Analytical Study on Fly Ash and GGBS Blended Reinforced Geopolymer Concrete Beams by using ANSYS

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Abstract— The present study mainly focuses on analytical study of fly ash and GGBS blended reinforced geo polymer concrete beams. The beams were analyzed by using Ansys R15.0. The reinforced geo polymer beams analyzed were cured for 28days in an ambient room temperature itself. The conventional reinforced concrete beam analyzed were cured for 28 days in water. The proportions of source materials for geo polymer concrete used are fly ash(FA) 50- Ground Granulated Blast Furnace Slag (GGBS) 50, FA0-GGBS100. The grade of Conventional Concrete (CC) was fixed equivalent to that of Geopolymer concrete with the earlier specified proportions. The grade of geo polymer concrete was fixed to be M45 by doing trial and error method. The beams were analyzed for two- point loading. The parameters such as Max.Equivalent stresses (Von-Misses stress), Max.Normal Stress, Max. Normal Elastic Strain, Max.Shear Stress, Max.Shear strain and Max.central deflection were found. The present study has given a final conclusion that the performance of reinforced geo polymer concrete (RGPC) beams was better than that of equivalent grade of reinforced conventional concrete beams.

Key words: Reinforced Geopolymer concrete beams; Ansys R15.0; Max.Equivalent stresses (Von-Misses stress); Max. Normal Elastic Strain; Max.Shear Stress; Max.central deflection

I. Introduction

Concrete is the most widely used construction material after water in the world and ordinary Portland cement (OPC) is the major ingredient used in concrete. The production of cement releases large amount of carbon dioxide (CO2) to the atmosphere that significantly contributes to greenhouse gas emissions. It is estimated that one ton of CO2 is released into the atmosphere for every ton of OPC produced [1].The mechanical properties of Geo-polymer concrete(GPC) mixes with different aggregates blending and also combination of sodium hydroxide and sodium silicate solution was used as alkaline activator and conclude that optimum fine aggregate blending and also all Splitting Tensile Strength (STS) and Flexural Strength(FS) of all mixes were compared with ACI 363R, CEB-FIP and ACI 318R predicted equations [2]. The mechanical properties of Geo-polymer concrete(GPC) using granite slurry(GS) as sand replacement at different levels and cured at room temperature and concluded that optimum replacement level of GS used in place of sand and can solve the natural resources [3]. The load deflection relationships, crack pattern, ultimate load was obtained and compared with the experimental results available in literature and obtained results shows good agreement with the experimental results for comparative study of experimental and analytical results of FRP strengthened beams in flexure [2]. A study on the unretrofitted RC beam designated as control beam, RC beams retrofitted with CFRP composites in uncracked and precracked beams were studied in Ansys and The results obtained was in good agreement with the experimental plots [3]. The dynamic analysis of the composite beam was studied and values of Young Modulus, Poisson's ratio and shear modulus were determined by using Ansys [4]. Beams strengthened with Carbon Fiber Reinforced Polymer and the beams were modelled using ANSYS and the obtained results were compared with the experimental one and was found to be in good agreement [5]. The load deflection relationship, crack pattern and ultimate load were obtained and also comparison were done for the CFRP and GFRP and reported that the performance of beams with retrofitting with CFRP was better than the beams with retrofitting with GFRP by using Ansys[6]. An Analytical Investigation of Bonded Glass Fiber Reinforced Polymer Sheets with Reinforced Concrete Beam Using Ansys which has been used to study the strengthened behavior of the beam and gave the conclusion as the Deflections in the beams retrofitted with GFRP are less than RCC beam and for the same load the RCC beam with GFRP have the less stresses and strains. In the comparison cases both experimental and analytical results are coinciding [7]. The models which are analyzed has shown the same structural response and failure modes as found in the experimental investigation [8]. The modelling of RC beams with and without openings by using Ansys and were investigated on beam strength, stiffness, deformed shape, and cracked patterns by the experimental and theoretical results were concluded that the both results were showed satisfactory [9]. A theoretical and experimental study on mechanical properties and flexural strength of fly ash-geo polymer concrete using young's modulus, Poisson's ratio stress-strain relation and indirect tensile strength with four-point loading and as FEM and concluded after the results there were approximate values by comparing both the theoretical and experimental study [10].

