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Investigation on Behaviour of Fly Ash Based Geopolymer Concrete in Acidic Environment

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Abstract: *Geopolymer concrete results from the reaction of a source material that is rich in silica and alumina with alkaline liquid. The term geopolymer was introduced by Davidovits; geopolymers are members of the family of inorganic polymers. Geopolymer binders have been reported as being acid resistant and thus are promising and alternative binders for sewer pipe manufacture. This paper presents experimental data on the Behavior of fly ash based geopolymer concrete exposed to 5% acid solutions for up to 4 weeks. A class F fly ash based geopolymer concrete was initially cured for 24 hours at 60°C. And also the obtained results were compared with the conventional concrete exposed to 5% acid solutions for up to 4 weeks. The compressive strength of geopolymer concrete and conventional concrete of 150-mm cubes at an age of 28 days were 32MPa and 48.5MPa, respectively. Initially concrete cubes were cured for a period of 28 days and later cubes were immersed in acid solutions, After immersion in a 5 % acid solutions, samples were tested at 7, 14 and 28 days. The mass loss, compressive strength reductions were determined. In this experimental work 3 type of acid solutions are used, i.e., HCl, H_2SO_4 and $MgSO_4$.*

The results confirmed that Geopolymer concrete is highly resistant to acid in terms of a very low mass loss and compressive strength loss when compared to conventional concrete.

Key Words*: Geopolymer; Fly ash; Alkaline Liquid; Acid Resistance; Acidic Environment*

I. 1ntroduction

In spite of a long-term recognition of the problem of sulphuric acid corrosion in concrete sewer pipes, this issue has not been satisfactorily resolved. A research looked at ways of enhancing the acid resistance of Portland Cement (PC) based concretes, using the partial replacement of Portland cement by supplementary materials, the use of epoxy modified binders, and the use of limestone as a sacrificial aggregate [Song et al 2003]. The acid attack in terms of mass loss was reduced; however, even the improved concretes lost significant mass with immersion time.

Sulphuric acid resistant binders are still required to enhance the long-term performance of concrete in sulphuric acid corrosion environments. Geopolymer binders might be a promising alternative in the development of acid resistant concrete. Since Geopolymers are a novel binder that relies on alumina-silicate rather than calcium silicate hydrate bonds for structural integrity, they have been reported as being acid resistant.

This paper reports experimental data on the response of Alkaline Activated Fly ash based Geopolymer (AAFG) concrete against 5% acid solutions for up to 4 weeks, in terms of visual inspection, mass change, and residual compressive strength. In this experimental work 3 type of acid solutions are used, i.e., HCl, H_2SO_4 and $MgSO_4$. And also the obtained results were compared with the conventional concrete exposed to 5% acid solutions for up to 4 weeks.

II. Mix Design Of Geopolymer And Conventional Concrete

2.1 CONVENTIONAL CONCRETE

Grade of concrete is M30

Mix proportion ($1m^3$ of concrete):

Water	:	Cement	:	FA	:	CA						
191.6	:	430.00	:	538.70	:	1214.91						
0.45	:	1	:	1.25	:	2.82						

2.2 GEOPOLYMER CONCRETE

Materials		Mass (kg/m3)
Coarse aggregates:	20 mm	277
	14 mm	370
	7 mm	647
Fine sand		554
Fly ash (low-calcium ASTM Class F)		394
Sodium silicate solution(SiO_2/ Na_2O =2)		113
Sodium hydroxide solution		45 (8 Molar)

Table 1: Geopolymer Concrete Mixture Proportions

III. Materials

Fly ash: Fly ash belonging to class-F obtained from Vijayawada thermal Power Station in Andhra Pradesh was used in the present investigation. The specific gravity of the fly ash was 1.975.

Alkaline Liquid: A combination of sodium silicate solution and sodium hydroxide solution was chosen as the alkaline liquid.

Fine aggregate: The fine aggregate used is natural sand obtained from the river Godavari conforming to grading zone-II of table 4 of IS: 383-1970. The specific gravity of the fine aggregate was 2.61.

Cement: The type of cement used all throughout the experiment was Ordinary Portland Cement of grade 53.The specific gravity of the fly ash was 3.10.

Coarse aggregate: The crushed coarse aggregate of maximum size 16 mm, 60% of it passing through 16 mm IS sieve and retaining on 12.5mm IS sieve and 40% of this passing through 12.5 mm IS sieve and retaining on 4.75 mm IS sieve size obtained from the local crushing plant, Rajahmundry, East Godavari, is used in the present study. The specific gravity of the coarse aggregate was 2.77.

