COMPARATIVE STUDY ON FLEXURAL BEHAVIOUR OF GEOPOLYMER CONCRETE MADE OF MARINE AND DISTILLED WATER ALKAINE BASED SOLUTION

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Abstract – *Geopolymer cement Concrete is made from Utilization of industrial waste material such as fly ash and GGBS (ground granulated blast furnace slag).The geo-polymer concrete is reducing the cement usage of the worldwide and reducing the CO_2.The cement have released 1-ton cement and releases the 1-ton CO_2. The main reason for using GPC is to replace cement. The fully replacement of fly ash and after that GGBS is partially replacement with different percentages 0, 10, 20, 30, 40 and 50 are used in this study. The alkali solution is used for activation of fly ash and GGBS leading to polymerization with results in geopolymer binder sodium hydroxide and sodium silicate solution are prepared and used for mixing of GPC. When the calculate mechanical properties and the casting the beams and after 28 days test under universal testing machine.*

Key words:- **Fly ash, GGBS, Sodium hydroxide, sodium Silicate solution, UTM.**

1. INTRODUCTION

The major problem that the world is facing today is environmental pollution. The production of OPC will cause the emission of pollutants which results in environmental pollution. During the manufacture of OPC, calcinations of limestone and combustion of fossil fuel, releases large volume of CO_2 into the atmosphere. It was estimated that the production of one ton of OPC emits one ton of CO_2 into the atmosphere. However, OPC is still the main binder in concrete construction prompting a search for more environmentally friendly materials. There are only two possible ways to reduce the cement usage in concrete are by partially replace the cement in concrete with suitable Supplementary Cementing Materials and by developing an alternative Material.

1.1 GEOPOLYMER CONCRETE

The term Geopolymer was introduced to the world by Davidovits of France in 1978. Geopolymers are Aluminosilicate inorganic polymers, which are formed from polymerisation of Aluminosilicates with Alkaline solutions. The polymerisation process involves a substantially fast chemical reaction under alkaline condition on Si-Al minerals, that results in a three-dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds. Alkaline Liquids – Ex: $NaOH + Na_2SiO_3$ (or) $KOH + K_2SiO_3$

Sodium based solutions are cheaper than potassium based solutions. It utilizes the polymerization process of silica & alumina to attain structural strength.

2. MATERIALS USED

Materials required for this concrete preparation are as follows:

1. Cement
2. Fine Aggregate
3. Coarse Aggregate
4. Class-F Fly Ash
5. Ground Granulated Blast Furnace Slag (GGBS)
6. Sodium Hydroxide (NaOH)
7. Sodium Silicate (Na_2SiO_3)
8. Super Plasticizer
9. water

2.1 Cement

Cement is a binding material and generates the heat of hydration for process and mixing of concrete.The physical properties obtained from the investigations are tabulated in Table 1 as per IS 4031.

Table 1: Test results of cement

S.No	Description	Values
1	Specific Gravity	3.13
2	Normal Consistency of the cement	30%
3	Initial Setting Time	49 min
4	Final Setting Time	495 min
5	Fineness of cement	6 %

2.2 Fine Aggregate

Locally available river sand in dry condition was used as a fine aggregate throughout the investigation. River sand having particle size less than 4.75mm and passing through 4.75mm was used. Sand used in this study conformed to Zone-II of Indian standard specifications IS 383-1970.

Table 2: Test results of Fine Aggregate

S.No	Description	Values
1	Specific Gravity	2.62
2	Grading Zone	II
3	Fineness Modulus	2.6

2.3 Coarse Aggregate

Crushed granite stones different sizes of coarse aggregates are grading by the machines and the used for the work. This project 20 mm and 10 mm aggregate used to complete project. The gradation of the coarse aggregate was determined by sieve analysis as per IS code and presented in the project.

