Effect Of Chlorides And Sulphates On Esp-Ggbs Based Alkali Activated Concrete At Different Molarities

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ABSTRACT: The Construction industry is playing a vital role in the deterioration of the environment by depleting natural resources, utilizing huge quantities of energy from fossil fuels. Conventional concrete production which uses cement as a constituent is one of the major contributors to emissions of greenhouse gases. Usage of Alkali-activated concrete is gaining importance in the recent past since it imparts less carbon footprint on the environment. Other eco-friendly alternative solutions can be adopted to reduce the depletion of resources. In the present study, Egg Shell Powder (ESP) and GGBS are used as an alternate source of the binder. Eggshell powder and GGBS can be activated through the alkaline solution, which polymerizes these materials into molecular chains and networks to create a hardened binder. In this paper apart from Eggshell powder and GGBS, Robo sand which is an excellent substitute for depleting natural sand was used which makes the alkali-activated concrete furthermore advantageous.

In this paper, the results of the detailed study done on alkali-activated concrete immersed in HCL and H2SO4 are presented. Workability test is done on fresh concrete and durability, compressive strength test is done on hardened concrete. Compressive strength of alkali-activated concrete has been reported with varying percentages of GGBS and ESP (G90E10, G80E20, G70E30, G60E40) at 8, 10 and 12 Molarities. NaOH and Na2Sio3 are used as Alkali Activators. Also, results of percentage loss in Compressive strength and Weight of cubes immersed in HCL and H2So4 are presented.

Keywords: Alkali activated concrete, Compressive strength, Sulphuric acid and hydrochloric acid resistance

1. INTRODUCTION

With drastic changes in climate all over the world, there has been an emphasis on reducing carbon footprint. The manufacture of Portland cement worldwide is increasing annually. The current involvement of greenhouse gas emission from Portland cement production is about 1.5 billion tonnes per year which contributes about 7% of the total greenhouse gas discharged to the atmosphere. Besides cement, river sand which is a precious natural material is being dredged without any control leading to loss of fertile soil and change of groundwater table conditions. Keeping in view all the disadvantages associated with conventional concrete production, Alkali-activated concrete is a new era material that was familiarised by Davidovits in 1978.

Alkali activated concrete uses materials such as ESP and GGBS which are by-products of steel industries and poultry respectively. India is one of the largest producers of poultry and in turn ESP. These materials pose a severe disposal problem occupying vast areas of precious land. Also, the water passing through these wastes is contaminating the groundwater table severely. Keeping in view the disposal problems and usage of Eco-friendly materials in the construction Industry these materials can be used as a replacement for cement. When these materials are used as binders with Alkali Activator solutions NaOH and Na2Sio3 they will form polymeric chains and gives the concrete more strength than the conventional concrete.

Keeping in view all the advantages associated with Alkali Activated Concrete, in the present study, ESP and GGBS are used as binders with varying percentages. Robo sand has been used in the place of conventional river sand. For testing chloride and sulphide attack, the cubes are immersed in HCl and H_2SO_4 solution for 28-, 56- and 90-days compressive strength test has been carried out.

2. MATERIALS USED

2.1 Egg Shell Powder (ESP)

Eggshell powder bought from local poultry is cleaned and sundried for one day. Then it is crushed into powder using ball mills. This powder is further sieved using a 90μ sieve and used in this study.

2.2 Robo Sand

The usage of Robo Sand (Specific gravity 2.05) in the construction sector as a perfect alternative for natural sand has been increasing in the recent past. Studies show that usage of Robo sand results in high compressive strength and better durability of concrete. Robo sand is obtained by crushing the rock into smaller pieces. The

Robo sand was obtained from a rock-crushing unit, Miyapur, Telangana. Sieve analysis was done on Robo sand and it was confined to Zone-II as per IS 383-1970.

