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Flexural Behavior of Fly ash and GGBS Based Ambient Cured Geopolymer Concrete Beams

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Abstract: ***Concrete is the world's most versatile, durable and reliable construction material. Next to water, concrete is the most used material, which required large quantities of Portland Cement. Ordinary Portland Cement production is the major generator of carbon di oxide, which polluted the atmosphere. In addition to that large amount energy was also consumed for the cement production. Hence, it is essential to find an alternative material to the existing most expensive, most resource consuming Portland Cement.The study describes experimental investigation on flexural behavior of reinforced GPC. A total of eighteen beams were tested. From this, nine were of M20 mix, i.e., conventional concrete beams while nine were of geopolymer concrete,from this nine beams, three beams with the ratio of binder i.e., flyash:GGBS ratio as 75:25, other three with 70:30 while remaining three beams with 65:35. Also, 12 cubes & 12 cylinders were also casted and tested for compressive strength and split tensile strength respectively. From them, three were of conventional concrete while other nine of GPC with three different ratios as mentioned above. The reinforcement was designed considering a balanced section for the expected characteristic strength. All the beam specimens were tested under two point static loading. The studies demonstrated, the study of conventional and geopolymer concrete beams related to deflection, first load at which crack appeared and their crack patterns.***

Keywords: Geopolymer concrete, Conventional concrete, Flyash, GGBS, Deflection, Ultimate load, Crack pattern, Compressive strength, split tensile strength.

I. INTRODUCTION

The term GP was firstly applied to describe a family of alkaline alumina-silicate binders formed by the alkali activation of alumina silicate materials. GP technology was introduced by Prof. Joseph Davidovits in 1978. In our project we made an attempt to study strength properties of geo polymer concrete using low calcium fly ash and blast furnace slag in different percentages replacing the OPC. Sodium silicate and sodium hydroxide solutions of 10molarity were used as alkaline solution. Since the geo polymer binder consists entirely of fly ash and GGBS, there has been a common perception that geo polymer concrete would develop its strength very slowly or require heat curing. Portland cement systems containing high volume replacement of fly ash or GGBS and many geo-polymer binders do develop compressive strength slowly. However, this particular geo-polymer concrete develops its strength quite rapidly with design strength. Typically achieved after 7 days under laboratory conditions. Strength development at early age (up to 3 days) is sensitive to ambient temperature but adequate early strength would be expected if the concrete temperature is above approximately 20°C. This paper presents information on replacement of complete binder cement with the mixture of flyash and GGBS with balanced section. This paper covers the materials, mix proportions of conventional as well as geopolymer concrete. This paper considers reinforced GPC and conventional beams with appropriate binder composition to study the flexural parameters of beams such as , Deflection, compressive strength, load at which the first crack appeared and also its crack patterns. Eighteen beams were casted, out of which nine were designed under geopolymer concrete beams while other nine as conventional concrete beams for research. Also, compressive strength and split tensile strength of cubes and cylinders respectively were also studied. Beams designed in this research where designed as Balanced section. And the curing of GPC was ambient type was for conventional it was pond curing.

II. MATERIALS USED

1) *Sand:* Locally available river sand was used as fine aggregate. The test carried out on fine aggregates is mentioned in table below.
2) *Cement:* Ordinary Portland cement (ACC -43 grade) is used for throughout casting of normal concrete specimens.
3) *Aggregate:* A crushed ballast rock of 20mm size was used as coarse aggregate. The following test were carried out on the coarse aggregate samples.
4) *Flyash:* Fly ash used in this study was obtained from coal burning power station, Jaysingpur ,from grading zone II.
5) *GGBS:* GGBS used in this study was obtained from MIDC, Miraj.
6) *Alkaline Activator:* Alkaline activators made the day before use by mixing NaOH with aquades thus concentrating 10M. The solution was mixed with Na2SiO3 with ratio between Na2SiO3/ NaOH is 2.

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Table 1 - Results of Sand

Properties	Average value
Specific Gravity	2.55

Table 2- Results of Cement

Properties	Average value for OPC Used in percent investigation	Standard value for OPC
Fineness	0.3%	10% max
Standard consistency	32%	
Initial setting time	40 min	>30min
Final setting time	10 h	<600min

Table 3 - Results of Aggregate

Properties	Average Value
Crushing value	5.17%
Water absorption test	1.07%
Specific Gravity	2.58
Impact test	6.41%

Table 4 - Chemical Analysis of Flyash and GGBS

MATERIAL	LOI	SiO2	Al2O3	Fe2O3	CaO	MgO	Na2O	K2O	TiO2	Mn2O3	SO3
FA	0.76	62.10	27.44	4.57	0.83	0.55	0.04	1.17	1.09	0.04	0.40
GGBS	2.1	43.4	12.5	0.82	40.3	0.75	0.26	0.35	0.5	0.14	0.34

III. MIX DESIGN

Unlike OPC's, GPC's are new class of construction materials and therefore no standard mix design approaches are available for GPC. Trial Mix proportions were arrived by considering the guidelines of IS mix design and from design procedure found in literature of GPC. Parameters of research study for this mix proportion were based on binder content, alkaline /binder ratio, flyash/GGBS ratio, type of curing and age of curing(7 & 28 days). By studying reference papers& literature review's, the mix proportion for the flyash and GGBS ratio of 75:25,70:30,65:35 was studied in this research paper.

