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Shear Behaviour of Ambient Cured Geopolymer Concrete by Varying size of Beam

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Abstract — *Geopolymer concrete (GPC's) are a new class of concrete based on a organic alumina-Silicate binder system compared to the hydrated calcium silicate binder system of concrete . They possess the advantages of rapid strength gain, elimination of water curing, good mechanical and durability properties and are additionally eco-friendly and sustainable alternative to ordinary Portland cement (OPC).The dimensions of the GPC beams are 100mm x 100mm x 1500mm. The width is varied as 100mm, 125mm and 150mm and depth is varied as 150mm , 250mm and 350 mm The effective span of the beam is 1400 mm. The beams have been designed to be critical in shear as per IS456-2000 provisions. The specimens were made considering fly-ash and GGBS as binder for 7 day strength of 60MPA. The main parameter which is considered is the variation of the width and depth . All the beams were cured under Ambient Curing for a period of 7 day . The beams were tested under a 1000KN servo-controlled hydraulic actuator. For all the beams the maximum load and deflection were in the range of 35KN to 172 KN and 16mm to 12mm respectively.*

Keywords*-Fly ash, Ground Granulated Blast Furnace Slag , Geopolymer Concrete*

1. INTRODUCTION

The fact that the production of cement adds to the pollution of environment is well known to civil engineers and environmentalists. Producing one tonne of cement requires about 2 tonnes of raw materials (shale and limestone) and releases 1 tonne of CO_2. The global release of CO_2 from all sources is estimated at 23 billion tonnes a year and the Portland cement production accounts for about 7% of total CO_2 emissions. The majority of Fly ash produced from thermal power stations in India is disposed in landfills, ponds or rejected in river systems. therefore, the abundant availability of fly ash worldwide creates opportunity to utilize this by-product of burning coal, as a substitute for OPC to manufacture concrete. In 1978 Davidots introduced geopolymer as new material for cement and describes the composition of mineral binder which is similar to zeolites with amorphous microstructure. Unlike Ordinary Portland Cement, geopolymer do not need calcium-silicate-hydrate (C-S-H) gel for matrix formation and strength, but utilize the polycondensation of silica and alumina precursors to achieve required mechanical strength level. Geo polymer materials are inorganic polymers synthesized by reaction of a strongly alkaline silicate solution and an alumina silicate source. Geo polymer is used as binder to completely replace the ordinary Portland cement in producing Geo polymer concrete(GPC). Geopolymer concrete is made by using 100% of (fly ash &GGBS) instead of cement .

Geopolymer concrete is new material to be developed for use in construction work which should be eco-friendly. The properties of Geopolymer concrete are Geopolymer concrete sets at room temperature ,It is non toxic, It has long life , It is impermeable , It is a bad thermal conductor and possess high resistance to inorganic solvents and It gives more strength. Shriram Marathe et.al [6] concluded that Water also play important role in Geopolymer concrete, similar to normal concrete produced using OPC. The amount of water used in Geopolymer concrete is to improve the workability, but it will increase the porosity in Geopolymer concrete due to the evaporation of water during curing process at elevated temperature. The Compressive strength is an essential property for all concrete where it also depends on curing time and curing temperature. When the curing time and temperature increase, the compressive strength also increases, due to a fact that at high temperature the rate of polymerization increases and hence a high strength is observed. In addition, the compressive strength of Geopolymer concrete depends on the content of fly ash fine particles (smaller than 43 μm).It has also observed that, as the fineness of fly ash increases, compressive strength also increases. For different fineness of fly-ash different test results are noted from which it is seen that the maximum strength is obtained for fly ash with fineness of $542m^2/kg$. With the addition of slag the curing temperature of geo-polymer concrete get reduce and it can be cured at room temperature also to get good strength. Rohit Zende et.al [7] concluded that with the increase in GGBS content there will be increase in the degree of workability. They also concluded that the concrete with 75% replacement of slag resulted in maximum Compressive , Split Tensile and Flexural strength values. Robina Kouser Tabassum et.al[8] concluded that the freshly prepared geopoylmer mixes were cohesive and their workability increased with the increase in the ratio of alkaline solution. They also concluded that the strength of geopoylmer concrete can be improved by decreasing the water/ binder and aggregate/binder ratios. Compressive strength obtained is in the range of 20.64-60N/ mm^2. And Split tensile strength obtained is in the range 3-4.9 N/mm^2respectively. Ambily P.S et.al[10] concluded that The mixes had good workability (225-250 mm slump). And also concluded that the mixes had compressive strength in the range of 30 to 44 MPa after 28 days of casting . The objectives of the present work is to finalize the parameters such as Amount of binder used, Molarity of NaOH, Ratio of Na_2SiO_3/NaOH and Ratio of Liquid to Binder . These finalized parameters are used in investigation of shear behaviour of geopolymer concrete beams by varying the width and depth of the beam..