2.3 Ground Granulated Blast Furnace Slag (GGBS)

GGBS (Specific gravity 2.61) is obtained by quenching molten iron slag from a blast furnace in water or steam, to produce a granular product that is then dried and grounded into a fine powder. From literature, it can be inferred that in concrete when GGBS is combined with GGBS it gives better strength and workability [5]. Concrete made from GGBS offers more temperature resistance than conventional concrete. Different materials used in the study are
shown in Figure 1

Figure 1: GGBS, Robo Sand, Coarse Aggregate, Activator Solution, GGBS

2.4 Coarse Aggregates

Coarse aggregate used in this study was procured from the local quarry with a nominal maximum size of 20 mm. Specific gravity was found out by the pycnometer method and its value was 2.6

3. EXPERIMENTAL INVESTIGATIONS

3.1 Preparation of Alkaline Activator Solution (8M)

An amalgamation of Sodium Silicate (Specific gravity 1.53) at different Molarities of Sodium Hydroxide (Specific gravity 1.13) was used in the investigational work. They were mixed one day before casting the cubes. Sodium Hydroxide, commercially available in flakes form, is white and produces a colourless solution when dissolved in distilled water. Sodium silicate is available in the form of thick viscous liquid and the combined solution was colourless and sticky.

3.2 Preparation of Alkali Activated Concrete mix (G90E10)

1. Since there is no customary method for GPC mix design for any grade of concrete which can be indirectly adopted for application, optimum mix proportion is chosen from previous studies [4]. In the present study, a trial value of 370 kg of binder is taken for the preparation of 1m^3 of GPC.
2. After deciding the quantity of Eggshell powder, a ratio of silicates to hydroxides, the molar concentration of sodium hydroxide, the ratio of alkaline solution to GGBS is taken as 0.7 [4] to calculate the quantities of the hydroxide and silicate solutions. The mix proportion of GGBS: fine aggregate: coarse aggregate has been taken as 1:1.6:3.7

All the constituents of Alkali Activated Concrete mix are carefully weighed and placed in a pan mixer individually and the dry constituents are uniformly mixed for 5 minutes. Then the prepared alkaline solution is added to the mix and mixing is continued for 4 minutes. In the end, superplasticizer sika plast (0.7% of GGBS) has been added to the mix and the mixing is continued further for 5 minutes. Immediately slump cone test has been done to determine the workability of the mix for all mix proportions. The fresh concrete mix is transferred to moulds (150mm x 150mm x 150mm) and compaction is done by vibrator for uniform placement of concrete in the cubes. Cubes are demoulded after 48 hrs and then placed at room temperature for 28 days.

3.3 Preparation of HCl and H_2SO_4 solution for durability study

For the preparation of 2N of H_2SO_4, 55ml of H_2SO_4 (98% concentrated) has been added in 945 ml of distilled water to make 1000 ml of solution. This solution is filled up to the drum accordingly and cubes are immersed in it for 28, 56, 90 days after demoulding. A pH of 4 was constantly maintained during the curing period. 2 N of HCl solution was also prepared in a similar method.

4. RESULTS AND DISCUSSION

4.1 Workability of Fresh Concrete

After the mix is prepared standard slump test is done for all mix proportions and the values are given in Table 1

Table 1: Slump Test Values for Different Mix Proportions

S.No.	Type of Concrete	Slump Value (mm)
1	GGBS Alkali activated Concrete	**100**
2	Alkali activated Concrete with G90%	**85**
3	Alkali activated Concrete with G80%	**80**
4	Alkali activated Concrete with G70%	**75**
5	Alkali activated Concrete with G60%	**70**

It can be inferred from Table 1 that the workability of the mix is increased by an increase in GGBS percentage.

4.2 Comparison of Compressive Strength

Compressive strength test has been performed on alkali-activated concrete for different mix proportions of Eggshell powder and GGBS at 28 days for 8M, 10M and 12M of NaOH and the results are presented in Table 1.

Table 2: Comparison of Compressive Strength (MPa) of Alkali Activated Concrete and Concrete Exposed to HCl at Different Molarities

Molarity	Mix proportion of GGBS& ESP	Compressive Strength (MPa) of Alkali activated concrete for 28 days curing	Compressive Strength (MPa) for 28days (exposed to HCL)	Compressive Strength (MPa) for 56days (exposed to HCL)	Compressive Strength (MPa) for 90days (exposed to HCL)
8	G90E10	50	44.28	39.43	37.29
	G80E20	55.26	46.88	41.83	40.84
	G70E30	56.91	47.57	44.88	42
	G60E40	60.84	48.51	47.76	43.98
10	G90E10	51.8	45.46	42.75	40.19
	G80E20	56.18	47.95	43.55	41.85
	G70E30	59.29	48.95	45.89	43.92
	G60E40	62.17	49.78	47.89	44.21
12	G90E10	52.11	49.32	44.74	41.25
	G80E20	58.1	48.06	46.97	43.29
	G70E30	62.23	49.45	49.06	46.19
	G60E40	64.18	50.12	49.64	47.29

