table 4.1**Chemical composition of fly ash

##### 4.2. Ground Granulated Blast Furnace Slag (GGBS):

Ground Granulated Blast Furnace Slag conforming to IS 12089-1987 with specific gravity of GGBS is about 2.76 was used for the study. Chemical composition of GGBS used is listed in table 4.2

S. No	Component	Weight%
1	SiO <sub>2</sub>	33.77
2	Al <sub>2</sub> O <sub>3</sub>	13.24
3	Fe <sub>2</sub> O <sub>3</sub>	0.65
4	MgO	8.46
5	CaO	33.77
6	MnO	0.05
7	Sulphide sulphur	2.23
8	Sulphite sulphur	0.23
9	Total chlorides	0.01

**Table 4.2** Chemical composition of GGBS

##### 4.3.Coarse aggregate:

Crush gravel aggregate conforming to IS 383-2016 of maximum size 20mm was used for the study. Physical properties of coarse aggregate is listed in table 4.3.

S. No	Parameter	Value
1	Bulk density	1480kg/m <sup>3</sup>
2	Specific gravity	2.94
3	Water absorption	1%
4	Crushing value	18.3%
5	Impact value	19.69%
6	Fineness modulus	6.90

**Table 4.3** Physical properties of coarse aggregate

**4.4. Steel slag aggregate:**

Scarp steel slag obtained from JSW steel Industry, Salem, Tamil Nadu steel re-rolling mill was crushed down using mechanical jaw type crusher and graded to a maximum size 20mm. Physical properties of steel slag are listed in Table 4.4.

S. No	Parameter	Value
1	Bulk Density	1260kg/m <sup>3</sup>
2	Specific Gravity	3.48
3	Water Absorption	1.5%
4	Fineness Modulus	5.43
5	Crushing value	20.5%
6	Impact value	25.75%

**Table 4.4** .Physical properties of steel slag aggregate

**4.5.M sand:**

M Sand of maximum size 4.75mm conforming to Zone II of IS 383-1970 was used as fine aggregate. Physical properties of M Sand are listed in Table 4.5

S. No	Parameter	Value
1	Bulk Density	1.75kg/m <sup>3</sup>
2	Specific Gravity	2.59
3	Water Absorption	0.5
4	Fineness Modulus	2.95

**Table 4.5** Physical properties of M sand

**V. MIX DESIGN**

The following mix quantities are arrived for the **M<sub>35</sub>** grade of Geo polymer concrete.

MATERIAL	QUANTITY (kg/m <sup>3</sup> )
Binder content	445.53
Fine aggregate	629.603
Coarse aggregate	1216.89
Alkaline solution	191.58
Solution to binder ratio	0.43

**Table 5.1** Quantity of materials

**VI. EXPERIMENTAL WORK**

**6.1. Mixing:**

Mixing procedure is also same as convention concrete. Initially we have to prepare the Sodium Hydroxide and mix it with sodium silicate solution a day before of casting. Initially all the materials are mixed in dry condition and then the alkaline solution was added to the dry mix and the mixing was continued until obtained the homogenous mix.

**6.2. Casting:**

Standard casting specimens such as cube size of 100mmX100mmX100mm, cylinder size of 100mm diameter and 200mm height, Prism size of 100mmX100mmX500mm were casted. After 24 hours, the specimens were demoulded.

**6.3. Curing:**

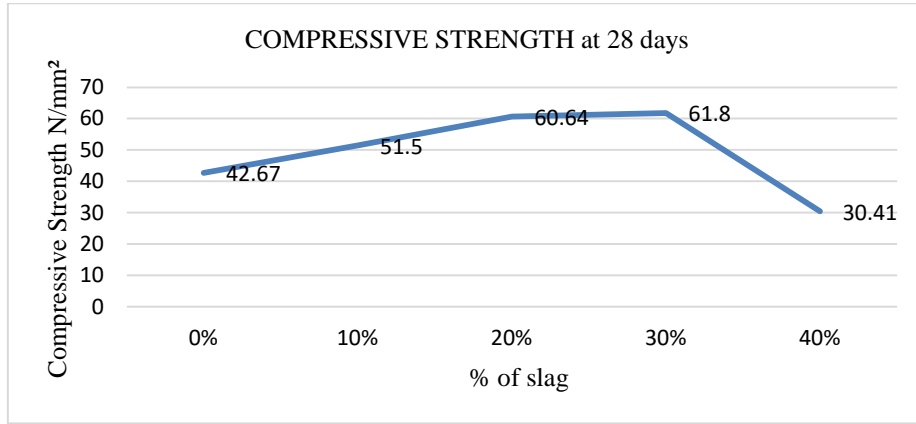
Geopolymer concrete specimens were subjected to ambient curing at a temperature of (32°C+2°C) for a period of 7 days and 28 days.