Table 5-Quantities for Geopolymer Concrete (75:25,70:30,65:35 respectively)

INGREDIENTS	QUANTITY (kg/m^3)								
	BEAM			CUBE			CYLINDER		
GGBS	1.58	1.57	2.205	0.27	0.265	0.371	0.42	0.417	0.59
FLYASH	4.73	4.72	4.095	0.80	0.796	0.69	1.26	1.252	1.085
NaOH	1	1	1	0.168	0.168	0.168	0.265	0.265	0.265
Na_2SiO_3	2	2	2	0.337	0.337	0.337	0.53	0.53	0.53
FINE AGG	14.25	14.25	14.25	2.401	2.401	2.401	3.77	3.77	3.77
COARSE AGG	26.46	26.46	26.46	4.459	4.459	4.459	7.013	7.013	7.013
TOTAL WATER	2.167	2.167	2.167	0.365	0.365	0.365	0.574	0.574	0.574
EXTRA WATER	0.07	0.07	0.07	0.013	0.013	0.013	0.02	0.02	0.02

Table 6 - Quantities For Conventional Concrete

INGREDIENTS	QUANTITY (kg/m^3)		
	BEAM	CUBE	CYLINDER
CEMENT	3.78	1	1.66
FINE AGG	9.85	2.98	4.4
COARSE AGG	13.32	3.74	5.9
WATER	2.00	0.6	0.9
ADMIXTURE	0.045	0.01	0.02

IV. PREPARATION OF TEST SPECIMEN AND CURING

The cube of 150X150X150 mm^3, cylinders of 150 mm X 300 mm and beams of 900X150X150 MM3 were casted . Three for conventional type study and three for GPC study in case of cube and cylinders while for the beams, nine were casted for conventional study and nine for GPC. Hand mixing was used. The concrete was placed in the moulds in three layers of equal thickness and each layer was vibrated until the concrete was thoroughly computed. Specimens were demoulded after 24 hrs. the conventional beams were water cured while GPC beams were ambient cured for 28 days after casting. After curing, the test specimens were tested for compressive strength, split tensile strength, deflection, first crack load & cracking patterns were observed.

V. EXPERIMENTAL INVESTIGATION

1) *Specimen Details:* The beam specimen were 150mm wide, 150mm deep in cross section. They were 900mm in length. All the beams were designed for balanced section . T he clear cover of the beam was 25mm, while cube of 150 mmX 150mm X 150mm and cylinder of 150mm X 300mm.
2) *Reinforcement Details:* High yield strength deformed steel bars of diameter 10 mm was used as the longitudinal reinforcement in the specimens. Two legged vertical stirrups of 6mm diameter at a spacing of 100 mm centre to centre were provided as shear reinforcement. Four stirrups were provided in each beam specimen to resist shear failure.

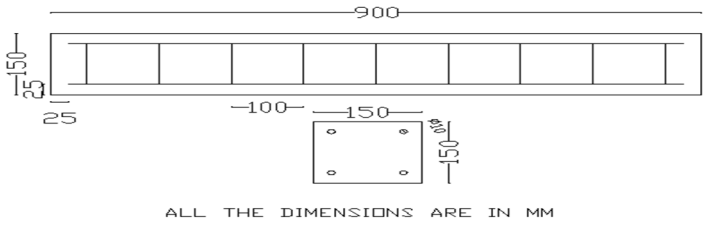
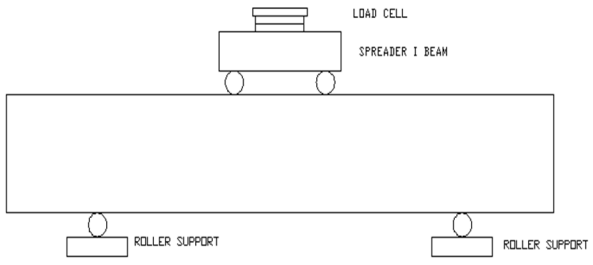


Figure 1. Geometry of beam specimen (All dimensions are in mm)

VI. TEST PROCEDURE

The image of test setup is shown. The beam specimen was mounted on UTM of 1200 KN capacity. The behavior of the beam was observed carefully and the crack patterns, load applied , deflection were observed. The load was gradually applied and the behavior of the beam was observed carefully, and the first crack was also observed and recorded.