Table 3: Test results of Coarse Aggregate

S.No	Description	Values
1	Specific Gravity	2.85
2	Maximum Aggregate Size used	20 mm
3	Minimum Aggregate Size used	10 mm

2.4 Class-F Fly Ash

Fly ash is a by-product produced from the combustion of coal in an electrical generation station. According to ASTM C 618 (2003) the fly ash is classified into class-N, class-C, and class-F. Class-N relates to raw or calcined pozzolans, whereas fly ash produced from burning lignite or sub bituminous coal is class-C and the one produced from burning anthracite or bituminous coal is class-F. Fly ash is classified based on the calcium oxide (CaO) content and the sum of silicon oxide (SiO_2), aluminum oxide (Al_2O_3) and iron oxide (Fe_2O_3). In this present study Class-F (Low Calcium) fly ash produced from NTPS Vijayawada, Andhra Pradesh was used.

2.5 Ground Granulated Blast Furnace Slag

Ground Granulated Blast furnace slag (GGBS) is a by-product for manufacture of the iron companies. This is the waste product of the iron industries. The cost of the GGBS is the low compare to cement .This have high durability and best reaction is sodium based alkaline solutions.. GGBS used in this present investigation is bought from local supplier ASTRRA Chemicals Chennai.

2.6 Alkaline Liquids

The alkaline solution is prepared by the sodium silicate and sodium hydroxide used for alkaline activator (AAS). The solution is prepared by the distilled and marine water for preparation of alkaline solution. The role of AAS is to dissolve the reactive portion of source materials Si and Al present in fly ash and GGBS good in polymerization react. The sodium hydroxide (NaOH) was taken in the form of pellets are round shaped and opened in the air at normal temperature the easily dissolved. The NaOH molecular weight is 40. This project 8M is taken because of temperature at the time of solution prepared. The 1 liter solution (8 x 40 = 320) is taken into the sodium Hydroxide pillets. The alkaline solution is prepared used the distilled or marine water sodium hydroxide pellets are dissolved after adding the sodium silicate solution to the solution that is called as alkaline solution. The sodium silicate solution was Na2O=14.7%, SiO2=29.4%, and water 55.9% by mass. Super plasticizers are water reducers which are capable of reducing water contents by about 30%, the super plasticizer used in this present study was CONPLAST SP 430 manufactured by M/s FOSROC India Pvt.Ltd.

2.7 Water

Clean potable water was used for making concrete. This project distilled and marine water is used to casting of specimens. Water fit for drinking is generally considered fit for making concrete. Water has two functions in a concrete mix. Firstly water permissible limits observed IS: 456-2000.

3. TEST AND RESULTS

3.1 Hardened Concrete

The geopolymer concrete is the casting by using the alkaline based solution and the different percentages of geopolymer Concrete in different sets and curing GPC is 7,14, and 28 days. And testing the GPC specimens are 7,14 and 28 days.

1. Compression Strength test
2. Split Tensile Test
3. Flexural Strength Test

The results of above test after curing period for 7days, 14days and 28 days are tabulated below. The notations for the specimens of the nominal concrete and the marine and distilled water based geopolymer concrete are

NC1 = Nominal Concrete Mix
GP1 = GPC - I Fly ash - 100% GGBS - 0%
GP2 = GPC - I Fly ash - 90% GGBS - 10%
GP3 = GPC - I Fly ash - 80% GGBS - 20%
GP4 = GPC - I Fly ash - 70% GGBS - 30%
GP5 = GPC - I Fly ash - 60% GGBS - 40%
GP6 = GPC - I Fly ash - 50% GGBS - 50%

Table 4: Compression Strength of Geopolymer concrete added with distilled water

Design Mixes	COMPRESSION STRENGTH (N/mm²)		
	7 days	14 days	28 days
NC1	30.66	35.84	40.44
GP1	10.18	15.12	20.18
GP2	18.65	21.32	28.88
GP3	23.24	27.55	33.77
GP4	28.14	32.00	38.67
GP5	32.74	37.00	42.66
GP6	37.62	42.81	46.81

