Experimental Investigation on Reinforced Geopolymer Concrete Slabs

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ABSTRACT

Geopolymer is an ecological binding material alternative to Ordinary Portland Cement (OPC). Concrete made with this Geopolymer has several recompense compared to Ordinary Portland Cement (OPC). Generally, geopolymer concrete is the combination of Fly ash, Ground granulated blast furnace slag (GGBS), alkaline activator solution, fine aggregate and coarse aggregate. Here in this study 100% GGBS is used. GGBS is the consequence of iron and steel manufacturing industry. Alkaline solution is made up of sodium silicate and sodium hydroxide solution (NaOH) with 2.5:1. This study illustrates the experimental investigation on reinforced geopolymer concrete slabs using GGBS. The aspire is to compare the flexural behaviour of geopolymer concrete slab with the straight concrete of grade M40. The slab dimension is taken as 1000 mm × 1000 mm × 60 mm. The dissimilar molarities of NaOH used in this study are 8M, 10M, 12M, 14M and 16M.

***Index Terms**: Geopolymer Concrete, Load Vs Deflection, Molarity, Sodium Hydroxide, Sodium Silicate.*

I. INTRODUCTION

Concrete is the major creation material used all over the world. The only compulsory material used in production of the concrete is Ordinary Portland Cement (OPC). The making of cement leads to many environmental effects due to the emission of a large amount of carbon dioxide (CO_2) throughout the manufacturing process. It is estimated that 1 ton of cement produces nearly 1 ton of CO_2 into the environment. It is compulsory to develop an alternate binder for the concrete to reduce the effect of CO_2 from the cement industry for a sustainable surroundings. Geopolymer is an unusual binding material to Ordinary Portland Cement. The electrical force demand is increasing day by day due to the increase of urbanization. To full fill these energy need, the electrical energy manufacture is also increased. Due to the increase in production of electrical energy, the manufacture of fly ash will also increase. The disposal of this fly ash is the major problem to the environment. On the other hand, the usage of steel also increases for construction of industries. Ground granulated blast furnace slag (GGBS) is the waste material produced in iron industry. By using these two wastes in concrete will decrease the assembly cost and safe disposal. Construction industry is in performance a major role in Indian economyIn 1978 " Davidovits " of France 1st introduced the term geopolymer to the world. Geopolymer concrete is produced by mixing Ground granulated blast furnace slag (GGBS), fly ash, coarse aggregate, fine aggregate, and alkali activator solution. Alkali activator solution is the combination of sodium silicate (Na_2Sio_3) and sodium hydroxide (NaOH). The chemical reaction which takes place in geopolymer concrete is known as polymerization process. Several research has been done from several years to state that geopolymer concrete is best for construction material . This research deals with the usage of 100 percent GGBS in reinforced geopolymer concrete slabs under ambient curing temperature. The reinforced geopolymer concrete slabs and conventional reinforced concrete slab are tested for comparison. A total of 5 reinforced geopolymer concrete slabs and 1 conventional reinforced concrete slabs are tested. Factors considered are load carrying capacity and deflections at different stages were studied. This paper compares the performance of reinforced geopolymer concrete slabs with Ordinary Portland Cement reinforced concrete slabs.

II. MATERIALS AND MIXING PROCEDURE

A. *Materials*

The materials used for this experimental work are Ordinary Portland Cement (OPC) confirming to IS : 12269- 2013, coarse aggregates, fine aggregates and portable water for the conventional OPC test specimen.

Here in this study, we use 100 percent GGBS instead of cement. GGBS is available from JSW cements confirming to IS : 12089-1987 in the form of 50 kgs bags were used. GGBS is the by-product of iron industry. The OPC cement used for normal specimen is of 53 grade.

Fine aggregate used for this work is river sand which is available in Vijayawada. Locally available crushed granite stones of maximum diameter 20 mm were used as coarse aggregates. GGBS, fine aggregates, coarse aggregates were tested as per IS : 2386-1963. Material Properties are shown in table 1 to table 4.

