Studies on Acid Attack Resistance of Geopolymer Concrete With Manufactured Sand As Fine Aggregate

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Abstract – The conventional concrete consists of cement which contributes about 7% of the global warming due to emission of carbon dioxide. There is need to find an alternative eco-friendly material, geopolymer concrete is best alternative for conventional concrete. On the other handriver sand is becoming scare day by day and costlier. So the manufactured sand turns out to be alternative material for river sand. The main objective is to study the acid attack resistance under HCl & H_2SO_4 on GPC of G30 and G50 grades. After 28 days the specimens were immersed in acids (HCl& H_2SO_4) for a period of 15, 30 and 45 days then tested according to codal provisions. The test results are comparatively better in case of geopolymer concrete than conventional concrete.

Index Terms – Acids, Geopolymer Concrete, GGBS, Oven Curing, Alkaline Solution

1. INTRODUCTION

Concrete is a widely used construction material for various types of structures due to its durability. The reduction in the carbon dioxide emission from cement production can contribute significantly to the turning down of the global thermostat. Utilization of waste materials has been encouraged in construction field for the production of cement and concrete because it contributes to reducing the consumption of natural raw materials as resource and also reducing emission of greenhouse gases. Fly ash based geopolymer concrete, made up of fly ash, sand, coarse aggregate, and an alkaline solution of sodium hydroxide and sodium silicate, plays a significant role in its environmental control of greenhouse effects.

The durability of concrete is an important requirement for the performance of the structure in aggressive environments. Acid resistance is one of the essential properties for structural materials. Even though the problem of hydrochloric and sulphuric acid corrosion in concrete sewer pipes is recognised, this problem has not been satisfactorily solved. A research looked at different ways of enhancing the acid resistance of ordinary Portland cement (OPC) based concretes, using the partial replacement of ordinary Portland cement by supplementary materials. The acid attack in terms of mass loss was reduced; Hydrochloric and sulphuric acid resistant binders are still required to improve the long-term performance of controlled concrete in acid corrosion environments. Geopolymer binders might be a promising alternative in the development of acid resistant concrete.

The objective of this paper is to study the behavior of low calcium flyash and slag based geopolymer concrete of G30 and G50 under acids. The loss in compressive strength and weight for specimens undergoing continuous immersion in acids of controlled and geopolymer concrete are evaluated.

2. MATERIALS

2.1 Ordinary Portland Cement

In the experimental investigations, 53-grade of ordinary Portland cement is used. The cement thus procured was tested for physical properties in accordance with the IS: 4031-1968 and found to be conforming various specifications of IS 12629-1987.

2.2 Fine aggregate

Manufactured sand nothing but crushing of hard stone aggregates to the size of natural sand. The M-sand used is collected from local suppliers. The manufactured sand used was without any organic impurities and conforming to IS: 383 – 1970 [Method s of physical tests for hydraulic cement]. The M-sand was tested for its physical requirements such as gradation, fineness modulus, specific gravity and bulk density in accordance with IS: 2386 – 1963 [Methods of test fo r aggregate for concrete] and is shown in below Table No.1

2.3 Coarse aggregate

The crushed angular aggregate of 20mm maximum size obtained from the local crushing plants is used as coarse aggregate in the present study. The physical properties of coarse aggregate such as specific gravity, bulk density, flakiness and elongation index are tested in accordance with IS: 2386-1963.

Table 1. Physical properties of Manufactured Sand

S. No.	Property	Method	Fine Aggregate
1	Specific gravity	Pycnometer IS:2386 part 3-1986	2.71
2	Bulk density (compact)	IS:2386 part 3-1986	1720 Kg/cum
3	Bulk density (loose)	IS:2386 part 3-1986	1663.27 Kg/cum
4	Fineness modulus	Sieve Analysis (IS:2386 Part 2-1963)	2.67
5	Bulking	IS:2386 Part 3-1986	4% wc
6	Grading		Zone –II

2.4 Fly Ash

In the present study of work, the Class F-fly ash is used, which is obtained from Vijayawada thermal power station in Andhra Pradesh.

2.5 Ground Granulated Blast Furnace Slag

Ground Granulated Blast Furnace Slag (GGBS) is a by product of the steel industry. Blast furnace slag is defined as "the non-metallic product consisting essentially of calcium silicates and other bases that is developed in a molten condition simultaneously with iron in a blast furnace". About 15% by mass of bind ers was replaced with GGBS.

2.6 Water

Water free from chemicals, oils and other forms of impurities is used for mixing of concrete as per IS: 456:2000.

2.7 Sodium Hydroxide

Sodium Hydroxide is one of the major ingredients of geopolymer concrete. The following are the specifications of Sodium hydroxide pellets and this material is procured from the local laboratory chemical vendors in Hyderabad. Specifications are tabulated in table 2 as given by the suppliers.