Chart 1: Compression Strength of Geopolymer concrete added with distilled water

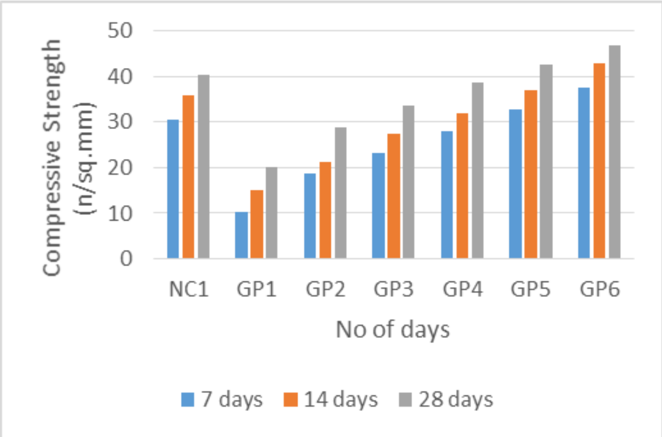


Table 5: Split Tensile Strength of concrete added with distilled water

Design Mixes	SPLIT TENSILE STRENGTH (N/mm²)		
	7 days	14 days	28 days
NC1	3.36	4.62	5.60
GP1	1.33	1.81	2.42
GP2	1.85	2.58	3.25
GP3	2.37	3.43	4.14
GP4	3.06	4.24	5.04
GP5	3.72	4.95	5.98
GP6	4.52	5.61	6.97

Chart 2: Split Tensile Strength of concrete added with distilled water

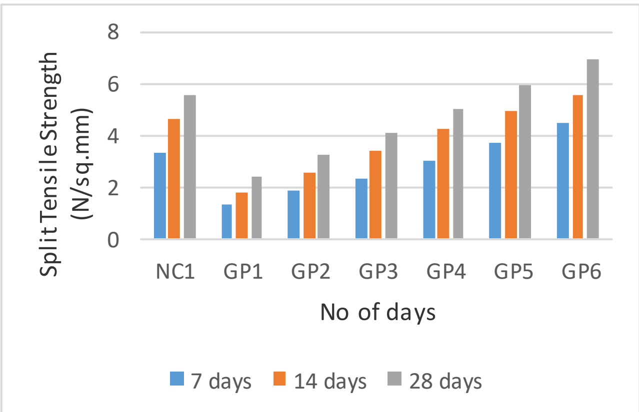


Table 6: Flexural Strength of concrete added with distilled water

Design Mixes	FLEXURAL STRENGTH (N/mm²)		
	7 days	14 days	28 days
NC1	3.99	4.55	5.12
GP1	2.16	2.67	3.57
GP2	2.98	3.46	4.56
GP3	3.45	3.93	4.93
GP4	3.91	4.61	5.45
GP5	4.43	5.16	5.78
GP6	5.05	5.75	6.23

Chart 3: Flexural Strength of concrete added with distilled water

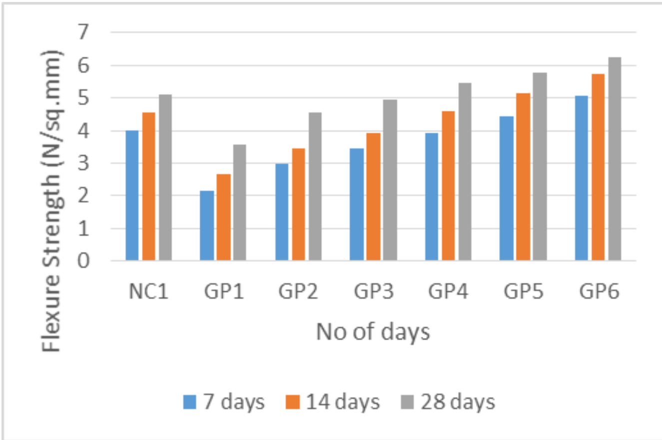


Table 7: Compression Strength of Geopolymer concrete added with Marine water

Design Mixes	COMPRESSION STRENGTH (N/mm²)		
	7 days	14 days	28 days
NC1	26.1	31.44	34.40
GP1	8.00	11.7	16.60
GP2	14.21	16.29	25.00
GP3	18.81	22.36	29.62
GP4	22.66	28.00	33.33
GP5	27.7	34.20	36.58
GP6	32.88	37.33	42.06