Water: Potable fresh water available from local sources was used for both mixing and curing.

Acids: The various acids used in the investigation are HCl, H_2SO_4 and $MgSO_4$ each of 5% concentration.

IV. Experimental Programme

In this experimental work, properties of materials used in the experimental work were determined. Then Fly ash based geopolymer concrete cubes and conventional concrete (M30 Grade) cubes of size 150mm×150mm×150mm were cast.

Now, geopolymer concrete cubes and conventional concrete cubes were cured for a period of 28 days. Generally, heat curing is recommended for geopolymer concrete and heat curing was done at a temperature of 60^0c for a period of 24 hours. After completion of curing process, weight of both conventional and geopolymer concrete cubes were taken. Later, concrete specimens were immersed in 5% of acidic solutions (HCl, H_2SO_4, MgSO4) for a period of 7, 14, 28 days.

After completion of immersion period, concrete specimens were taken out and allowed for drying for a period of 1 day and weight of concrete cubes were determined. And also, the compressive strength of concrete cubes after acid immersion was determined by using U.T.M. and the obtained results are compared. Residual compressive strength and percentage weight loss of geopolymer and conventional concrete cubes after acid immersion have been studied and compared.

Compressive strength of reference mixes:
Compressive strength of geopolymer concrete after 28 days of curing was 32MPa
Compressive strength of conventional concrete after 28 days of curing was 49.53 MPa.

V. Results And Discussion

The compressive strength test on hardened concrete was performed on U.T.M. Three 150x150x150 mm concrete cubes were tested for every compressive strength test. The results given in various Figures and Tables are the mean of these values. The curing media was replaced with fresh solution at the end of every week to maintain the same concentration (5%) throughout the exposure period.

Residual compressive strength on acid immersion:

S.No	Type of concrete	Compressive strength at 28days (Before acid immersion) (N/mm^2)	Compressive strength After 7 days of acid immersion (N/mm^2)		
			Type of Acid		
			HCl	H_2SO_4	$MgSO_4$
1	C. C(M30)	49.53	44.34	35	45
2	G.C	32	29.44	27.36	28.8

Table 2: Residual compressive strength after 7 days of acid immersion.

S.No	Type of concrete	Compressive strength at 28days (Before acid immersion) (N/mm^2)	Compressive strength After14 days of acid immersion (N/mm^2)		
			Type of Acid		
			HCl	H_2SO_4	$MgSO_4$
1	C. C(M30)	49.53	42.35	29	44
2	G.C	32	28.6	25.69	27.52

Table 3: Residual compressive strength after 14 days of acid immersion.

S.No	Type of concrete	Compressive strength at 28days (Before acid immersion) (N/mm^2)	Compressive strength After 28 days of acid immersion (N/mm^2)		
			Type of Acid		
			HCl	H_2SO_4	$MgSO_4$
1	C. C(M30)	49.53	40.86	21	42
2	G.C	32	27.5	23.2	26.4

Table 4: Residual compressive strength after 28 days of acid immersion.

Percentage loss of compressive strength after acid immersion:

S.No	Type of concrete	% loss of Compressive strength After 7 days of acid immersion(N/mm^2)		
		Type of Acid		
		HCl	H_2SO_4	$MgSO_4$
1	C. C(M30)	11	29.76	9.61
2	G.C	8	14.5	10

Table 5: Percentage loss of compressive strength after 7 days of acid immersion.

S.No	Type of concrete	% loss of Compressive strength After 14 days of acid immersion (N/mm^2)		
		Type of Acid		
		HCl	H_2SO_4	$MgSO_4$
1	C. C(M30)	15	41.80	11.69
2	G.C	9.9	19.7	14

Table 6: Percentage loss of compressive strength after 14 days of acid immersion.

S.No	Type of concrete	% loss of Compressive strength After 28 days of acid immersion (N/mm^2)		
		Type of Acid		
		HCl	H_2SO_4	$MgSO_4$
1	C. C(M30)	18	57.85	15.65
2	G.C	14.06	27.5	17.5

Table 7: Percentage loss of compressive strength after 28 days of acid immersion.