TYPICAL BEAM LOADING DIAGRAM UNDER UTM

Figure 2 – Test Setup for Flexural test

VII. RESULT AND DISCUSSION

1) *Compressive Strength Of Conventional Concrete Cubes:* Compressive test of concrete has been taken by testing cube of size 150x 150x150mm after 7 and 28 days of curing.
2) *Splittensile Strength Test On Conventional Concrete Cubes: Split* tensile strength test was taken on cylinders after 7 and 28 days respectively. Whose results are discussed below

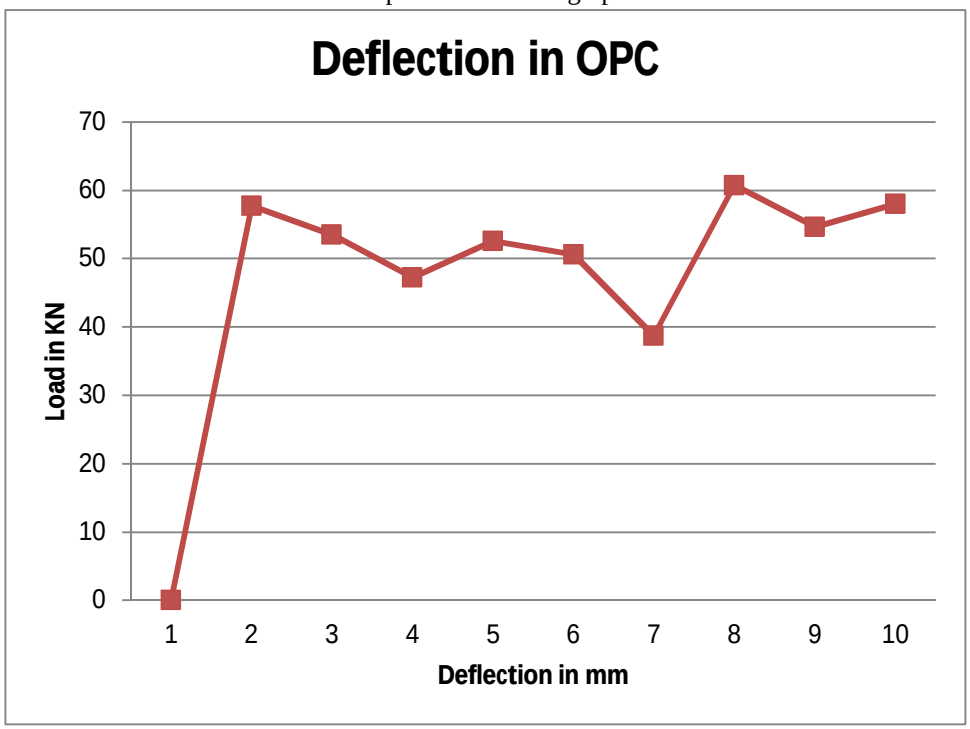
Table 7 – Average Value of Compressive strength:

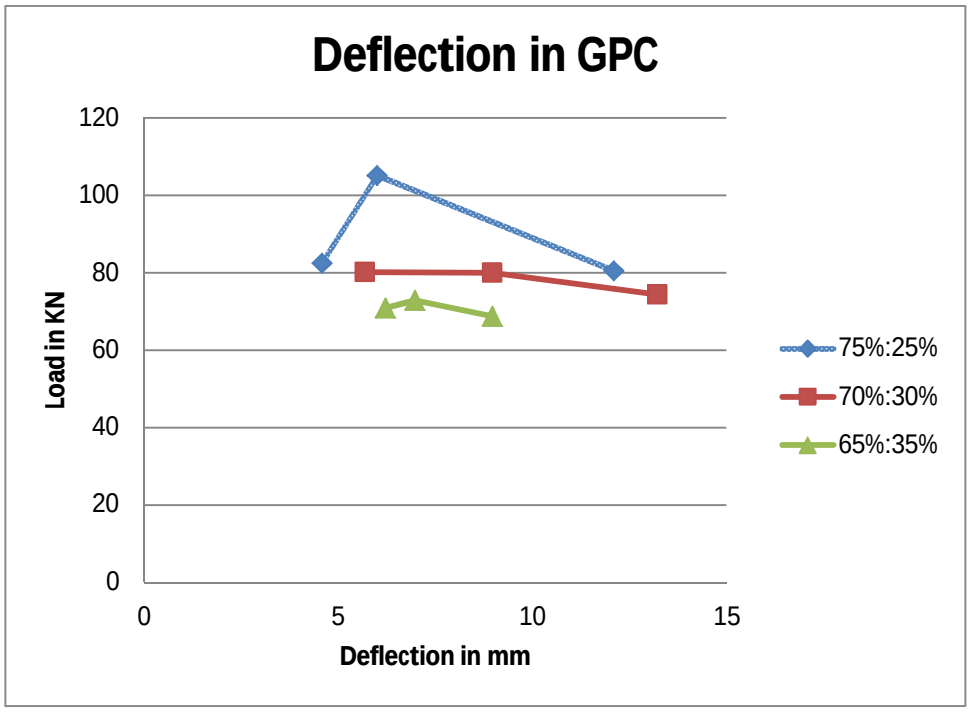
Sr No.	Concrete	7 days strength	28 days strength	Average(MPa) 7	28
1	Conventional	6.7	29.02		
2	Concrete	6.8	30.22	6.7	30.60
3		6.8	32.57		
1	Geopolymer	16.96	39.65		
2	Concrete	16.58	41.36	16.47	42.85
3	(75:25)	15.86	47.56		
1	Geopolymer	18.71	50.26		
2	Concrete	17.52	50.02	17.85	49.68
3	(70:30)	17.32	48.77		
1	Geopolymer	19.21	58.2		
2	Concrete	18.98	63.6	18.74	60.44
3	(65:35)	18.02	59.52		