2. MATERIALS USED

2.1 Basalt Aggregate :

Basalt aggregate of two fractions i.e. 20mm and 12.5 mm were used in the project with specific gravity of 2.81, Finess modulus of aggregate was 8.26, Bulk density in the loose and compacted condition was 1.49 and 1.74g/cc ,aggregates had a crushing value of 15.29%, Impact Value of 13.94% and water absorption of 2.34%. The Sieve analysis test was carried to determine the grading of the aggregate and it was found that the aggregates were nearly graded .

2.2 Fine Aggregate :

Good quality zone-II fine aggregate locally available was used having Specific gravity of 2.74, Finess Modulus of 3.60, Water Absorption of 0.61% and having Loose and Compacted Bulk Density of 1.51g/cc and 1.69 g/cc respectively. The fine aggregate conforming to IS:383-1970[8] was used.

2.3 Fly Ash

In this experimental work, low calcium, class F fly ash from Raichur thermal power station , Karnataka state was used. The Chemical Composition and Physical Properties of fly ash as supplied by supplier is presented in Table 1 and Table 2 respectively.

Table 1: Chemical Composition of Fly Ash

Sl o.	Characteristic	Fly Ash(%wt)
1.	Silica	55-65
2	Aluminium Oxide	22-25
3	Iron Oxide	5-7
4	Calcium Oxide	5-7
5	Magnesium Oxide	< 1
6	Titanium Oxide	< 1
7	Phosphorous	< 1
8	Sulphates	0.1
9	Alkali Oxide	< 1
10	Loss on Ignition	1-1.5

Table 2: Physical Properties of Fly Ash

Sl o.	Sieve Size in Micron	Weight Retained in Grams	% Passing
1.	90	95	92%
2	75	122	83%
3	45	704	62%
4	Specific Gravity	1.8	
5	Finess (Blains Air Permiability	$519m^2/kg$	

2.4 GGBS (Ground Granulated Blast Furnace Slag)

In this experimental work, GGBS from the JSW Steel Ltd of Bellary, Karnataka state was used. The chemical composition of GGBS as supplied by supplier is presented in Table 3.

Table 3: Chemical Composition of GGBS

Sl o.	Characteristics Chemical Requirements	Requirement as per BS:6699	Test Result
1.	Fineness(M^2/Kg)	275(Min)	404
2	Specific Gravity		2.88
3	45 Micron (Residue)(%)		6.60
4	Insoluble Residue(%)	1.5(Max)	0.40
5	Magnesia Content(%)	14.0(Max)	7.90
6	Sulphide Sulphur(%)	2.00(Max)	0.55
7	Sulphite Content(%)	2.50 (Max)	0.33
8	Loss on Ignition(%)	3.00(Max)	0.33
9	Manganese content(%)	2.00(Max)	0.12
10	Chloride Content (%)	0.10(Max)	0.007
11	Glass Content (%)	67(Min)	91
12	Moisture Content(%)	1.00(Max)	0.12
13	Chemical Modulus		
A	Cao +Mgo+SiO2	66.66(Min)	77.25
B	(Cao + Mgo)/SiO2	>1.0	1.38
C	Cao/SiO2	<1.40	1.13

2.5 Alkaline liquids (Sodium Hydroxide & Sodium Silicate):

2.5.1 Sodium Hydroxide : The Sodium Hydroxide (NaOH) is commonly called as caustic soda and it is available in flakes or pellets form with 97%-98% Purity. It was purchased from suppliers in bulk. According to the requirement concentration the NaOH solids were dissolved in water to make the solution.

2.5.2 Sodium Silicate : The Sodium Silicate Solution was purchased from the local supplier in bulk, and it is commonly called as liquid glass . The Chemical composition of sodium silicate used for this experimental work was Na_2O =13.7%, SiO_2 = 29.4%, and water = 55.9% by mass.

3 DETERMINATION OF GEOPOLYMER CONCRETE PARAMETERS

This Chapter presents the details of mix design, casting and Testing of Geopolymer concrete specimens.. In order to simplify the development process the compressive strength was selected as the benchmark parameter. . The mix proportions for Geopolymer concrete are given in the following Tables.

Table 4. Mix Proportion of Geopolymer Concrete

Sl No.	GPC(Liquid to Binder)	Binder in Kg/m^3		Aggregate in Kg/m^3		Sand in Kg/m^3	NaOH in Kg/m^3	Na_2SiO_3 in Kg/m^3
		Fly Ash	GGBS	12.5mm	20mm			
	G1	147.2	220.8	517.44	776.16	554.4	73.6	110.4

Trial casting of Geopolymer Concrete :

The various parameters considered for trial casting are Binder Content(Fly ash: GGBS) as 40:60, L/B Ratio= 0.5 , Molarity of NaOH= 8M and $NaSiO_3$/NaOH= 2.5. Based on the numerous trial casting the following material were finalized to be used in the preparation of the geopolymer concrete beams.