**6.4. Testing:**

Cubes casted were put for compressive strength test and cylinders casted were put for tensile strength test under Universal Testing Machine (UTM). Prisms casted were put for flexural strength test.

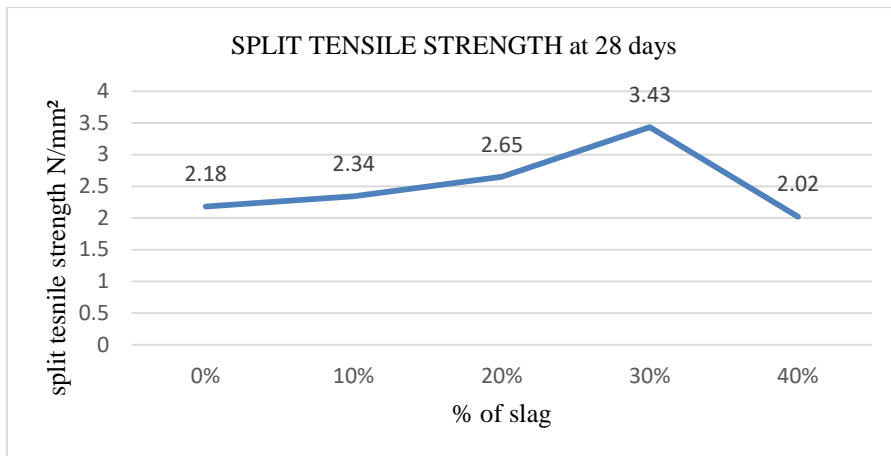
**VII.RESULTS AND DISCUSSION**

**7.1.Compressive strength test result:**



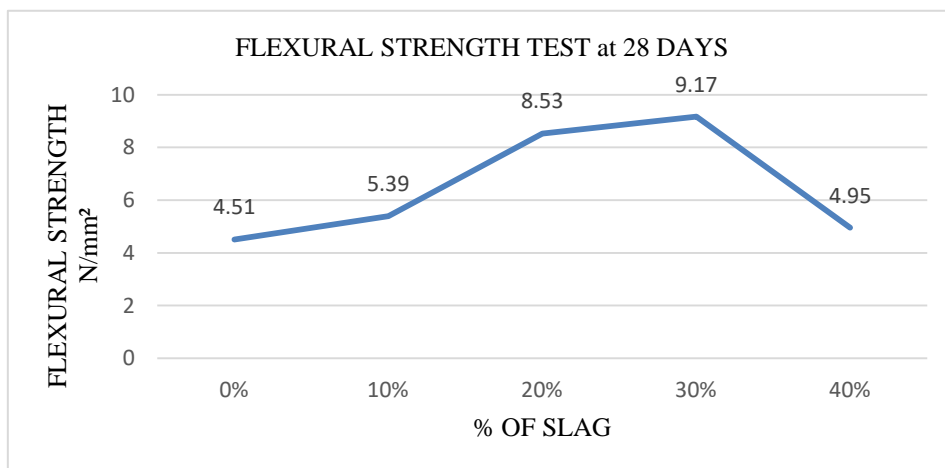
**Fig 1** Compressive Strength of geopolymer concrete at 28 days

**7.2. Split Tensile Strength Test Results:**



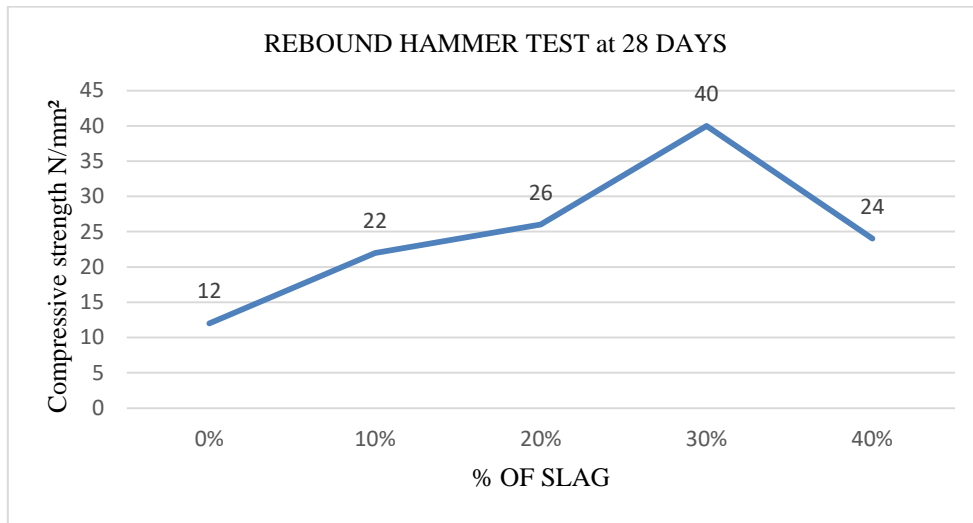
**Fig 2** Split Tensile Strength of geopolymer concrete at 28 days