Durability Studies

S.No	Type of Acid	Weight of concrete cubes after 28 days of casting and before acid immersion in days for (Kg)			Weight of concrete cubes after acid immersion in days (Kg)		
		7	14	28	7	14	28
1	HCl	8.78	8.80	8.76	8.58	8.53	8.43
2	H_2SO_4	8.79	8.78	8.7	8.30	8.20	8.0
3	$MgSO_4$	8.78	8.79	8.8	8.60	8.60	8.56

Table 8: Conventional concrete

S.No	Type of Acid	Weight of concrete cubes after 28 days of casting and before acid immersion in days for (Kg)			Weight of concrete cubes after acid immersion in days (Kg)		
		7	14	28	7	14	28
1	HCl	7.84	7.85	7.83	7.8	7.79	7.76
2	H_2SO_4	7.95	7.78	7.82	7.87	7.64	7.65
3	$MgSO_4$	7.88	7.9	7.8	7.85	7.86	7.74

Table 9: Geopolymer concrete

Percentage weight loss on acid immersion.

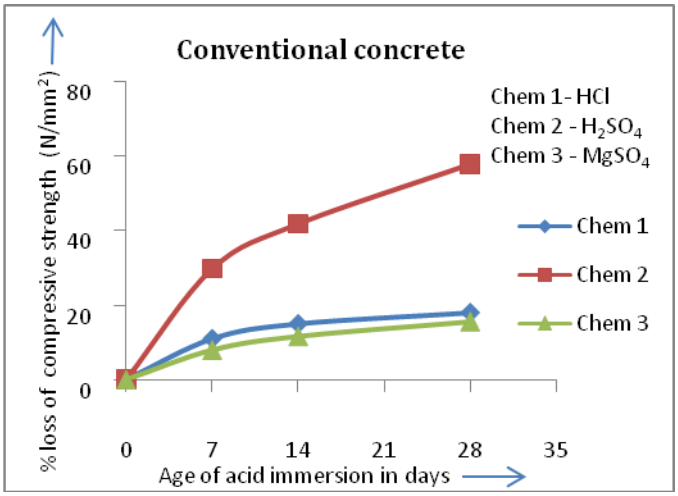
S.No	Type of Acid	% Weight loss of concrete cubes after acid immersion		
		Age of acid immersion in days		
		7	14	28
1	HCl	2.2%	3.06%	3.76%
2	H_2SO_4	5.5%	6.6%	8%
3	$MgSO_4$	2.0%	2.16%	2.72%

Table 10: Conventional concrete

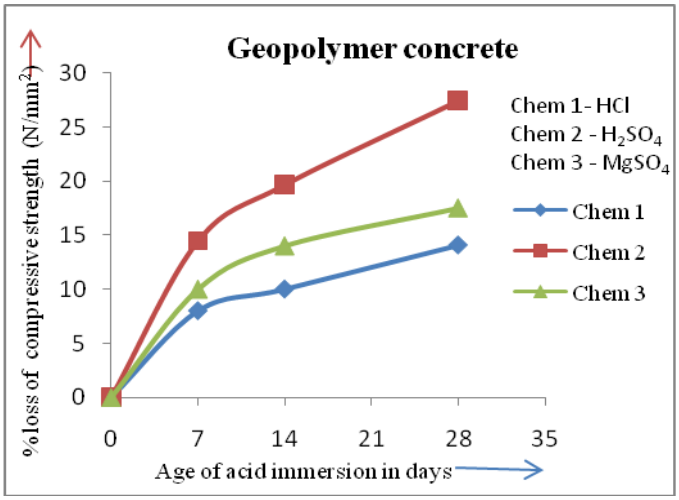
S.No	Type of Acid	% Weight loss of concrete cubes after acid immersion		
		Age of acid immersion in days		
		7	14	28
1	HCl	0.4%	0.7%	0.9%
2	H_2SO_4	1.0%	1.7%	2.2%
3	$MgSO_4$	0.3%	0.5%	0.7%

