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Experimental studies of Ambient Cured Geopolymer Concrete

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Abstract: *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 In the présent work, experimental investigations were performed such as compressive strength test on the ambient cured geopolymer concrete. By trial casting geopolymer concrete paramètres were finalized such as binder (Fly Ash : GGBS)as (40 :60), molarity content as 8M, Ratio of Na_2SiO_3/NaOH of 1.5 and Ratio of Liquid to binder of 0.5. . The tests were conducted for Geopolymer Concrete spécimens at diffèrent curing âges of (1, 3 and 7 days). The results of compressive strength of Binder ratio of (fly ash : GGBS) of (40 :60), Molarity of NaOH of 8M ,Ratio of Na_2SiO_3/NaOH of 1.5 and Ratio of Liquid to binder of,0.5 gave a higher results of 24 N/mm^2 ,40 N/mm^2 60 N/mm^2 for 1,3 and 7 days respectively.*

Keywords: *Compressive strength.*

I. 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 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.

II. Materials Used

2.1Basalt Aggregate:

Basalt aggregate of two fractions i.e. 20mm and 12.5 mm were used in the present work 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 the Raichur thermal power station , Karnataka state was used. The Chemical Composition and Physical Properties of fly ash as supplied by supplier are presented in Table 1 and Table 2 respectively.

Fly Ash

Table 1: Chemical Composition of Fly Ash

Slo.	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

Slo.	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.

GGBS

Table 3: Chemical Composition of GGBS

Slo.	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):

Sodium Hydroxide Flakes Sodium Silicate Solution

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.

III. Methodology

3.1 Casting:

Cube specimen of size 15cm×15cm×15cm were cast using the finalized mix proportion of Geopolymer concrete for compressive strength test as per IS:516-1959[10].

3.2 Curing:

The cubes were demoulded after 24 hours of casting. The cubes of Geopolymer concrete were kept for curing Under Ambient Curing at laboratory temperature 27±2˚C.for 1, 3 and 7 Days. After curing cubes were tested for compressive strength and details of testing procedure is presented in the following section.

3.3 Testing:

3.3.1 Compressive strength:

The compressive strength test was carried out using IS: 516-1959 [10] code book. At the end of curing period, i.e. 1 days, 3 days and 7 days for Geopolymer Cubes and for a period of 28 days for Geopolymer Concrete cubes. compressive strength test was conducted.. Cube specimens were tested for compressive strength under UTM as per IS 9013 (1978). Specimens were placed under in a direction perpendicular to the direction in which they were cast. Rate of loading is maintained at 140kg/sq cm/min.

Universal Testing Machine

IV. Determininationn Of Geopolymer Concrete Parametres

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.
The following Parameter had to be finalized in order to prepare the Geopolymer Concrete

- The Percentage of Binders used (Fly Ash+ GGBS)
- Molarity of NaOH Considered (8M-16M)
- Ratio of Na_2SiO_3/NaOH
- Ratio of Liquid/Binder

Table 4. Mix Proportion of Geopolymer Concrete for determining Percentage of Binder

Sl No.	GPC(Fly Ash : GGBS)	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			
1	G1(20:80)	73.6	294.4	517.44	776.16	554.4	52.57	131.43
	G2(40:60)	147.2	220.8	517.44	776.16	554.4	52.57	131.43
	G3(50:50)	184	184	517.44	776.16	554.4	52.57	131.43
	G4(60:40)	220.8	147.2	517.44	776.16	554.4	52.57	131.43
	G5(80:20)	294.4	73.6	517.44	776.16	554.4	52.57	131.43

4.1 Trial casting of Geopolymer Concrete to determine Binder Content:

The various parameters considered for trial casting are L/B Ratio= 0.5 , Molarity of NaOH= 8M and $NaSiO_3$/NaOH= 2.5. Trial castings were carried out for the different combinations of Binder (Fly Ash + GGBS) to prepare the Geopolymer Concrete. Cubes were cured under ambient curing for 1, 3 and 7 days. Compressive strength of cubes were determined and results are presented in the Table 5.

Table 5. Trial Casting Results for Geopolymer Concrete for Binder Content

Sl No.	GPC	Binder		Compressive Strength in N/mm2 [Ambient Curing]		
		Fly Ash	GGBS	1 Day	3 Day	7 Day
1	G1	20	80	27.3	46.5	67.1
	G2	40	60	24	40	60
	G3	50	50	21	37	54
	G4	60	40	20	33	48
	G5	80	20	15.7	26	31

Based on the results of trial castings presented in Table no 5. It is observed that for G3 Mix of Geopolymer Concrete Containing Binder Content(Fly ash : GGBS) of (40:60) resulted in good compressive strength. Therefore binder content (Fly ash :GGBS) of (40:60) is considered for final casting.

Table 6. Mix Proportion of Geopolymer Concrete for determining Molarity of NaOH

Sl No.	GPC(Molarity of NaOH)	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			
1	G1(8M)	147.2	220.8	517.44	776.16	554.4	52.57	131.43
	G2(10M)	147.2	220.8	517.44	776.16	554.4	52.57	131.43
	G3(12M)	147.2	220.8	517.44	776.16	554.4	52.57	131.43

4.2 Trial casting of Geopolymer Concrete to determine Molarity of NaOH

The various parameters considered for trial casting are Binder(Fly Ash: GGBS) = (40:60), L/B Ratio= 0.5 , $NaSiO_3$/NaOH= 2.5. Trial castings were carried out for the different Molarity of NaOH to prepare the Geopolymer Concrete .Cubes were cured under ambient curing for 1, 3 and 7 days. Compressive strength of cubes were determined and results are presented in the Table 7.