From Table 2, it can be inferred that the compressive strength of alkali-activated concrete is increasing with an increasing percentage of GGBS. Since GGBS is a fine powder that has more cohesion between particles than ESP, it can be inferred as a reason for increasing compressive strength. However, a detailed study can be done by further increasing the GGBS percentage and reducing the ESP percentage. When exposed to HCl, the compressive strength of alkali-activated concrete steadily decreased with the increasing age of curing. The neutralizing action of HCl on the polymerization process of alkali activator can be inferred as a reason for a decrease in compressive strength. Figure 2 shows the Concrete cube (8 M) immersed in HCl solution for 28 days. Pores of different sizes and white coloured salts can be seen deposited on the surface conforming to the neutralization action of HCl.

Figure 2: Alkali activated concrete cube after HCl exposure for 28 days (8 M)

Table 3: Comparison of Compressive Strength (MPa) of Alkali Activated Concrete and Concrete Exposed to H_2SO_4 at Different Molarities

Molarity	Mix proportion of GGBS& ESP	Compressive Strength (MPa) of Alkali activate concrete for 28 days curing	Compressive Strength (MPa) for 28days (exposed to H_2SO_4)	Compressive Strength (MPa) for 56days (exposed to H_2SO_4)	Compressive Strength (MPa) for 90days (exposed to H_2SO_4)
8	G90E10	50	37.12	35.80	32.19
	G80E20	55.26	37.69	37.41	33.28
	G70E30	56.91	38.19	37.59	35.29
	G60E40	60.84	39.62	38.58	36.45
10	G90E10	51.8	38.42	36.38	34.19
	G80E20	56.183	38.97	37	35.98
	G70E30	59.29	39.79	38.97	35.29
	G60E40	62.17	40.26	39.25	36.45
12	G90E10	52.11	39.30	39.15	37.29
	G80E20	58.1	39.55	39.27	38.25
	G70E30	52.23	40.12	40	37.28
	G60E40	64.18	41.26	40.15	38.87

From Table 3, it can be observed that, when exposed to H_2SO_4, the compressive strength of alkali-activated concrete cubes is steadily decreasing with the increased age of curing. However, the decrease in the compressive strength while the cubes were immersed in H_2SO_4 was more than that of HCl immersion, indicating that the neutralising action of H_2SO_4 is stronger than HCl. Figure 3 shows the geopolymer cube (8M) immersed in H_2SO_4 solution for 28 days.

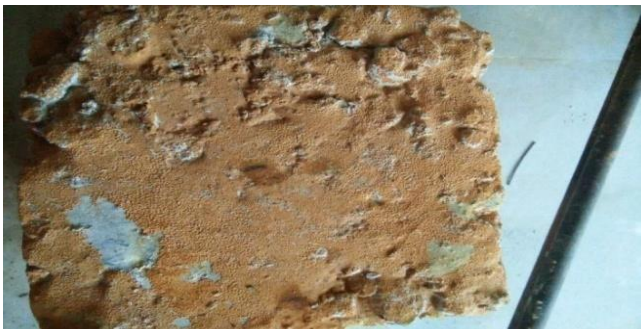

Figure 3: Alkali activated concrete cube after H_2SO_4 exposure for 28 days (8M)

Table 4: Comparison of Percentage Loss of Compressive Strength of Alkali Activated Concrete for HCl Exposure to Different Molarities of NaOH at Different Ages of Curing

Molarity of NaOH	Mix proposition of GGBS & GGBS	Percentage Loss in compressive strength of alkali-activated concrete after HCl exposure		
		28 DAYS	**56DAYS**	**90DAYS**
8	G90E10	11.44	21.14	25.42
	G80E20	15.16	24.30	26.09
	G70E30	16.11	21.138	26.66
	G60E40	20.26	21.499	27.71
10	G90E10	10.94	17.47	22.41
	G80E20	14.65	22.48	25.51
	G70E30	15.53	22.60	25.92
	G60E40	19.92	20.96	26.88
12	G90E10	5.129	14.61	20.84
	G80E20	17.28	19.51	25.49
	G70E30	20.53	21.16	25.77
	G60E40	21.90	22.65	26.31

