FINITE ELEMENT METHOD OF INVESTIGATION ON FLEXURAL BEHAVIOUR OF GEOPOLYMER CONCRETE WITH PARTIAL REPLACEMENT OF COARSE AGGREGATE BY USING STEEL SLAG

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Abstract— **This research work aims to study further sustainability to the cement - less geopolymer concrete by replacing its natural gravel coarse aggregate by an industrial by-product, scrap steel slag. Geopolymer RC beam of grade M35 with 30% scrap steel as coarse aggregate was studied for its flexural behaviour and compared with conventional reinforced cement concrete beam with gravel coarse aggregate. The analysis was also carried out using ANSYS software. The study derived that in all stages, the performance of the geopolymer beam with scrap steel slag was marginally better than the conventional beam with gravel coarse aggregate. From this numerical investigation, it is concluded that the ultimate load at failure and ultimate deflection is higher for geopolymer concrete with steel slag partially used as a coarse aggregate. This investigation work encourages the use of steel slag as coarse aggregate in concrete with its inherent structural advantage, easy availability and low cost, if not free.**

Keywords- **Alkaline liquids, Fly ash, GCBS, GPC, Steel slag**

I. INTRODUCTION

India also is facing the problem of depletion on natural resources such as limestone, which is the most important ingredient to produce cement, and in turn the concrete in India. . Ordinary Portland cement (OPC) is used as the primary binder to produce the concrete. The demand of concrete is increasing day by day for the need of development of infrastructure facilities. However, it is well known that the production of OPC not only consumes significant amount of natural resources and energy but also releases substantial quantity of carbon dioxide to the atmosphere. The global cement industry contributes around 2.8 billion tons of the greenhouse gas emissions annually, or about 7% of the total man-made (artificial) greenhouse gas emissions to the atmosphere. It is essential to find alternatives to make eco-friendly concrete .In this situation; detailed study of geopolymer concrete, which is the concrete with zero cement in concrete naturally, becomes very important. Therefore, an attempt has been made in the present investigation by casting geopolymer concrete mixes with 100% replacement of OPC with processed fly ash in each concrete mix. It is an alternative to make environmentally friendly concrete is the development of inorganic alumina-silicate polymer, called Geopolymer, synthesized from materials of geological origin or by-product materials such as fly ash that is rich in silicon and aluminium. Fly ash, one of the source materials for geopolymer binders, is available abundantly worldwide, but to date its utilization is limited. Currently, 90 million tons of fly ash is being generated annually in India. By exploring use of the fly ash based geopolymer concrete two environment related issues are tackled simultaneously i.e. the high amount of CO2 released to the atmosphere during production of OPC and Utilization of this fly ash. The production of geopolymer concrete is carried out using the conventional concrete technology methods. The fly ash based geopolymer concrete consists 75% to 80% by mass of aggregate, which is bound by a geopolymer paste formed by the reaction of the silicon and aluminum within the fly ash and the alkaline liquid made up of sodium hydroxide and sodium silicate solution with addition of superplasticizer. Hence, the effect of various parameters affecting the compressive strength i.e. ratio of alkaline liquid to fly ash, concentration of sodium hydroxide, ratio of sodium silicate to sodium hydroxide, curing time, curing temperature, rest period and additional water content in the Geopolymer concrete mixes has been investigated in order to enhance its overall performance.

II. RESEARCH SIGNIFICANCE

Approximately no research data on the flexural behavior of reinforced concrete using scrap steel slag coarse aggregate in geopolymer concrete is cited at present. Reinforced geopolymer concrete with scrap steel slag coarse aggregate attains comparable strength and serviceability and in cases, marginally higher than that of the conventional reinforced cement concrete with natural gravel coarse aggregate. This research work provides satisfactory detailed numerical data on reinforced geopolymer beam.

III. METHODOLOGY

1. To carry out a literature survey on geopolymer concrete and steel slag properties that can be feasible to use in concrete.
2. To compare the result of the ANSYS model with 0% steel slag model with 30% replacement steel slag model.

IV. MATERIAL COLLECTION

A. *Fly ash*

Class F fly ash collected from coal-fired power stations. Its spherical in nature, ranging in diameter from less then 1µm to no more then 150µm and fineness is defined by no more then 35% retained on a 45µm sieve. Class F fly ash as containing a minimum amount of silicon dioxide (SiO_2) plus aluminum oxide (Al_2O_3) plus iron oxide (Fe_2O_3) of 70%, whereas class C fly ash must contain a minimum of 50% of the same chemical constituents. Class F fly ashes will normally have a low calcium oxide (CaO)content (less than 10%), while Class C fly ashes may contain more than 10% and often15-30% calcium oxide. For this investigation a low calcium Class F fly ash is used.