The Finalized parameter considered for the casting of the beams to Study shear Behaviour of Geopolymer Beams is as follows

- Binder(Fly Ash: GGBS)=(40:60)
- Molarity of NaOH= 8M
- Ratio of Na_2SiO_3/NaOH = 1.5

- Ratio of Liquid/Binder = 0.5

4. METHODOLOGY

4.1 Casting:

For Testing the beam in Shear ,Beams of different Sizes as shown in the table below were cast using the mix proportion of Geopolymer concrete. The moulds were filled in three layers and each layer is compacted by giving 25 blows with standard rod.

Table 5: Reinforcement Details of the Geopolymer Beams (Stirrup of 8mmϕ were Provided)

Sl No.	Top Steel	Bottom Steel	Stirrup Spacing	Breadth (B)	Depth (D)	Span/Depth
1	2nos of 8mmϕ	2nos of 10mmϕ	210mm	100	150	2.5
2	2nos of 8mmϕ	2nos of 10mmϕ	210mm	125	150	2.5
3	2nos of 8mmϕ	2nos of 10mmϕ	210mm	150	150	2.5
4	2nos of 8mmϕ	2nos of 10mmϕ	210mm	100	250	2.5
5	2nos of 8mmϕ	2nos of 10mmϕ	210mm	100	350	2.5



Reinforcement of Beams **Moulds** **During Concreting**


Beams After Demoulding **Beams After Whitewashing**

Plate 1: Photos of casting of geopolymer Beams

4.2 Curing:

The beams were demoulded after 24 hours of casting. The beams of Geopolymer concrete were kept for curing Under Ambient Curing .for 7 Days.

Plate 2: Curing of the Geopolymer concrete

4.3 Testing:

4.3.1 Testing Under Loading Frame

All the specimens were white washed in order to facilitate marking of cracks. The beam specimen were kept under loading frame with simply supported conditions at both ends. The beam were simply supported on the reaction blocks. A 1000kN servo-controlled hydraulic actuator was used to apply the monotonic loadings. All specimens were tested using two point loading . LVDTs were located at three places, one at mid span and two under load points. LVDTs were also used for each test to monitor shear strain of beams. Electrical strain gauges were used in the test. All the test specimens were tested increment loadings. After applying each increment of load, load, deflection and strain were measured simultaneously. Loading increment is continued in increments up to the failure of the specimen. The behaviour of the beam was observed carefully and the crack widths should be measured using a hand held microscope. All the measurements including deflections, strain values and crack widths should be recorded at regular intervals of load until the beam failed. The parameters such as initial cracking load, ultimate load and the deflected shape of the specimens were noted.

Controller Unit of Loading Frame

Computer to record readings

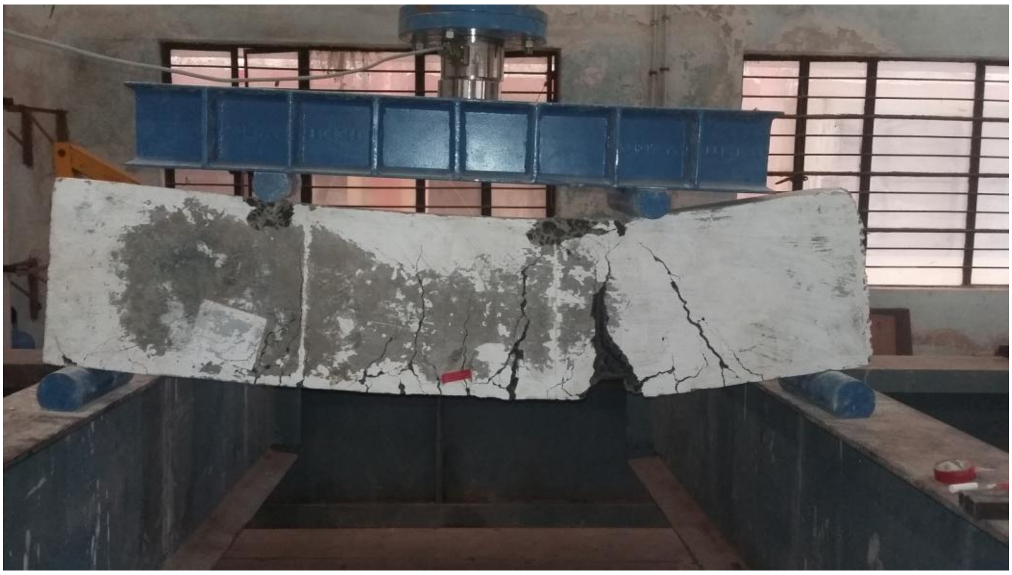


Plate 3 : Testing of beams under the servo Hydraulic Loading frame

5. Results And Discussion

Five different types of beams were cast by varying width as 100mm , 125mm and 150mm keeping the depth same and the depth was varied as 150mm, 250mm and 350mm keeping width constant The beams were tested under the loading frame.