Table 8- Average value of Split Tensile Strength

Sr No.	Concrete	7 days strength	28 days strength	Average(MPa) 7	28
1	Conventional	1.11	3.26		
2	Concrete	1.07	3.78	1.1	3.55
3		1.12	3.63		
1	Geopolymer	1.38	3.02		
2	Concrete	1.25	3.11	1.25	3.06
3	(75:25)	1.12	3.06		
1	Geopolymer	1.39	3.18		
2	Concrete	1.46	3.19	1.4	3.23
3	(70:30)	1.37	3.34		
1	Geopolymer	1.43	3.86		
2	Concrete	1.54	3.55	1.48	3.76
3	(65:35)	1.49	3.89		

Graph 1- Deflection graph



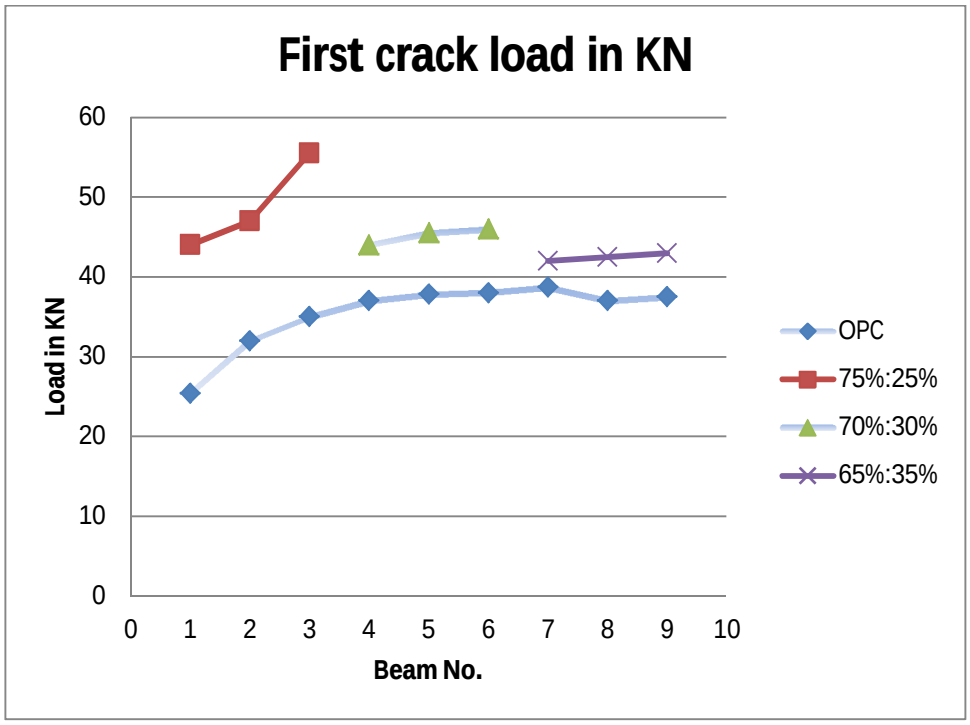


7) Compressive Strength of Geopolymer Concrete Cube:Compressive test of concrete has been taken by testing cube of size 150x 150x150mm after 2 days of heat curing. The corresponding compressive strength of m20 concrete is as follow:

8) Split tensile strength test on geopolymer concrete cylinders: Split tensile strength test of cylinders for geopolymer concrete beams is taken after 7 and 28 days of curing.