2.8 Sodium Silicate Solution

Sodium silicate solution is a type of alkaline liquid plays an important role in the polymerisation process. This material is procured from the local laboratory chemical vendors in Hyderabad. Specifications are tabulated in table 3 as given by the suppliers.

Table 2. Shows Physical properties of NaOH

Molar mass	40 gm/mol
Appearance	White solid
Density	2.1 gr/cc
Melting point	318^{o}C
Boiling point	1390^{o}C
Amount of heat liberated when dissolved in water	266 cal/gr

Table 3. Properties of Na_2SiO_3 Solution

Specific gravity	1.57
Molar mass	122.06 gm/mol
Na_2O (by mass)	14.35%
SiO_2 (by mass)	30.00%
Water (by mass)	55.00%
Weight ratio (SiO_2 to Na_2O)	2.09
Molarity ratio	0.97

2.9 Super Plasticizer

Super plasticizer GLENIUM B233of Fosroc chemical India Ltd. was used as water reducing admixture, it increases workability.

3. EXPERIMENTAL INVESTIGATIONS

3.1 General

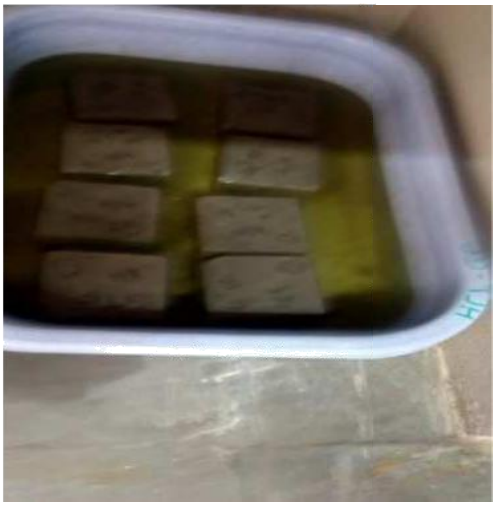
This paper presents experimental investigations on the behaviour of fly ash and slag based geopolymer concrete under acids of M30 and M50 which are entitled as G30 and G50 grades respectively. The alkaline solution used for the present study is combination of sodium silicate (Na2Sio3) and sodium hydroxide (NaOH). The ratio of Na2SiO3 to NaOH is 2.5 and SiO2 to Na2O is 2.09 has been used since the compressive strength is maximum at these ratios. The cubes of size 100mm×100mm×100mm were cast and after one day rest period, the specimens were cured in an oven at 60°C for 24 hours and the remaining peri od cured in sun light until the specimens immersed in. After 28 days the specimens were immersed under acids such as HCl & H2SO4for 15, 30 and 45 days, then the loss of compressive strengths and weights of both grades of controlled and geopolymer concrete are evaluated on 15th 30th and 45th day.

3.2 Concrete Mix Design

The mix proportions for the presen t investigations are designed as per IS 10262-2009 a nd are given in table 4.

Table 4. Shows the Mix Proportions

Standard grade (M30) of Controlled Concrete	1:1.89:3.27:0.45
Standard grade (G30) of Geopolymer Concrete	1:1.89:3.27:0.45
Standard grade (M50) of Controlled Concrete	1:1.35:3.16:0.4
Standard grade (G50) of Geopolymer Concrete	1:1.35:3.16:0.4



period of 45 days. From the tables and graphs it is observed that as the immersion period increases the percentage loss of compressi ve strength and weights are increased for both the grades and in both the acid solutions such as HCl, H2SO 4.

Concrete grade	Immersion Period	Nominal Strength (MPa)	Strength(MPa) after Immersion in Acids		Strength in percentage after Immersion in Acids	
			HCl	H_2SO_4	HCl	H_2SO_4
M30	0 days	41.32	41.32	41.32	-	-
G30		**42.37**	**42.37**	**42.37**	**-**	**-**
M50		61.56	61.56	61.56	-	-
G50		**62.43**	**62.43**	**62.43**	-	-
M30	15 days	41.32	39.64	39.68	4.06	3.96
G30		**42.37**	**41.28**	**41.42**	**2.57**	**2.24**
M50		61.56	59.63	59.12	3.13	3.96
G50		**62.43**	**61.23**	**61.32**	**1.92**	**1.77**
M30	30 days	41.32	38.41	37.46	7.04	9.34
G30		**42.37**	**40.12**	**39.24**	**5.31**	**7.38**
M50		61.56	57.48	57.34	6.62	6.85
G50		**62.43**	**59.62**	**59.68**	**4.50**	**4.41**
M30	45	41.32	37.26	35.65	9.82	13.72
G30		**42.37**	**39.14**	**37.56**	**7.62**	**11.35**