Table 11: Geopolymer concrete

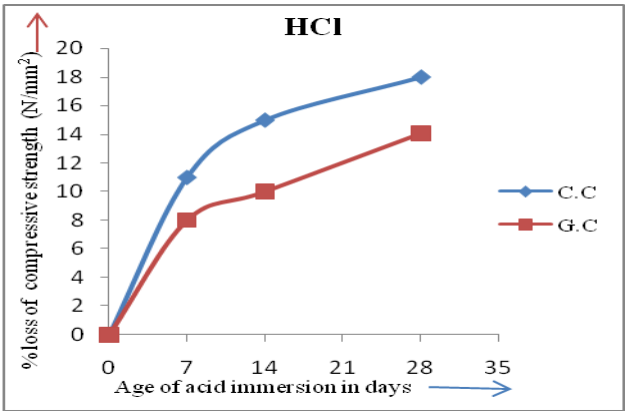
GRAPHS



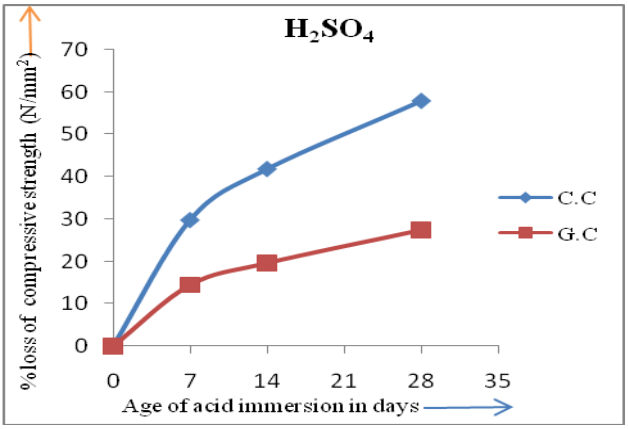
Graph 1: % loss of compressive strength in Conventional concrete



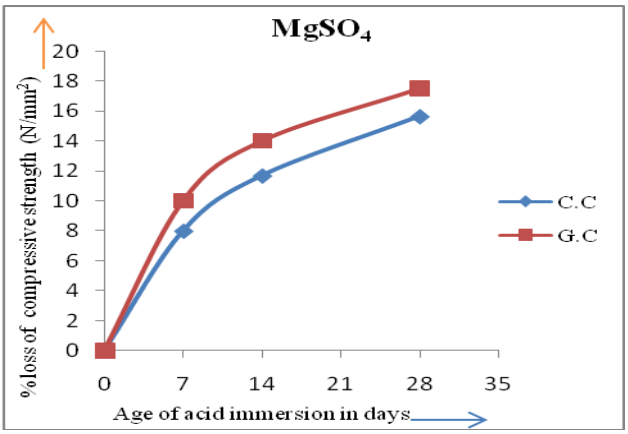
Graph 2: % loss of compressive strength in Geopolymer concrete



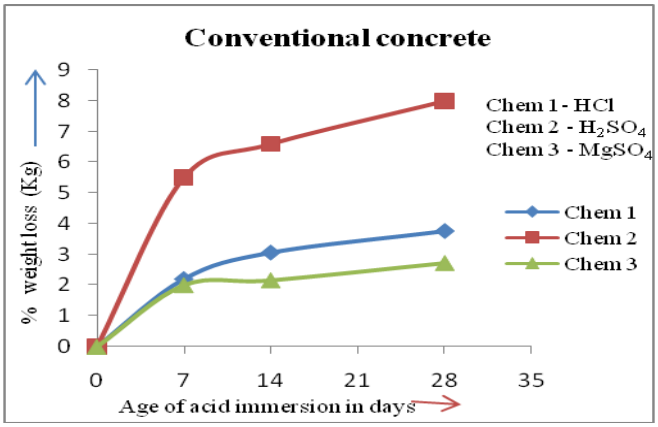
Graph 3: % loss of compressive strength in HCl acid



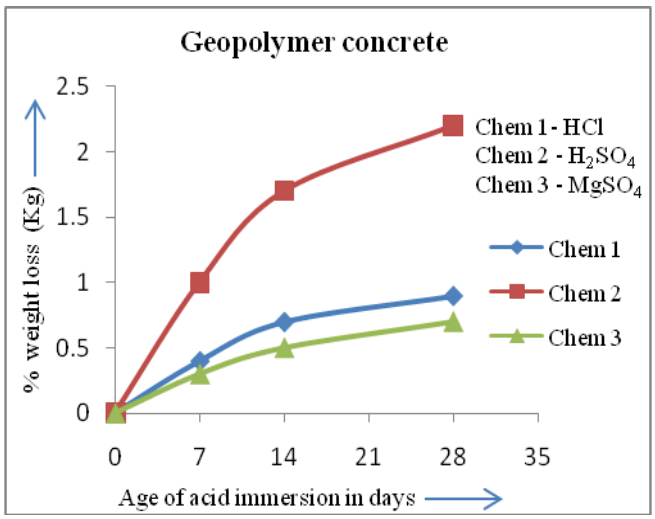
Graph 4: % loss of compressive strength in H_2SO_4