Table 7. Trial Casting Results for Geopolymer Concrete for Binder Content

Sl No.	GPC	Molarity of NaOH	Compressive Strength in N/mm2 [Ambient Curing]		
			1 Day	3 Day	7 Day
1	G1	8M	24	40	60
	G2	10M	24.7	41	62
	G3	12M	23	39	57

Based on the results of trial castings presented in Table no 7. It is observed that for G1 Mix of Geopolymer Concrete Containing 8M Molarity of NaOH has resulted in good compressive strength . Therefore 8M Molarity of NaOH is considered for final casting.

Table 8. Mix Proportion of Geopolymer Concrete for determining Ratio of Na_2SiO_3/NaOH

Sl No.	GPC(Na_2SiO_3/NaOH)	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			
1	G1(1.5)	147.2	220.8	517.44	776.16	554.4	73.6	110.4
	G2(2)	147.2	220.8	517.44	776.16	554.4	61.3	122.6
	G3(2.5)	147.2	220.8	517.44	776.16	554.4	52.57	131.43

4.3 Trial casting of Geopolymer Concrete to determine Ratio of Na_2SiO_3/NaOH:

The various parameters considered for trial casting are Binder(Fly Ash: GGBS) = (40:60), L/B Ratio= 0.5 , Molarity of NaOH = 8M. Trial castings were carried out for the different Ratio of $NaSiO_3$/NaOH to prepare the Geopolymer Concrete. Cubes were cured under ambient curing for 1, 3 and 7 days. Compressive strength of cubes were determined and results are presented in the Table 9.

Table 9. Trial Casting Results for Geopolymer Concrete for Ratio of Na_2SiO_3/NaOH

Sl No.	GPC	Ratio of Na_2SiO_3/NaOH	Compressive Strength in N/mm2 [Ambient Curing]		
			1 Day	3 Day	7 Day
1	G1	1.5	27	44	64
	G2	2	25	42	61
	G3	2.5	24	40	60

Based on the results of trial castings presented in Table no 9. It is observed that for G1 Mix of Geopolymer Concrete Containing Ratio of $NaSiO_3$/NaOH of 1.5 has resulted in good compressive strength .Therefore Ratio of $NaSiO_3$/NaOH of 1.5 was considered for final casting.

Table 10. Mix Proportion of Geopolymer Concrete for determining Liquid to Binder ratio

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			
1	G1(0.45)	152.4	228.6	517.44	776.16	554.4	68.4	102.6
	G2(0.5)	147.2	220.8	517.44	776.16	554.4	73.6	110.4
	G3(0.55)	142.4	213.6	517.44	776.16	554.4	78.4	117.6

4.4 Trial casting of Geopolymer Concrete determine Liquid to Binder ratio :

The various parameters considered for trial casting are Binder(Fly Ash: GGBS) = (40:60),Molarity of NaOH= 8M , $NaSiO_3$/NaOH= 1.5. Trial castings were carried out for the different Ratio of Liquid to Binder to prepare the Geopolymer Concrete. Cubes were cured under ambient curing for 1, 3 and 7 days. Compressive strength of cubes were determined and results are presented in the Table 11.

Table 11. Trial Casting Results for Geopolymer Concrete for determining Ratio of Liquid to Binder

Sl No.	GPC	Ratio of Liquid to Binder	Compressive Strength in N/mm2 [Ambient Curing]		
			1 Day	3 Day	7 Day
1	G1	0.45	23	37	54
	G2	0.50	24	40	60
	G3	0.55	21	30	49

Based on the results of trial castings presented in Table no 11. It is observed that for G1 Mix of Geopolymer Concrete Containing Ratio of Liquid to Binder of 0.5 has resulted in good compressive strength .Therefore Liquid to binder ratio of 0.5 was considered for final casting.
The Finalized parameter obtained for the Geopolymer Concrete 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

Table 12. Final Casting Results for Geopolymer Concrete

Sl No.	GPC	Compressive Strength in N/mm2 [Ambient Curing]		
		1 Day	3 Day	7 Day
	G1	24	40	60

The various parameters considered for final casting are Binder (Fly Ash: GGBS) = (40:60), Molarity of NaOH= 8M, $NaSiO_3$/NaOH= 1.5. and Liquid to Binder Ratio of 0.5 Final castings were carried out to prepare the Geopolymer Concrete. Cubes were cured under ambient curing for 1, 3 and 7 days. Compressive strength of cubes were determined and results are presented in the Table 12.

V. Conclusion

Following conclusions are drawn from this investigation.

- Addition of GGBS in Geopolymer concrete enhances the polymerization at Ambient Temperature only and results in good compressive strength.
- The Mix containing Binder of (Fly Ash: GGBS) of (40:60) resulted a higher strength.
- In the present study it is observed that with increase in the Molarity (8M, 10M & 12M) of NaOH there is marginal increase in the strength was observed.
- It is observed that Ratio of Na_2SiO_3/NaOH of 1.5 resulted in good compressive strength as compared to the other ratio of Na_2SiO_3/NaOH of 2 and 2.5 .
- It is observed that Ratio of Liquid/Binder of 0.5 resulted in higher compressive strength.

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