Table 5. Compressive Stre ngth Loss in Percentage of Controlled (M30 & M50) & Geopolymer Concrete (G30 & G50) when immersed in 5% concentrations of Aci ds

Fig.1 Shows specimens immersed in HCl solution

Fig.2 Shows specimens immersed in H_2SO_4 solution

4. TEST RESULTS

4.1 Residual Compressive Strength and Weight loss

The tables 5 and 6 and Figs 3 an d 6 shows the compressive strengths, percentage loss of compressive strengths and weights, percentage loss of weights of controlled and geopolymer concrete specimens exposed to 5% concentration of HCL and H2SO 4 solutions for a Controlled (M30) & Geopolymer Concrete (G30) when immersed in 5% conc entrations of Acids

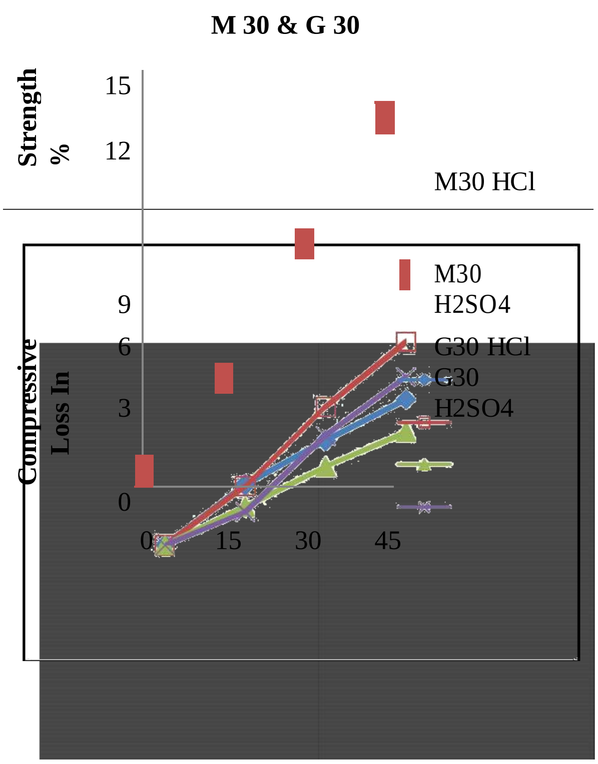


Fig 3: Loss of Compressive Strength in Percentage of

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	da					
M50		61.56	55.74	55.76	9.45	9.42
	ys					
G50		**62.43**	**57.86**	**58.21**	**7.32**	**6.75**

Table 6: Weight Loss in Percentage of C ontrolled (M30 & M50) & Geopolymer Concrete (G30 & G50) when immersed in 5% concentrations of Acids

Grade of concrete	**Immersion Period**	**Weights (kg) before Immersion**		**Weights (kg) after Immersion in Acids**		**Loss of Weights in Percentage after Immersion in Acids**	
		HCl	**H_2SO_4**	**HCl**	**H_2SO_4**	**HCl**	**H_2SO_4**
M30		2.43	2.51	2.43	2.51	-	-
G30	0	**2.25**	**2.28**	**2.25**	**2.28**	-	-
M50	days	2.52	2.61	2.52	2.61	-	-
G50		**2.39**	**2.40**	**2.39**	**2.40**	-	-
M30		2.47	2.54	2.34	2.45	5.26	3.54
G30	15	**2.29**	**2.30**	**2.21**	**2.24**	**3.49**	**2.60**
M50	days	2.56	2.64	2.37	2.56	7.42	3.03
G50		**2.44**	**2.44**	**2.29**	**2.38**	**6.14**	**2.45**
M30		2.56	2.50	2.17	2.32	15.23	7.20
G30	30	**2.36**	**2.27**	**2.05**	**2.16**	**13.13**	**4.84**
M50	days	2.62	2.57	2.30	2.45	12.21	4.67
G50		**2.44**	**2.41**	**2.20**	**2.32**	**9.83**	**3.73**
M30		2.49	2.53	1.96	2.32	21.28	8.30
G30	45	**2.34**	**2.32**	**1.87**	**2.16**	**20.51**	**6.89**

M50	days	2.54	2.62	2.05	2.46	19.29	6.10
G50		**2.46**	**2.44**	**2.01**	**2.33**	**18.29**	**4.50**