Chart 4: Compression Strength of Geopolymer concrete added with Marine water

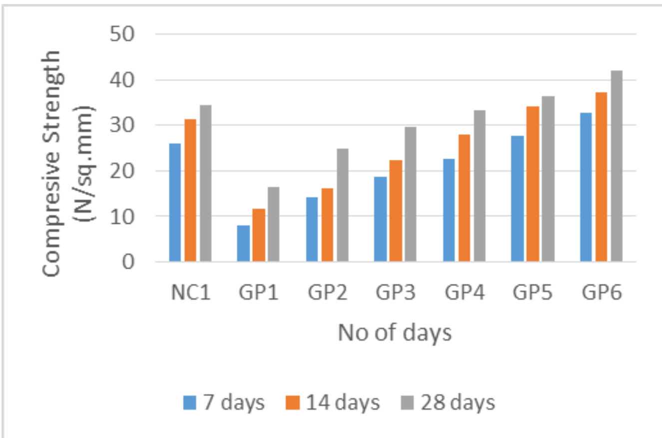


Table 8: Split Tensile Strength of concrete added with Marine water

Design Mixes	SPLIT TENSILE STRENGTH (N/mm²)		
	7 days	14 days	28 days
NC1	2.71	3.46	4.23
GP1	0.84	1.24	1.76
GP2	1.29	1.76	2.35
GP3	1.79	2.30	2.99
GP4	2.44	2.97	3.96
GP5	3.06	3.79	4.49
GP6	3.82	4.35	5.75

Chart 5: Split Tensile Strength of concrete added with Marine water

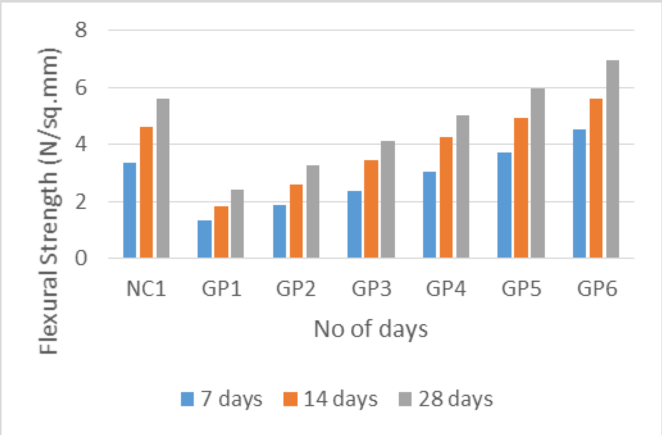
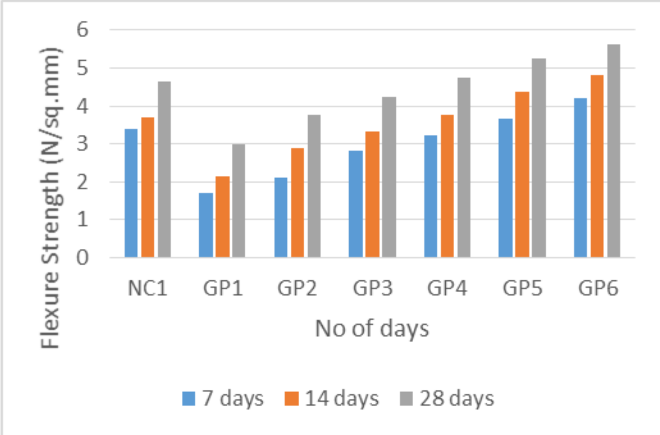


Table 9: Flexural Strength of concrete added with Marine water

Design Mixes	FLEXURAL STRENGTH (N/mm2)		
	7 days	14 days	28 days
NC1	3.38	3.70	4.66
GP1	1.71	2.15	2.98
GP2	2.11	2.88	3.78
GP3	2.83	3.33	4.25
GP4	3.21	3.76	4.75
GP5	3.68	4.36	5.26
GP6	4.20	4.83	5.61

Chart 6: Flexural Strength of concrete added with Marine water



The beams are designed assumed as 50 KN. The OPC and GPC is beams are casted marine and distilled water based Alkaline solution used. The beams are tested after 28 days And deflection values are calculated.

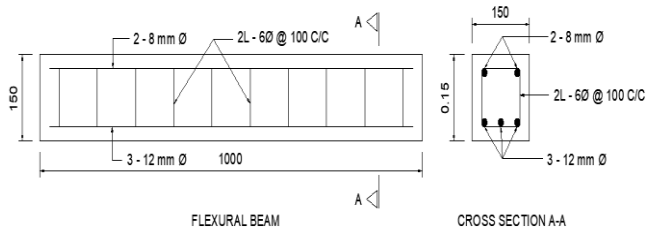


Figure 3: Beam Details

Four beams are casted with optimum values of strength Results. The distilled OPC and GPC and Marine OPC and GPC are casted and testing under UTM machine.