B. Ground Granulated Blast Furnace Slag (GCBS):

Granulated blast furnace slag (GBFS) is the by-product of iron making process and is produced by water quenching of molten blast furnace slag. GBFS is ground to improve its reactivity during cement hydration. It contains mainly inorganic constituents such as silica, calcium oxide, magnesium oxide, Al2O3 and Fe2O3. Generation of blast furnace slag varies considerably from 430-650 kg/tone of hot metal. Two types of blast furnace slag such air-cooled slag and granulated slag are being generated from the steel plants. In India, around 40% of this slag is produced in the form of granulated slag. The activity of GBFS is determined by the quantities and the properties of amorphous glass, as well as the chemical compositions. Fine grinding and mechanical activation was suggested to improve the reactivity of the blended cement constituents. Fine grinding leads to generation of larger surface area for better reaction.

C. Steel Slag:

Slag is a co-product of the iron and steel making process. Iron cannot be prepared in the blast furnace without the production of its co-product; blast furnace slag. Steel can be prepared in the Basic Oxygen Furnace (BOF) or in an Electric Arc furnace (EAF) by leaving its by-product steel slag. This slag, which floats on the surface of molten steel, is then poured off. The main constituents of iron and steel slags are silica, alumina, calcium, and magnesia, which together make about 95% of the total composition and minor elements forms 5% of total composition. Physical characteristics such as porosity, density, particle gradation, are affected by the cooling rate of the slag and its chemical composition. The chemical composition and cooling of molten steel slag have a great effect on the physical and chemical properties of solidified steel slag.

D. Alkaline liquids:

In looking at the alkaline liquids used in Geopolymerization, various researchers have found that different combinations of alkali-silicates and alkali-hydroxides are Ideal. The Geopolymerization reactions occur at a higher rate than when hydroxides are used as activators. The reaction between alkaline solutions containing sodium hydroxide (NaOH) or potassium hydroxide (KOH) was also studied. When activating multiple natural Al-Si minerals, higher extent of dissolution was observed when in NaOH than in KOH. Higher concentration (in molar units) of sodium hydroxide results in higher compressive strength and higher ratio of sodium silicate-to-sodium hydroxide ratio by mass results in higher compressive strength.

V. MIX PROPORTION

Fly Ash	Fine Aggregate	Coarse Aggregate	Alkaline Solution
445.53	629.603	1216.89	191.58
1	1.43	2.73	0.43

VI. METHODOLGY

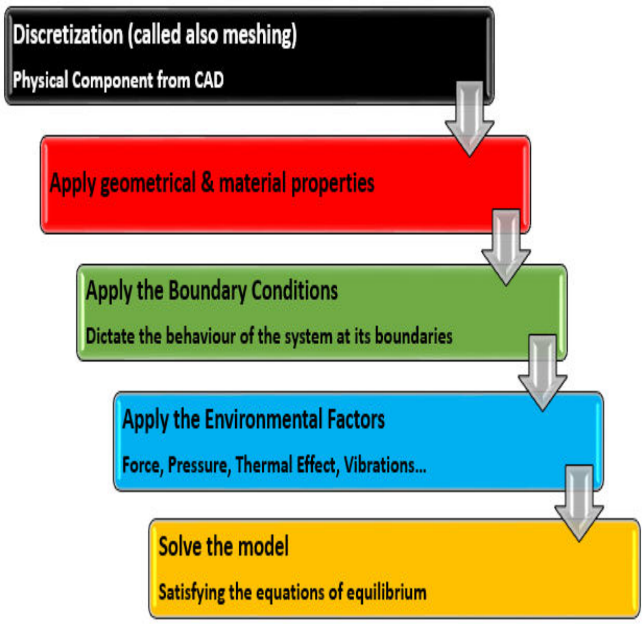
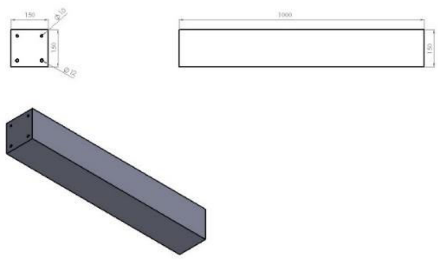


Fig-1: Methodology of the study

VII. TEST RESULTS AND DISCUSSIONS

The specimen is fabricated in the size of 1000*150*150 mm and imported on ANSYS software with fixed support.