The initial cracks were developed near the flexure zone and after considerable increments of the load, the cracks at the flexural zone stopped propagating. Whereases, the cracks in the shear span of the beam propagated towards the loading point.

The results in terms of load and maximum deflection of the beam at failure is presented in the table below

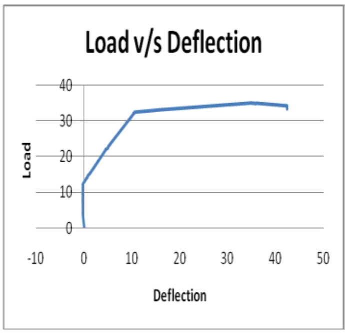
Table 6: Load and deflection values of GPC beams (Stirrup spacing at 210mm c/c)

Beam No.	Top Steel	Bottom Steel	Breadth (B)	Depth (D)	Max Load(KN)	Max Deflection (mm)
B1	2nos of 8mmϕ	2nos of 10mmϕ	100	150	34.96	16
B2	2nos of 8mmϕ	2nos of 10mmϕ	125	150	41.7	20.21
B3	2nos of 8mmϕ	2nos of 10mmϕ	150	150	53.4	38.41
B4	2nos of 8mmϕ	2nos of 10mmϕ	100	250	132.6	24.91
B5	2nos of 8mmϕ	2nos of 10mmϕ	100	350	172	12.57

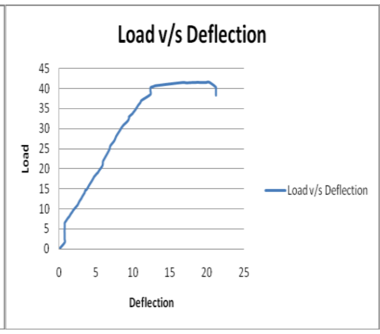
From the above results it is clear that with the increase in the width of the beam there is increase in the load carrying capacity and increase in the deflection of the beam.

From the above results it is clear that with the increase in the depth of the beam there is increase in the load carrying capacity and decrease in the deflection of the beam.

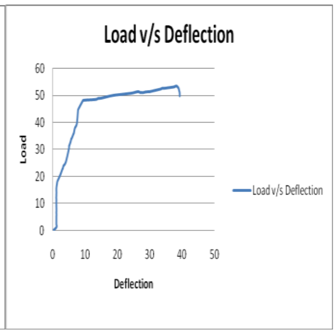
Figure: The variation of the Load v/s Deflection for all five types of Beam



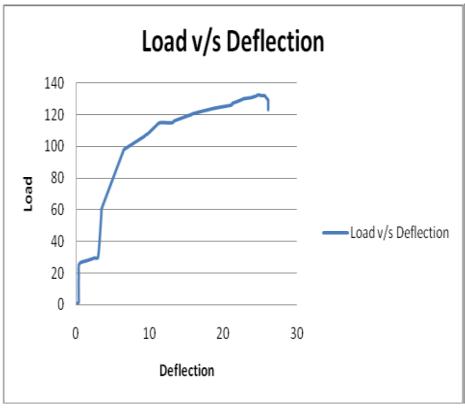
Beam B1



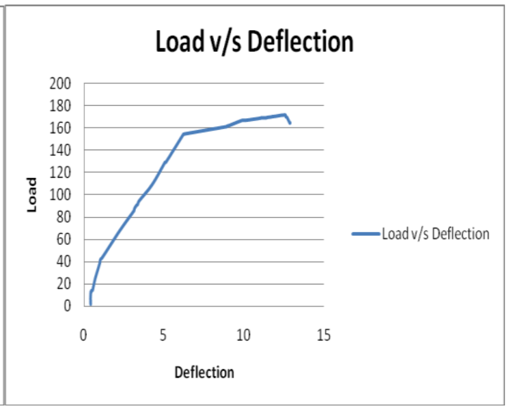
Beam B2



Beam B3



Beam B4



Beam B5

6. CONCLUSION

The following conclusions were drawn from the above experimental work:

1 It was observed that for all the beams flexural cracks appeared first at the initial stages of the loading. However as the load increased, the shear cracks were noticed in the shear zone.

2 For all the beams the cracking load was found to be within the range of 35KN to 170 KN.

3 It is observed that with the increase in the width of the beam there is increase in the load carrying capacity and increase in the deflection of the beam.

4 It is observed that with the increase in the depth of the beam there is increase in the load carrying capacity and decrease in the deflection of the beam.

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