II. Experimental study

Our objective was to determine the parameters such as Max.Equivalent stresses (Von-Misses stress), Max.Normal Stress, Max. Normal Elastic Strain, Max.Shear Stress, Max.Shear strain and Max.central deflection for reinforced beams of M45 grade of conventional concrete (CC) and geo polymer concrete having proportions of FA 50- GGBS 50and FA0-GGBS100 were FA is fly ash and GGBS is Ground Granulated Blast Furnace Slag.

A. *Materials*

The source materials for silica and aluminum were taken as Fly Ash and GGBS. Class F fly ash has been taken as it has low calcium content and is produced from RTPP, Andhra Pradesh. GGBS which is taken has been produced from Vizag Steel Plant, Andhra Pradesh. The alkaline solution taken for polymerization is sodium silicate and sodium hydroxide is taken as an alkaline activator.

B. Mix proportion:

The proportions of materials required for geo polymer concrete has been designed based on Rangan's method [11]. The proportions for geo polymer concrete is as shown in Table 1.

Materials		Mass (kg/m^3)		
		M 45	FA50-GGBS50	FA0-GGBS100
Coarse aggregate	20 mm	606.4	776	776
	10 mm	404.3	517	517
Fine aggregate		625	554	554
Cement		533.33	-	-
Fly ash (Class F)		-	204.5	0
GGBS		-	204.5	409
Sodium silicate solution		-	102	102
Sodium hydroxide solution		-	41 (10M)	41 (10M)
Water		201.35	-	-
Extra water		-	42	42
Super plasticizer		-	2.86	2.86
Alkaline solution/ (FA+GGBS) (by weight)		-	0.35	0.35

Table 1:

The proportions of geo polymer concrete have been made by varying proportions of source materials viz. FA50-GGBS50 and FA0-GGBS100.These geo polymer concrete proportions are to be compared with the conventional concrete. The grade of geo polymer concrete with the earlier specified proportions was fixed to that of conventional M45 grade concrete by doing number of trial and error procedures.

C. Reinforcement Details:

Reinforced beams were casted for earlier specified proportions of geo polymer concrete and conventional concrete. Reinforcement has four main bars of 12mm dia (2 bars at top and two bars at bottom) and stirrups of 8mm dia at 150mm c/reinforcement is of Fe500 grade steel. The beams so casted were cured for 28 days. The reinforced geo polymer concrete beams were cured in an ambient room temperature while the reinforced conventional concrete beams were cured in water.

The beams were tested after curing for two-point loading in a manually operated loading frame having capacity of 1000kN.

The same experimental beams were analyzed with the loading conditions obtained experimentally by using Ansys R15.0. The values of Ultimate load taken for analyzing is as shown in Table 2 and the values of concrete properties is as shown in Table 3.

BEAM ID	EXP. ULTIMATE LOAD AT 28 DAYS (KN)
M45(CC)	172.22
FA 50-GGBS 50	177.25
FA 0-GGBS 100	190.26

Table 2:

PROPORTION	Modulus of elasticity (MPa)	Poisson's Ratio	Density (Kg/m^3)
	28days	28days	28days
M45(CC)	33599.04	0.24	2420.74
FA50-GGBS50	35416.39	0.25	2466.67
FA0-GGBS100	36768.9	0.25	2487.23

Table 3:

III. ANALYSIS

A. Geometrical design in CATIA:

By using Catia software, Firstly a solid rectangular path has been taken according to the dimension of the experimental beam and reinforcement has been placed as in the case of experimental beam as shown in Figure 1. The positions of loading conditions and supports has been imposed.