9) Flyash and GGBS proportion taken here in this project is 75:25, 70:30, 65:35.

Graph 2-First Crack load comparison between OPC and GPC:



A. Crack Pattern in GPC and OPC Beams

1) Failure in both the cases of beam i.e., GPC and Ordinary concrete beams is Same.
2) Both the cases, failure was diagonal tension failure as cracks occurred near the supports.
3) The bending collapse occurred because the bond between GP binder with aggregate is more solid compared to cement ties with aggregate in ordinary concrete.
4) The failure in all cases was initiated by yielding of the tension steel followed by crushing of concrete in the compression face.
5) GPC has high compressive strength than ordinary concrete.
6) In some cases, few cracks appeared in the flexural zones.
7) At failure loads, beam deflected significantly.

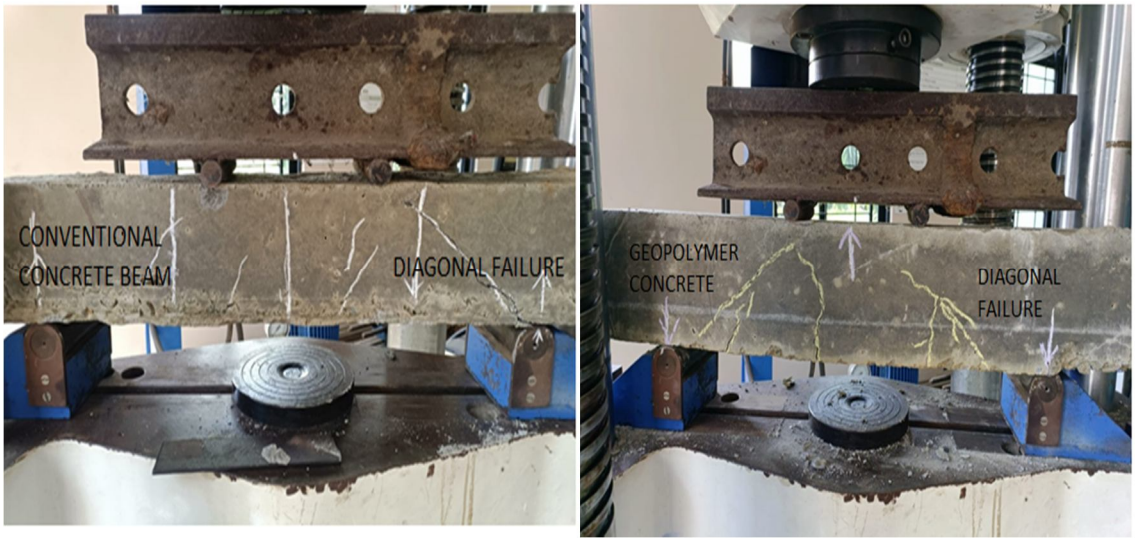
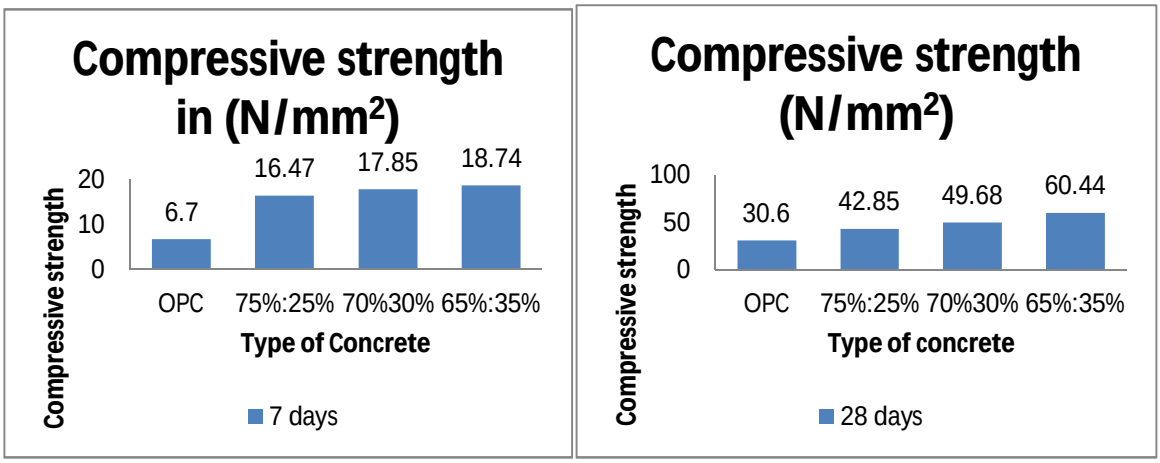