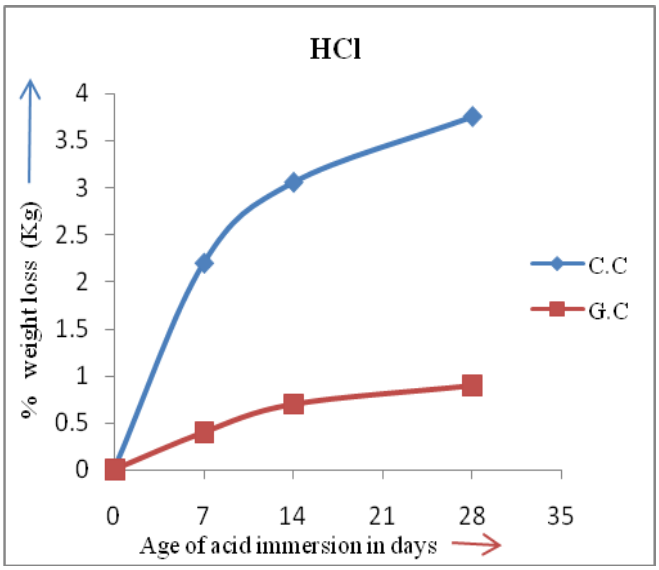
Graph 5: % loss of compressive strength in $MgSO_4$



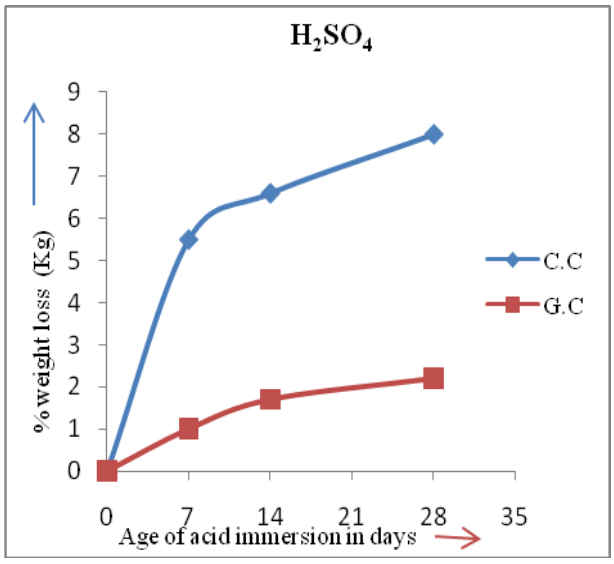
Graph 6: % weight loss in Conventional concrete



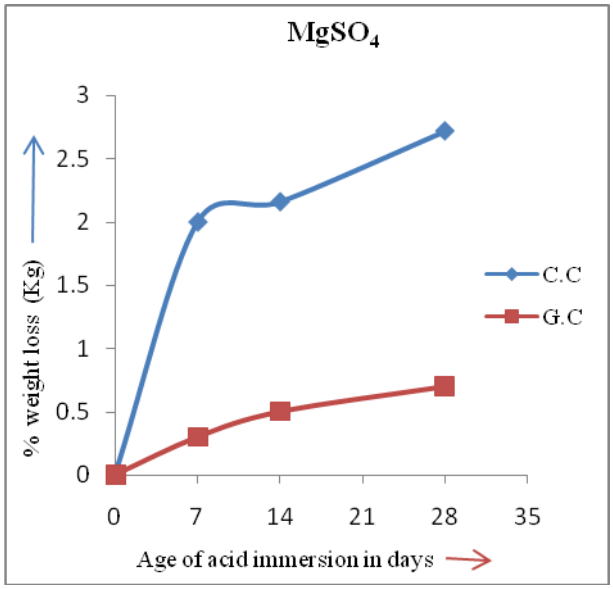
Graph 7: % weight loss in Geopolymer concrete



Graph 8: % weight loss in HCl acid



Graph 9: % weight loss in H_2SO_4 acid



Graph 10: % weight loss in $MgSO_4$ acid

VI. Conclusions

The following conclusions are made based on the laboratory experiments carried out in this investigation.

1. Geopolymer concrete mixes resisted acid attack in a better way as compared to conventional concrete at all ages of exposure to HCl, H_2SO_4.
2. It is observed that the percentage loss of Compressive strength of all Geopolymer Concrete mixes are considerably lower than that of Conventional concrete mixes at all ages of acid exposure.
3. It is also observed that the maximum loss of compressive strength and weight occurs in case of H_2SO_4 acid immersion as compared to HCl and $MgSO_4$.
4. The loss of compressive strength of conventional concrete is almost double the loss of compressive strength of geopolymer concrete in H_2SO_4 acid immersion at all ages.
5. The percentage weight loss of Conventional concrete is more when compared to Geopolymer concrete. This is true for all the acids tried in this investigation.
6. It is observed that the loss of compressive strength of Geopolymer concrete is more when compared to conventional concrete in $MgSO_4$ immersion. So Geopolymer concrete is sensitive to $MgSO_4$.
7. The weight loss of Geopolymer concrete is very low when Geopolymer concrete mixes are exposed to 5% acid attack.

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