**7.3 Flexural Strength Test Results:**



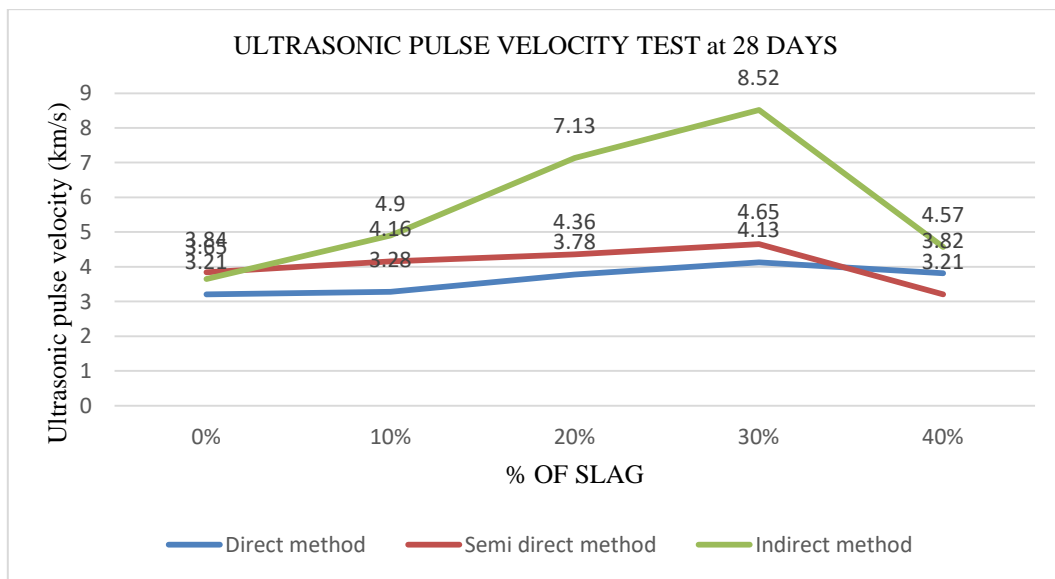
**Fig 3** Flexural Strength of geopolymer concrete at 28 days

**7.4 Rebound Hammer Test Results:**



**Fig 4** Rebound Hammer of geopolymer concrete at 28 days

**7.5 Ultrasonic Pulse Velocity Test Results:**



**Fig 5** Ultrasonic Pulse Velocity of geopolymer concrete at 28 days

**VIII.CONCLUSION**

The aim of our experimental work is to determine the strength behavior of fly ash based geopolymer concrete in which the coarse aggregate was partially replaced with steel slag. The compressive, tensile, flexural strength tests, Rebound hammer and Ultrasonic pulse velocity test results showed that the optimum amount of steel slag required to replace coarse aggregate by weight in geopolymer concrete is 30%.

- The Compressive strength of Geopolymer concrete increases to about 44.83% compared to control geopolymer concrete on 30% replacement of Coarse aggregate by Steel Slag and further increasing of percentage of Steel Slag leads to decrease in Compressive strength of Geopolymer concrete.

- The Tensile strength of Geopolymer concrete increases to about 57.33% compared to control Geopolymer concrete on 30% replacement of Coarse aggregate by Steel Slag and further increasing of percentage of Steel Slag leads to decrease in Tensile strength of Geopolymer concrete.
- The Flexural strength of Geopolymer concrete increases to about 103.32% compared to control geopolymer concrete on 30% replacement of Coarse aggregate by Steel Slag and further increasing of percentage of Steel Slag leads to decrease in Flexural strength of Geopolymer concrete.
- The Rebound Hammer (Compressive strength) of Geopolymer concrete increases to about 233.33% compared to control Geopolymer concrete on 30% replacement of Coarse aggregate by Steel Slag and further increasing of percentage of Steel Slag leads to decrease in Compressive strength of Geopolymer concrete.
- The quality of Geopolymer concrete gets improved from the condition Good to Very Good in Ultrasonic pulse velocity test conducted on Geopolymer concrete with 30% replacement of coarse aggregate by steel slag on comparing to control Geopolymer concrete.

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