Figure 3 – Crack Pattern on beam

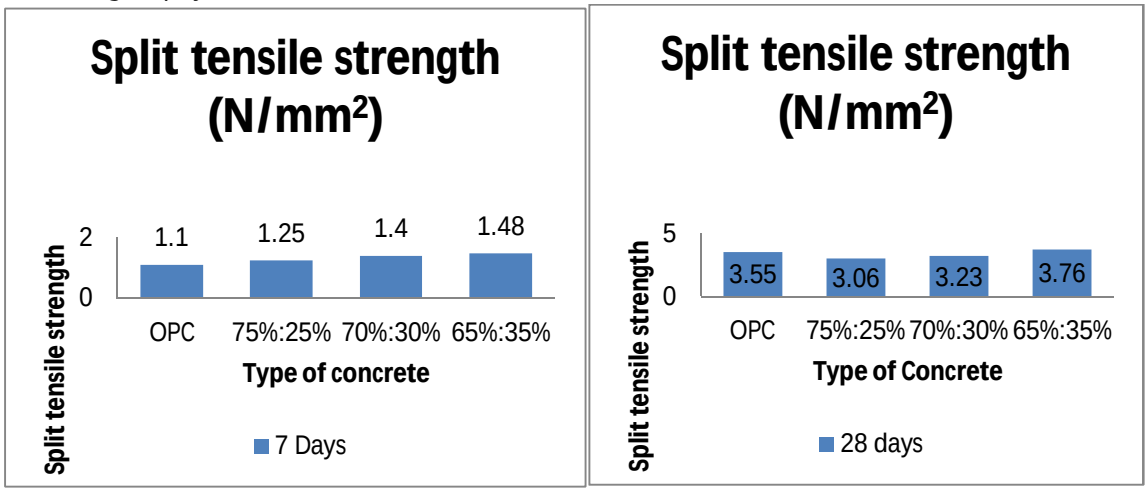
B. Comparision Between Conventional And Geopolymer Concrete

1) Compressive Strength of Cubes



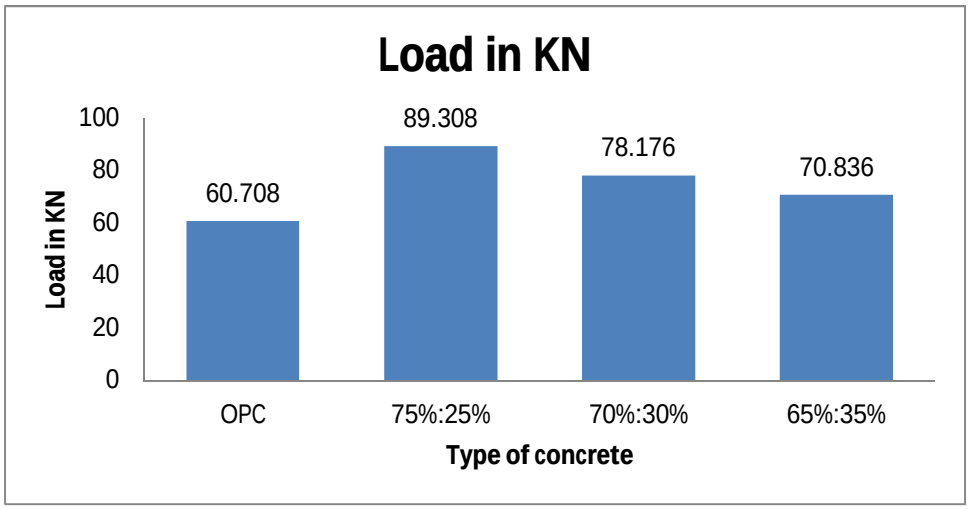
Bar graph 1- Bar Graph of Comp Strength of Cube

2) Split Tensile Strength of Cylinders



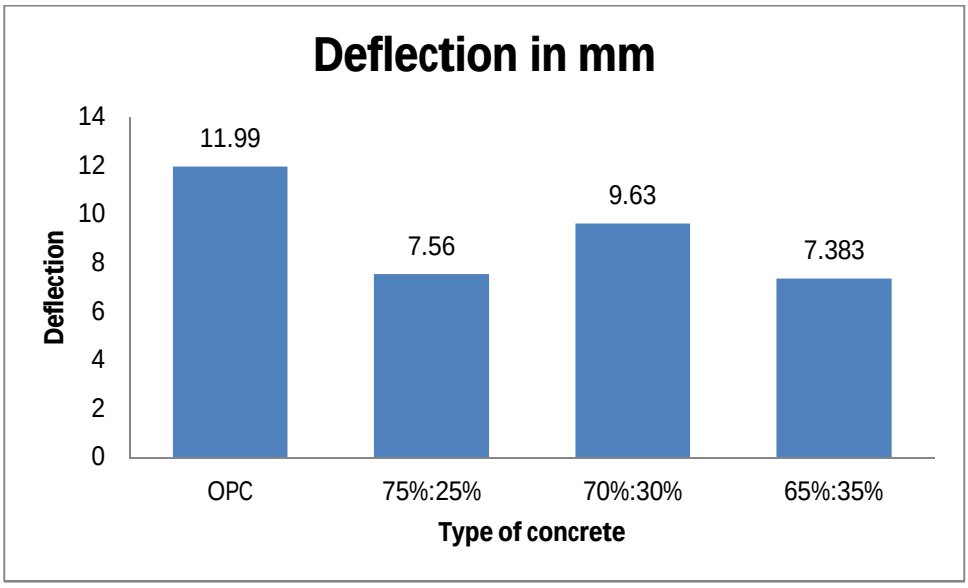
Bar graph 2 - Bar graph of Split Tensile strength of cylinders