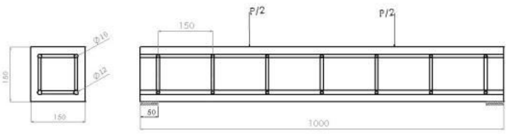


Fig-2 Dimensional of Beam

Meshing:

To obtain good results from the Solid 65 element, the use of a rectangular mesh is recommended. Therefore, the mesh was set up such that square or rectangular elements were created. The volume sweep command was used to mesh the steel plate and support. This properly sets the width and length of elements in the plates to be consistent with the elements and nodes in the concrete portions of the model.

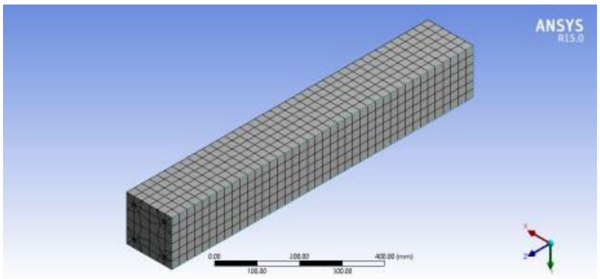


Fig-3 Geometry meshing model

A. Reinforced GPC Beam with 0% Steel Slag:

S.no	*Property*	*Value*
1	*Density*	*7850Kg/m³*
2	*Young's modulus*	*2E+05 MPa*
3	*Poisson's ratio*	*0.3*
4	*Bulk Modulus*	*1.6667E+11Pa*
5	*Shear modulus*	*9.3167E+09Pa*

properties of steel(Fe500)

S.no	*Property*	*Value*
1	*Density*	*2500Kg/m³*
2	*Youngs modulus*	*22360MPa*
3	*Poisson's ratio*	*0.2*
4	*Bulk modulus*	*1.2422E+10Pa*
5	*Shear modulus*	*9.3167E+09Pa*

Properties of Concrete with Geopolymer

S.No	*Load (KN)*	*Deformation (mm)*	*Stress (MPa)*	*Strain*
1	*10*	0.03293	7.446	0.00013
2	*20*	0.06586	14.892	0.00025
3	*30*	0.09879	22.339	0.00038
4	*40*	0.13172	29.785	0.00050
5	*50*	0.16465	37.232	0.00063
6	*60*	0.19759	44.678	0.00076
7	*70*	0.23052	52.124	0.00088
8	*80*	0.26345	59.57	0.0010

Results of Reinforced Geopolymer Concrete Beam with 0% Steel Slag

The beam is design and analysis of specified dimension (1000*150*150mm) with geo polymer. The analysis based on gradually load acting on the beam. Load applied on the beam is 10 to 100KN and deflection value is 0.03293 to 0.32931 mm respectively. As well as the von misses stress and von misses strain values are increased gradually.

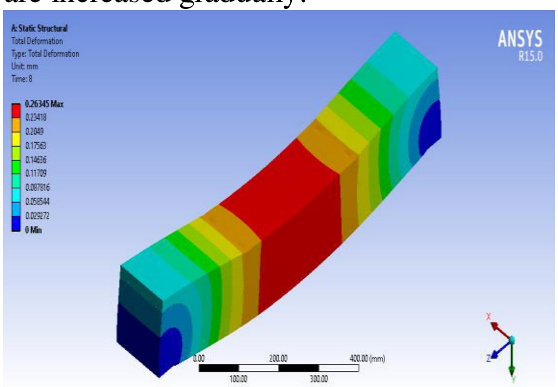


Fig-4: Total Deformation of Geopolymer Beam with 0% steel slag

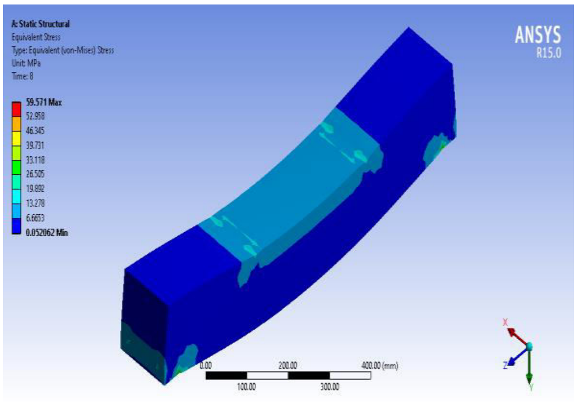


Fig-5 Von misses Stress Geopolymer Beam with 0% steel slag

B. Reinforced GPC Beam with 30% Steel Slag:

S.no	*Property*	*Value*
1	*Density*	*2341 Kg/m^3*
2	*Youngs modulus*	*38406 MPa*
3	*Poisson's ratio*	*0.26*
4	*Bulk modulus*	*2.667E+10Pa*
5	*Shear modulus*	*1.52E+09Pa*