From Table 4, it can be inferred that with an increase in HCl exposure the Alkali Activated Concrete is continuously losing its strength. For the G90E10 mix (8M), it is observed that the percentage loss is almost doubled for 56 days when compared with 28 days of HCl exposure. Also, for 8, 10, and 12M of NaOH, for all mix proportions, the loss of compressive strength is almost the same for 90 days of HCl exposure. For the 10 M, G60E40 mix, the compressive strength loss almost doubled when compared with the G90E10 mix for 28 days HCl exposure. The compressive strength loss is almost the same for 90 days HCl exposure for all mix proportions for all molarities except G90E10 mix indicating that the effect of HCl exposure almost seizes beyond 56 days exposure

Table 5: Comparison of Percentage Loss of Compressive Strength of Alkali Activated Concrete for H_2SO_4 Exposure to Different Molarities of NaOH at Different Ages of Curing

Molarity of NaOH	Mix proposition of GGBS & GGBS	Percentage Loss in compressive strength of alkali-activated concrete after H_2SO_4 exposure		
		28 DAYS	**56DAYS**	**90DAYS**
	G90E10	**25.76**	**28.4**	**35.62**
8	**G80E20**	**31.79**	**32.30**	**36.31**
	G70E30	**32.89**	**33.94**	**37.98**
	G60E40	**34.87**	**36.89**	**40.08**
	G80E20	**25.58**	**29.76**	**33.99**
	G70E30	**30.63**	**34.14**	**35.95**
10	**G80E20**	**32.38**	**31.27**	**39.02**
	G70E30	**39.19**	**40.7**	**39.97**
	G80E20	**24.64**	**24.64**	**28.49**
	G70E30	**31.92**	**32.40**	**34.16**
12	**G80E20**	**23.18**	**35.72**	**28.62**
	G70E30	**33.71**	**35.71**	**39.43**

Table 5 shows that the percentage compressive strength loss of Alkali Activated concrete for H_2SO_4 exposure is more when compared with HCl exposure for all mix proportions indicating that the sulphate attack is more predominant. However, it was visually observed that the cubes were structurally intact and had good load carrying capacity even after the sulphate attack.

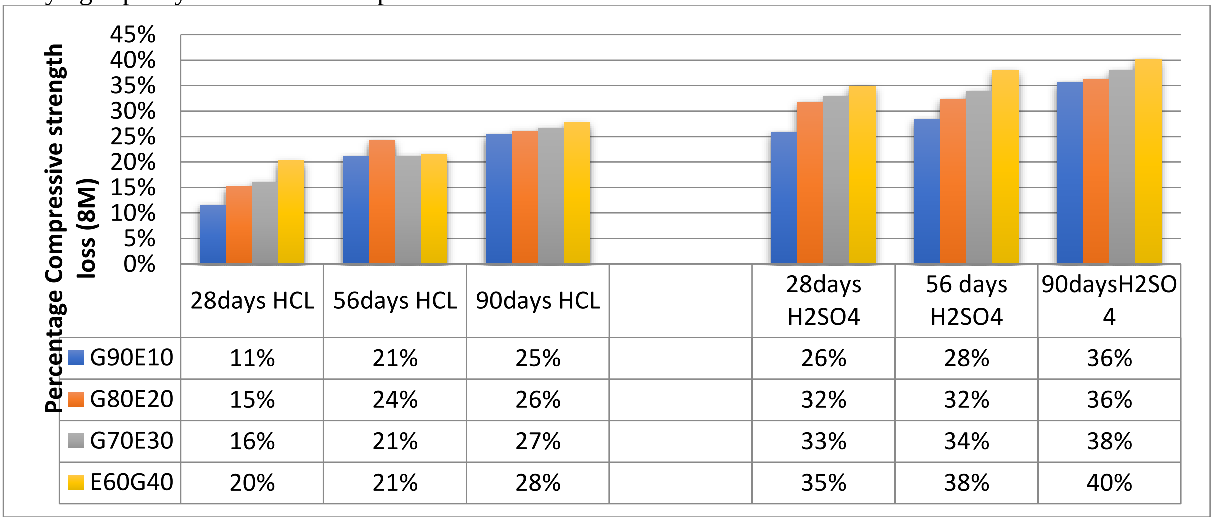

Figure 4: Graphical representation of Compressive Strength Loss for HCl and H_2SO_4 Exposure for 8M of NaOH for Different Ages of Curing