3) Ultimate Load Of Conventional And Geopolymer Concrete



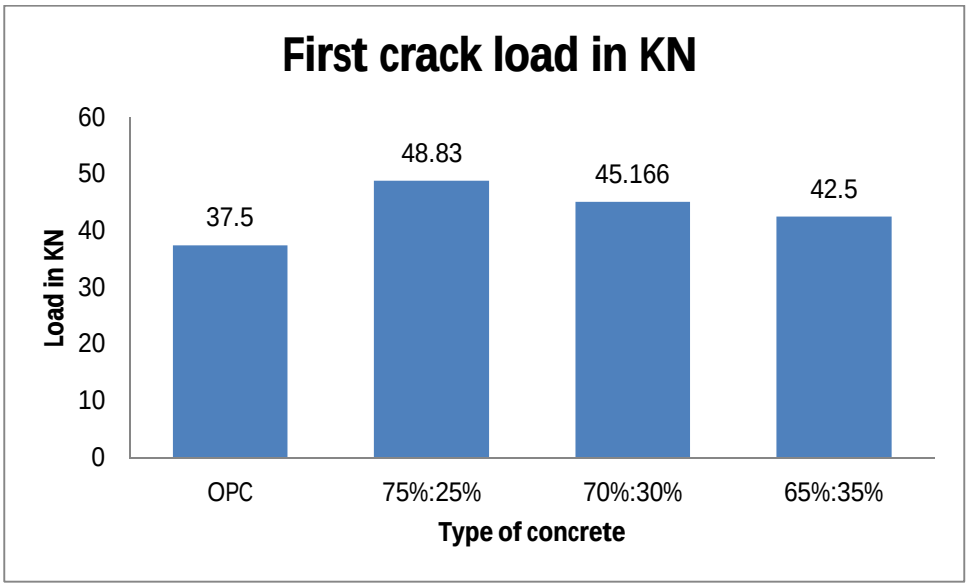
Bar graph 3 -Bar Graph of Loads

4) Deflection



Bar graph 4 - Bar graph of Deflection in Beams

5) First Crack Load on Beams



Bar graph 6 - Bar Graph of First Crack load in Beams

VIII. RESULT SUMMARY

1) The slump of geopolymer is 25 mm and compared to conventional concrete is 55mm.
2) The compressive strength of conventional concrete cubes after 7 days is 6.8 N/mm^2 while after 28 days was 30.22 N/mm^2. Also, compressive strength of geopolymer concrete after 7 days of mixes 75:25,70:30 &65:35 are 16.47 N/mm^2,17.85 N/mm^2 & 18.74 N/mm^2 respectively while after 28 days are 42.85 N/mm^2,49.68 N/mm^2,60.44 N/mm^2, respectively.
3) The split tensile strength cylinders of conventional concrete after 7 days is 1.05 N/mm2 while after 28 days is 3.5N/mm^2.Also tensile strength of geopolymer concrete after 7 days of mixes 75:25,70:30 &65:35 are 1.25 N/mm^2,1.4 N/mm^2 & 1.48 N/mm^2 respectively while after 28 days are 3.06 N/mm^2,3.23 N/mm^2,3.46 N/mm^2, respectively.
4) Average ultimate load applied on Conventional concrete beams is 55 KN while that of geopolymer concrete beams is 80 KN.
5) Deflection of GPC beams of the ratios 75:25, 70:30, & 65:35 in average of all the tested beams in the group of three is 7.56mm, 9.63mm & 7.383mm respectively, while that of conventional concrete beams is 11.99mm.

6) Crack pattern was Diagonal tension failure in both the types of beams while in some cases it was flexural failure.
7) Average value of first crack appeared in conventional concrete beams is 37 KN while that of GPC beams with different ratios is 75:25 as 48.83 KN, 70:30 as 9.63 KN &that of 65:35 is 42.5 KN.