Properties of 30% steel slag

S. No	*Load (KN)*	*Deformation (mm)*	*Stress (MPa)*	*Strain*
1	*10*	0.03353	7.603	0.00013
2	*20*	0.06705	15.206	0.00026
3	*30*	0.10058	22.81	0.00039
4	*40*	0.1341	30.413	0.00052
5	*50*	0.16763	38.017	0.00065
6	*60*	0.20115	45.62	0.00078
7	*70*	0.23468	53.224	0.00091
8	*80*	0.26821	60.827	0.00104
9	*90*	0.30173	68.431	0.00117
10	*100*	0.33526	76.034	0.00129
11	*110*	0.36878	83.638	0.00143

Results of steel slag 30% added beam

The beam is design and analysis of specified dimension (1000*150*150mm) with 30% steel slag. The analysis based on gradually load acting on the beam. Load applied on the beam is 10 to 110KN and deflection value is 0.03353 to 0.36878 mm respectively. As well as the von misses stress and von misses strain values are increased gradually.

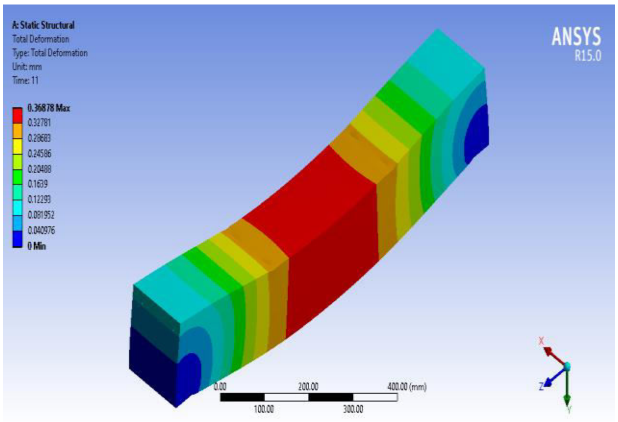


Fig-6 Total deformation of 30% steel slag added beam

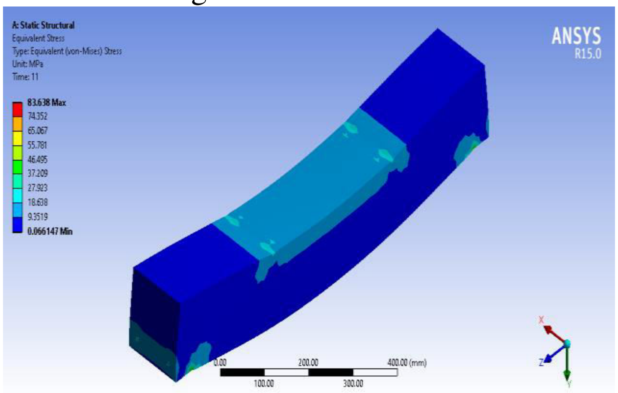


Fig-7 Von misses stress of 30% steel slag added beam

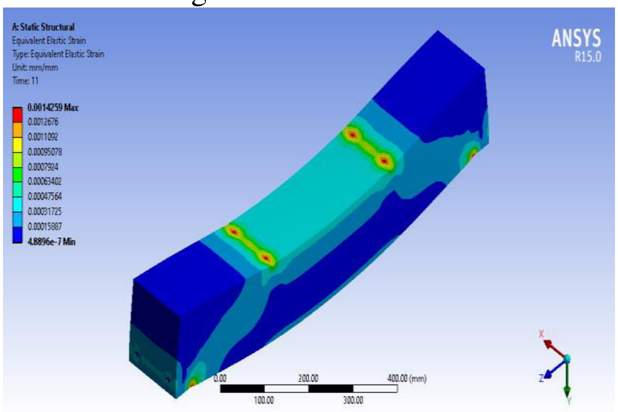


Fig-8 Von misses strain of 30% steel slag added beam

VIII. CONCLUSIONS

From the study, the following conclusions are described as follows:

1. Geopolymer concrete(GPC)is not only environmental friendly but also possesses excellent mechanical properties

2. It is a promising construction material due to its low carbon dioxide emission
3. High early strength, low creep and shrinkage, acid resistance, fire resistance makes its better usage than OPC
4. Addition of steel slag to the concrete to increases the strength in concrete compared than normal concrete.
5. The compressive strength highly influenced by the amount of CaO content in the Fly ash.
6. Compressive strength of the Geopolymer concrete increases with increases of concentration in terms of molarities of sodium hydroxide.
7. Ratio of alkaline liquid to Fly ash, by mass does not affect the compressive strength of Geopolymer concrete.
8. Workability of the Geopolymer concrete mix increase with the addition of Super plasticiser.
9. Geopolymer concrete with steel slag as coarse aggregate offered higher strength in compression and flexure, when compared with the geopolymer concrete without adding steel slag.

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