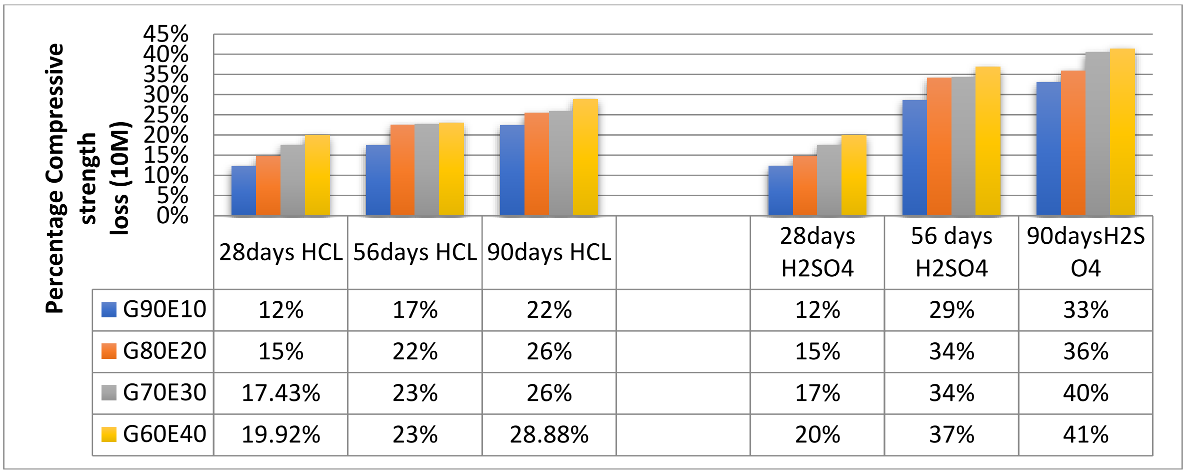

Figure 5: Graphical representation of Compressive Strength Loss for HCl and H_2SO_4 Exposure for 10M of NaOH for Different Ages of Curing

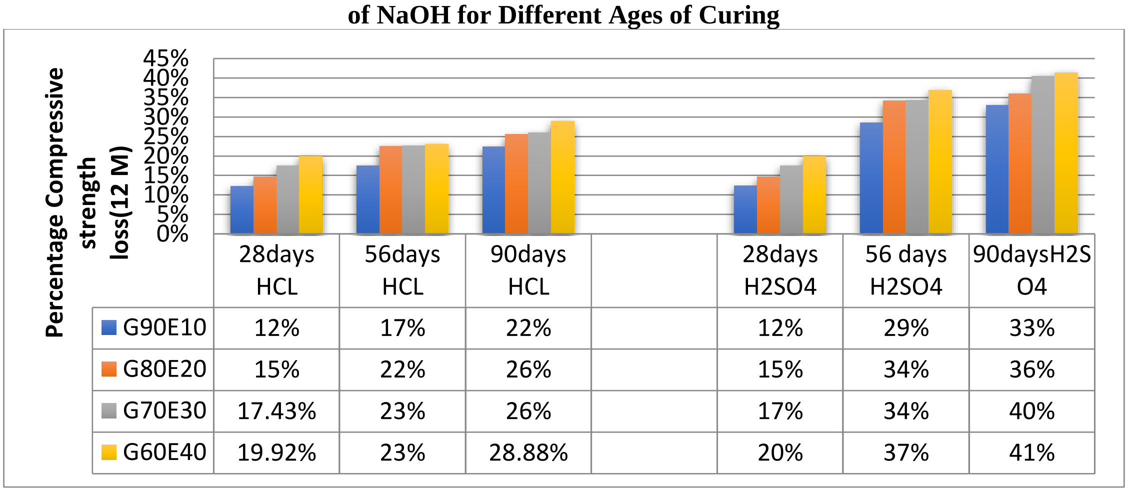

Figure 6: Graphical representation of Compressive Strength Loss for HCl and H_2SO_4 Exposure for 12M of NaOH for Different Ages of Curing

5. CONCLUSIONS

The following conclusions are drawn based on the above experimental investigations.

1. The workability of GPC is decreased with the increasing percentage of GGBS. However, for better workability tests need to be done with increasing sika plast percentage.
2. Maximum compressive strength of 64 MPa was observed in this study for G60E40 mix (12M of NaOH)
3. Even after 90 days of H2SO4 exposure, the minimum substantial residual strength of GPC was 32 MPa for the G90E10 mix indicating the acid resistance of GPC.
4. Maximum percentage compressive strength loss for H2SO4 and HCl exposure are 40% and 27% respectively for 10M of NaOH indicating that H2SO4 is strong in neutralising the binding action than HCl.

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