IX. CONCLUSION

The experimental investigation carried out to study properties of geopolymer concrete & conventional concrete and concluded the following:

1) The split tensile strength of geopolymer concrete is slightly more than that of conventional concrete. Split tensile strength of mix 65:35 is more than that of 70:30 and 75:25, tested after 7 as well as 28 days of curing.
2) The split tensile strength of mix 65:35 is more than other two mixes.
3) The compressive strength of GPC cubes is greater than that compressive strength of conventional beams.
4) Compressive strength of mix 65:35 is more than other two mixes.
5) Comparing Load and Deflection rates, deflection of GPC beams is slightly less as load bared by GPC beams is more. Deflection in conventional beams is slightly more as load bared is less as compared to GPC.
6) First crack occurred in GPC at that particular load is 16% greater than that of conventional concrete.
7) Crack pattern observed was Diagonal tension failure in both the types of beams while in some cases it was flexural failure.

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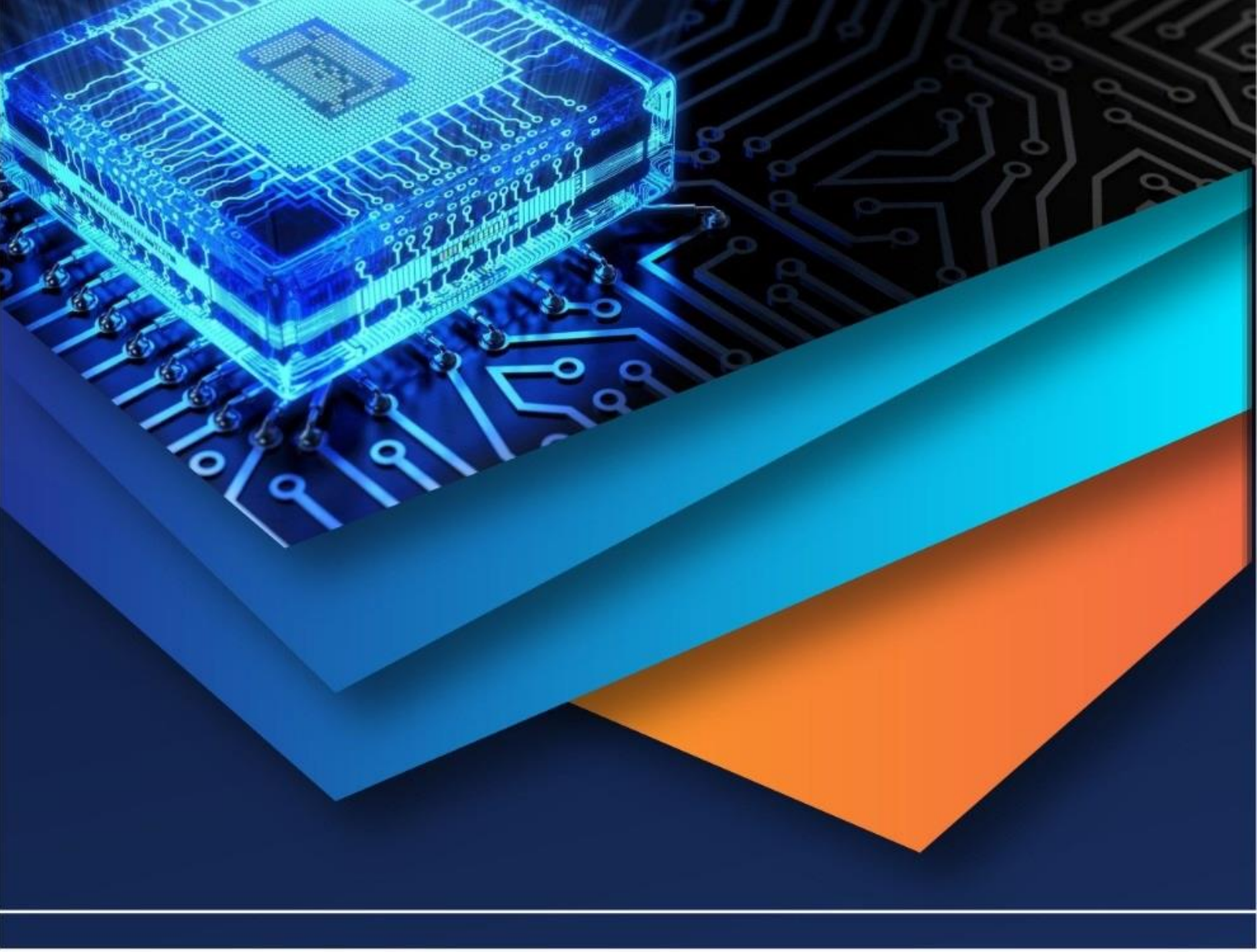

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