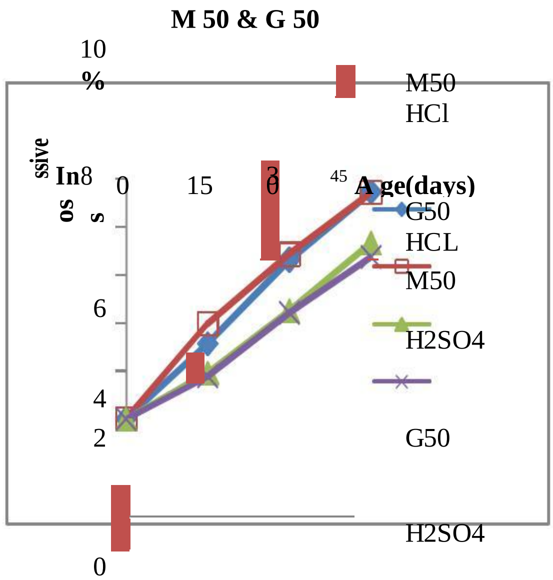


Fig 4: Loss of Compressive Strength in Percentage of Controlled (M50) & Geopolymer Concr ete (G50) when immersed in 5% concentrations of Acids

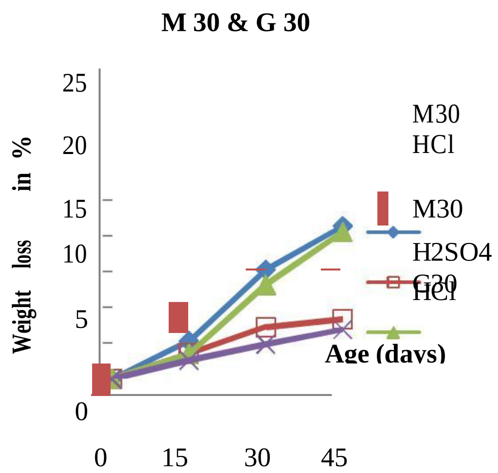
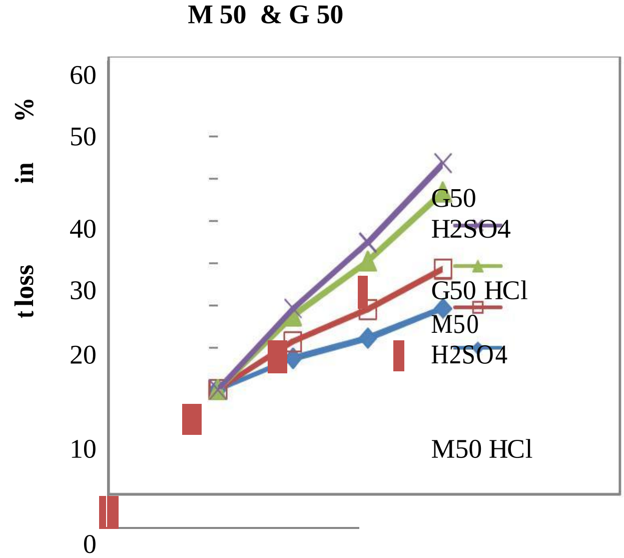


Fig 5: Weight Loss in Perce ntage of Controlled (M30) Geopolymer Concrete (G 30) when immersed in 5% concentratio ns of Acids

Fig 6: Weight Loss in Perce ntage of Controlled (M50) Geopolymer Concrete (G 50) when immersed in 5%



concentrations of Acids

4. CONCLUSIONS

The following conclusio ns can be drawn from the present experimental investi gations:

1. When the specimens are exposed to HCl and H_2SO_4, the percentage loss o f compressive strength and weights are increased as the immersion period increases for all the grades of co ntrolled and geopolymer concrete.
2. The loss of compressive strength of controlled concrete specimens when e xposed to HCl for both the grades considered is in the range of 4.06 to 9.82%, where as it is about 2.57 to 7.62% in case of geopolymer concrete. Thus , geopolymer concrete is more resistant than controlled concrete.
3. The loss of compressive strength of controlled concrete specimens when exposed to H_2SO_4 for both the grades considered is in the range of 3.96 to 13.72%, where as it is about 2.24 to 11.35% in case of geopolymer concrete. Thus , geopolymer concrete is more resistant than controlled concrete.
4. The loss of weigh t of controlled concrete specimens when exposed t o HCl for both the grades considered is in the range of 5.26 to 21.28%, where as it is about 3.49 to 20.51% in c ase of geopolymer concrete. Thus, geopolymer concrete is more resistant than controlled concrete.
5. The loss of weigh t of controlled concrete specimens when exposed to H_2SO_4 for both the grades considered is in the range of 3.54 to 8.3%, where as it is about 2.60 to 6.89% in case of geopolymer concrete. Thus, geopolymer concrete is more resistant than controlled concrete.
6. It can be concluded that both the acids are dangerous as the strengt hs and weights are lost

significantly even at 45 days, however geopolymer concrete specimens are relatively better than controlled concrete.

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