N-1 = Distilled water based GPC beam
N-2 = Distilled water based OPC beam
M-1 = Marine water based GPC beam
M-2 = Marine water based OPC beam

Figure 1: Testing of beam in UTM

Figure 2: Marking Crack Pattern

Table 10: Load Vs deflection results for the beam N-1

S.No	Load (kN)	Deflection (mm)	Remarks
1	0	0	
2	5	0.257	
3	10	0.396	
4	15	0.574	
5	21	0.623	FIRST CRACK
6	25	0.757	
7	30	0.841	
8	35	0.939	
9	40	1.026	
10	45	1.228	
11	50	1.558	
12	55	1.763	
13	60	2.124	
14	65	2.523	
15	70	2.839	
16	75	3.132	
17	80	3.52	
18	85	3.69	ULTIMATE LOAD

Chart 7: Load Vs deflection Curve for the beam N-1

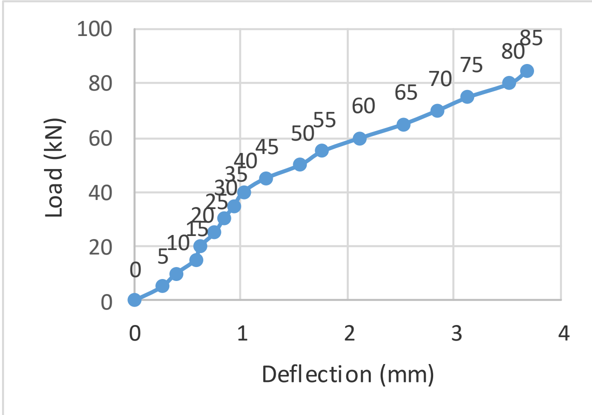


Table 11 Load Vs deflection results for the beam N-2

S.No	Load(kN)	Deflection(mm)	Remarks
1	0	0	
2	5	0.168	
3	10	0.332	
4	15	0.418	
5	20	0.474	
6	27	0.531	FIRSTCRACK
7	30	0.596	
8	35	0.682	
9	40	0.749	
10	45	1.022	
11	50	1.358	
12	55	1.632	
13	60	2.142	
14	65	2.724	
15	70	3.122	
16	75	3.53	ULTIMATELOAD

Chart 8 Load Vs deflection chart for the beam N-2

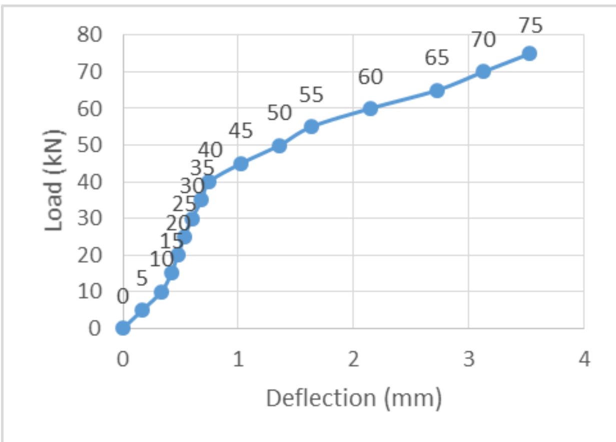


Table 10 Load Vs deflection results for the beam M-1

S.No	Load(kN)	Deflection(mm)	Remarks
1	0	0	
2	5	0.267	
3	10	0.428	
4	17	0.612	FIRSTCRACK
5	20	0.741	
6	25	0.885	
7	30	0.983	
8	35	1.355	
9	40	1.532	
10	45	1.885	
11	50	2.152	
12	55	2.534	
13	60	2.966	
14	70	3.523	ULTIMATELOAD