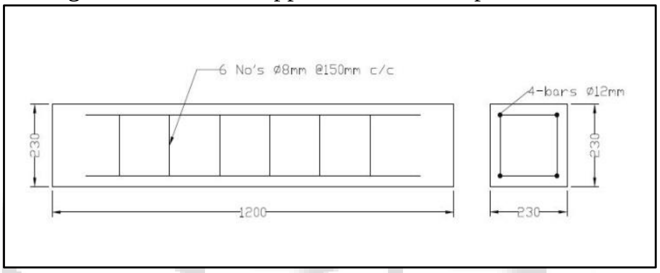

Fig. 1: Beam Considered For the Study

B. Assigning of properties to the Geometrical model:

The Geometrical model designed in catia has been imported to Ansys Workbench R15.0. The properties such as Density, Poisson's Ratio, Young's modulus of concrete and Grade of Steel obtained experimentally has been assigned to the model. The values of Density, Poisson's ratio and young's modulus of concrete is as shown in Table 3.

C. Meshing:

The geometrical model is divided into number of elements by using isoperimetric meshing is as shown in Figure2

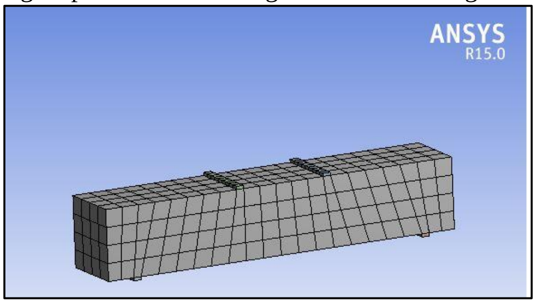

Fig. 2: Isoperimetric Meshing of the beam

D. Boundary conditions and Loads:

The boundary conditions as in the case of simply supported beam has been assigned to the model and the maximum load obtained experimentally for each proportion is assigned to the geometrical model. The maximum load obtained at 28 days of curing for each proportion is shown in the Table 2.

E. Solution:

The parameters which are to be found such as Deflection, Max.Equivalent stresses (Von-Misses stress), Max.Normal Stress, Max. Normal Elastic Strain, Max.Shear Stress and Max.Shear strain can be obtained upon selection.

IV. RESULTS & DISCUSSION

A. Deflection:

From Table 4, the deflection values have been increased for proportions M45 CC to FA50-GGBS50 and FA50-GGBS50 to FA0-GGBS100. This is due to formation of aluminium-silicate-hydrate.The formation of aluminium silicate hydrate is in geo polymer concrete specimens and also aluminuim silicate hydrate is higher in FA0-GGBS100 proportion. The Analytical deflection values have found similar to that of experimental values. And deformation is shown in Figure 3.

SPECIMEN ID	Exp. Ultimate deflection (mm)-28days	Analytical Ultimate Deflection (mm)- 28 days
M45(CC)	7.9	7.01
FA50-GGBS50	10.1	9.02
FA0-GGBS100	18.7	16.25

Table 4: Experimental and Analytical Deflection at 28-days of curing

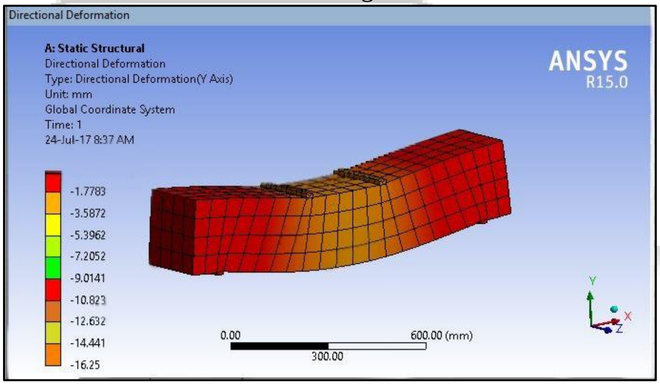

Fig. 3: Deflection of Beam

B. Max. Equivalent Stresses (Von-Misses stresses):

From Table5, it can be noticed that the values of max. equivalent stresses increased in Y-direction from FA50-GGBS50 to FA0-GGBS100. The increase in the stress is due to increase in the load carrying capacity. But in M45 grade for the small range of loading the stress taken is very high.The stresses shown in Figure 4