For OPC specimen portable water is been used & for geopolymer concrete distilled water is used. Thermo mechanically treated (TMT) Simhadri steel bars of 500 MPa and diameter of 10 mm is used as reinforcement in slab is shown in table 5.

In geopolymer concrete the alkaline activator solution is used with the combination of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) of ratio 1:2.5. The role of AAS is to dissolve the reactive portion of source materials Si and Al which is present in GGBS and for

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polymerization reaction it provide a highly alkaline liquid medium. [8], [9].

The sodium hydroxide is used of 2.5 mm in size in the form of flakes. sodium hydroxide solution is prepared by mixing the sodium hydroxide (NaOH) flakes in distilled water. Since the heat generated is very high when sodium hydroxide flakes reacts with water. So, 24hrs Before casting, sodium hydroxide solution is prepared.

Table 1: Properties of GGBS

Parameters	GGBS
Cao	37.34%
Sio_2	37.73%
Al_2O_3	14.42%
Fe_2O_3	1.11%
Glassy content	99.90%
Loss of ignition	1.41%

Table 2: Physical Properties of Coarse Aggregate

Sieve size	Requirement as per IS: 383-1970 (20 mm)	Percentage Passing
40mm	100%	100%
20mm	85-100%	93%
16mm	-	-
12.5mm	-	-
10mm	0-20%	12%
Specific gravity	2.9	

Table 3: Physical Properties of Fine Aggregate

Sieve size	Percentage Passing
10mm	100%
4.75mm	100%
2.36mm	99.50%
1.18mm	86.70%
600μ	35.80%
300μ	8.60%
150μ	0.80%
Zone	II
Fineness modulus	2.7
Specific gravity	2.6

Table 4: Physical Properties of Cement

Description	Cement
Fineness	3.40%
Normal consistency	34%
Initial setting time	75 min
Final setting time	310 min

B. Mix Proportion

Geopolymer concretes are the new trend in construction material. There is no standard mix design for geopolymer concrete. While rangan and hardjito has presented some guidelines for flyash based geopolymer concretes. using these guidelines, some of the trails has been done that indicates the workability and strength characteristics of such mixes were not satisfactory. But it is possible when geopolymer concrete have more constituents in its binder (GGBS, sodium silicate, sodium hydroxide and water) [10].

The micro structure of the geopolymer concrete is more complex. While the strength of cement concrete is based on its water cement ratio. But there is no formulation for the geopolymer concrete.

This formulation is done based on trial and error. Therefore, various trail mixes were casted and tested for compressive strength for the 28 days.

In this study, the test results were compared between the conventional concrete casted with OPC cement of 53 grade designed as per IS : 10262-2009 to the geopolymer concrete [11], [12].

For conventional Concrete, mix proportion is shown in table no 6 & for geopolymer concrete, mix proportion is given in the table no 7.

Table 5: Mix Proportion of Cement Concrete

Materials	Quantity (Kg/m^3)
Cement	400
Fine Aggregate	687.1
Coarse Aggregate (20 mm)	817.3
Coarse Aggregate (10 mm)	544.9
Water	140
w/c	0.35

Table 6: Mix Proportion of Geopolymer Concrete

Materials	Quantity (Kg/m^3)
GGBS	414
Fine Aggregate	660
Coarse Aggregate(20mm)	681.6
Coarse Aggregate(10mm)	454.4
Sodium hydroxide	53
Sodium silicate	133
Extra water	10%

C. Mix Design of Geopolymer Concrete

The density of geopolymer concrete is similar to the OPC concrete of 2400 kg/m^3. The percentages of coarse and fine aggregates used in design of OPC concrete is taken as 75 – 80%. Similarly, in the geopolymer concrete the percentage of aggregates is also taken as 75%. By assuming the ratios of alkaline liquid to cementitious material, the mass of GGBS and alkaline liquid is determined. 20 mm and 10 mm are the different sizes of coarse aggregates that are used. Extra water other than the alkaline activator solution is used to obtain the workable concrete. Sodium hydroxide solution is prepared in different molarities such as 8 M,10 M, 12 M, 14 M, 16 M. For every 1 molar solution, 40 gm of NaOH flakes mixed with distilled water to form a total mix of 1 liter solution.