Chart 11 Load Vs deflection chart for the beam M-1

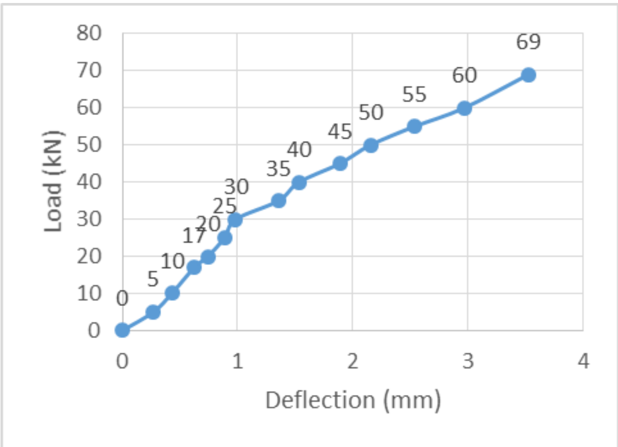


Table 10: Load Vs deflection results for the beam M-2

S.No	Load(kN)	Deflection(mm)	Remarks
1	0	0	
2	5	0.238	
3	10	0.465	
4	15	0.497	
5	20	0.512	FIRSTCRACK
6	25	0.838	
7	30	0.975	
8	35	1.274	
9	40	1.693	
10	45	2.578	
11	50	3.243	
12	55	3.632	ULTIMATELOAD

Chart 11 Load Vs deflection chart for the beam M-2

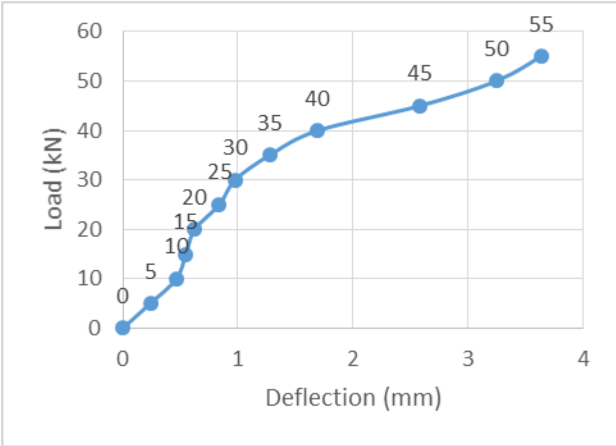


Table 12 Comparison of Beams casted with Nominal Concrete and Geopolymer Concrete

BEAM ID	CRACKING LOAD (KN)	ULTIMATE LOAD (KN)
N-1	18	85
N-2	22	75
N-3	20	65
N-4	23	55

The deflections are 0.62, 0.53, 0.61 and 0.51 for beam casted with nominal concrete, Geopolymer concrete and theoretical beam design respectively. By comparing the practical values obtained from the test results with the theoretical values from beam design, we observe that deflection of the normal concrete and Geopolymer concrete , the GPC have attain the more strength values.

5. CONCLUSIONS

The following main conclusions were drawn from the experimental results obtained this study:

- ❖ With the increase in GGBS content up to 50%, compressive strength, split tensile strength and flexural strength were tend to increased. By keep on increasing the percentage of GGBS, strength values will increase.
- ❖ Fly ash and GGBS based GPC mixes attained enhanced mechanical properties at ambient room temperature curing than the conventional concrete.
- ❖ When the GPC percentage of F60G40 values is equal to the nominal mix M 30 Grade of concrete.
- ❖ The comparison of nominal mix, the percentage of increases in compressive strength for distilled GPC is increases up to 5.48% and marine is marine GPC is 7.27%.Spilt tensile of distilled GPC increases 6.78 % and marine is 6.14%. The flexural strength of distilled GPC and marine GPC is increases 12.8%.
- ❖ The comparison of N-1 beam to N-2 beam, the N-1 value is increased by 13.3%, the comparison of M-1 beam to

M-2 beam, the M-1 value is increased by 27.2% and the comparison of N-1 beam to N-2 beam, the N-1 value is increased by 21.42%.

- By comparison the normal values obtained from the test results with the theoretical values from beam design, we observe the deflection of distilled based RCC is 0.53 and distilled based GPC is 0.62 and marine based RCC is 0.51 and marine based GPC is 0.61, which are less than the theoretical value.
- From the test results the failure of GPC beams are more ductile than RCC beams accompanied by crushing of the concrete in the compression zone.
- All the beams were failed in flexural mode by yielding of the tensile steel followedby the crushing of concrete in the compression face.

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