SPECIMEN ID	Max. Von-Misses stress (MPa)-28 days
M45(CC)	309.87
FA50-GGBS50	220.15
FA0-GGBS100	236.55

Table 5: Max Von-Misses Stress

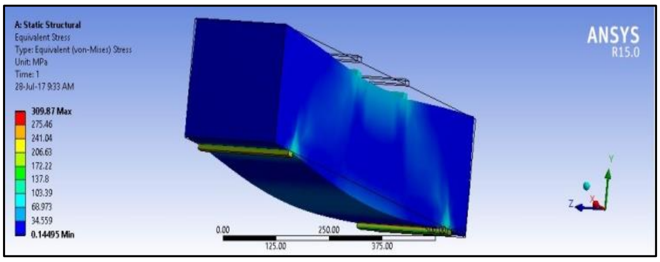

Fig. 4: Max. Von-Misses Stresses

C. Max. Normal Elastic Strain:

From Table 6, it can be notice that values of maximum normal elastic strain in Y-direction increased from M45(CC) to FA50-GGBS50 and from FA50-GGBS50 to FA0-GGBS100. The value of Max.Normal elastic strain increased 95% from M45 (CC) to FA50-GGBS50 and increased 94.5% from M45(CC) to FA0-GGBS100 as shown in Figure 5.

SPECIMEN ID	Max.Normal Elastic Strain-28 days		
	X-direction	Y-direction	Z-direction
M45(CC)	0.001233	0.0024037	0.0012161
FA50-GGBS50	0.0011	0.00012	0.00018
FA0-GGBS100	0.0011867	0.0001322	0.0001881

Table 6: Max.Elastic Strain

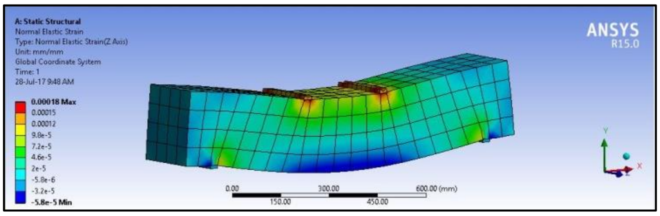

Fig. 5: Max. Elastic Strain

D. Max. Shear Stress:

From Table 7, it can be notice that values of maximum shear stress in XZ-plane has increased from M45 (CC) to FA50-GGBS50 and from FA0-GGBS100 at the bottom of supports. The Max.Shear stress is indicated in Figure 6.

SPECIMEN ID	Max.shear stress(Mpa)-28 days		
	XY-PLANE	YZ-PLANE	XZ-PLANE
M45(CC)	149.69	46.864	6.4784
FA50-GGBS50	86.759	21.629	29.613
FA0-GGBS100	93.22	23.24	31.819

Table 7: Max. Shear Stress

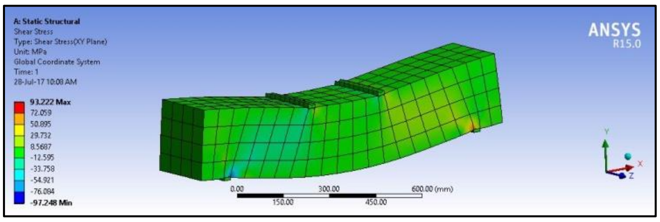

Figure 6: Max. Shear Stress

CONCLUSIONS

Based on the results of this Analytical investigation, the following conclusions can be drawn:

1) From the results the deflection values of beams are approximately near to the experimental values.
2) From the experimental results, the deflection of beams with different mix proportions has been increased for M45 to FA50-GGBS50 and FA0-GGBS100 due to (Al-Si-H) proportion is more in FA0-GGBS100.
3) It is clearly seen that the load carrying capacity of geo polymer concrete increased with the increase of GGBS replacement.
4) It is noted that M 45 (CC) has attained higher stress at lower load when compared to that of GPC.
5) It is noted that shear stress values have increased proportionally with the increase of ultimate load.

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