D. Preparation of Specimen

The cross section of the slab specimens was 1000 mm × 1000 mm × 60 mm. the slab mould is prepared by the wooden material. The inner to inner dimensions of slab mould is 1000 mm × 1000 mm length. The thickness of the mould is 60 mm. Cover blocks of 15 mm thickness is used in the bottom of the reinforcement bars.

10 mm diameter steel bars with 160 mm spacing center to center are used in compression zone as reinforcement in slabs. The mould is coated with a lubricating oil before casting to avoid adhesion with hard concrete. The mix is prepared and placed in the mould in 3 layers. Vibration is done by using needle vibrator. 3 cubes of size 150 mm ×150 mm ×150 mm and cylinders of 150 mm diameter and 300 mm height is casted along with the casting of slab.

These cubes and cylinders are used to determine the 28 days compressive strength and

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tensile strength. The OPC slab is cured for 28 days and the geopolymer slabs are cured in ambient temperature. The test specimens are tested after the 28 days curing period for the compressive strength, tensile strength and the structural behavior. The geometry of the slab specimen is shown in Fig. 1. Slab after casting is shown in Fig. 2.

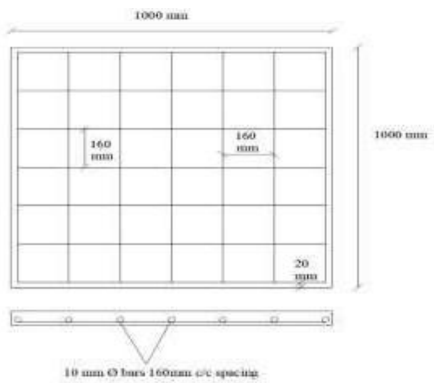

Fig. 1. Reinforcement Detailing of Slab

Fig. 2. Test Setup of Slab

III. TEST RESULTS AND DISCUSIONS

A. *Compressive Test Results*

The specimens are tested under 2000 kN capacity compression testing machine as per IS : 516-1959. The cubes of standard size 150 mm × 150 mm × 150 mm are tested[10]. The test setup of compressive strength testing is shown in Fig. 4. The specimens are identified by using table 8. The 7 days compressive strength results are given in Fig. 5(a). The 28 days compressive strength results are given in Fig. 5(b).

Split Tensile Test Results

The specimens are tested under 2000 kN capacity compression testing machine as per IS : 516-959. The cylinders of standard size 150 mm diameter and 300 mm height are tested for 7 days and 28 days. The split tensile strength results for 7 days are given in Fig. 6(a). The 28 days split tensile strength results are given in Fig. 6(b).

Failure mode and crack pattern

All slab specimens which are tested was failed at the ultimate load. By the application of load the slab will deflect towards downward direction. Due to the deflection, the cracks are developed at the bottom of the slab. The crack pattern for the normal OPC slab and GPC slabs are similar. The crack pattern on top of slab is shown in Fig. 14. The crack pattern on top of slab is shown in Fig. 15.

Fig. 14. Crack Pattern on Top of Slab

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Fig. 15. Crack Pattern on Bottom of Slab

IV. CONCLUSION

Based on the experimental studies that were carried out on the conventional concrete slab and geopolymer concrete slab, it can be concluded that the strength characteristics of GPC is higher than the OPC.

a) The load V_s deflection behaviour of Geopolymer concrete slabs are more than the OPC slab.

b) The load carrying capacity of GPC slabs will increase in increase of molarity.

c) In higher molarity GPC slabs, the deflection is decreasing when increase in molarity.

d) The Geopolymer concrete slabs were used as the structural members due to its high strength and early strength gaining capacity.

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