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Acid Attack on Lime Mortar

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Abstract:- **In this paper an experimental investigation on effect of various types of acid on Lime mortar 1:5 was carried out. The various acids were used in diluted form, viz. Hydrochloric acid, Sulphuric acid, citric acid and acetic acid. While hydrochloric acid and sulphuric acid were used as percentage of dilution. The citric and acetic acids were used as moles in water. hydrochloric acid and sulphuric acid in various percentages such as 2, 4 and 6 as a curing medium. citric acid and acetic acid in various moles such as 0.05, 0.1 & 0.2 for citric and 0.1, 0.2, 0.3 for acetic acid as a medium for acid attack. The Lime mortar cubes exposed with acetic acid showed higher strength than ambient cured cubes. While other acids showed lesser strength and many cubes disintegrated and dissolved in acids which are discussed in result section. Lime mortar cubes cured in diluted acids were tested for strength, water absorption and weight.**

Keywords: ***Acid, Lime mortar, Hydrochloric acid, Sulphuric acid, Citric acid, Acetic acid.***

I.INTRODUCTION

Lime mortar is being used for eons. But due to advent of Portland cement and allied cementitious materials lime mortar usage is on decline. Lime mortar in various combinations is now widely used for renovation of ancient and heritage structures.

Nowadays ancient heritage structures are seeing fast deterioration due to atmospheric pollution and acid rains. Hence a basic study on effect of acids on lime mortar is explained in this paper.

Hydrochloric acid is also known as muriatic acid, is an aqueous solution of hydrogen chloride. It is a colourless solution with a distinctive pungent smell. It is a component of the gastric acid in the digestive system of most animal species, including humans. Hydrochloric acid is an important laboratory reagent and industrial chemical.

Sulphuric acid also known as oil of vitriol, is a mineral acid composed of the elements sulfur, oxygen and hydrogen, with molecular formula H_2SO_4. It is a colorless and viscous liquid that is miscible with water at all concentrations.

Acetic acid systematically named **ethanoic acid** is a colourless liquid organic compound with the chemical formula CH_3COOH (also written as CH_3CO_2H, $C_2H_4O_2$, or $HC_2H_3O_2$). When undiluted, it is sometimes called *glacial acetic acid*. Vinegar is no less than 4% acetic acid by volume, making acetic acid the main component of vinegar apart from water. Acetic acid has a distinctive sour taste and pungent smell. In addition to household vinegar, it is mainly produced as a precursor to polyvinyl acetate and cellulose acetate. It is classified as a weak acid since it only partially dissociates in solution, but concentrated acetic acid is corrosive and can damage skin.

Citric acid is a weak organic acid that has the molecular formula $C_6H_8O_7$. It occurs naturally in citrus fruits. In biochemistry, it is an intermediate in the citric acid cycle, which occurs in the metabolism of all aerobic organisms.

Gypsum is a particularly useful processed material. Its main application is as a building material, mostly produced as so –called plaster of Paris for plastering walls and making decorative features in buildings. However gypsum also has a diversity of other uses including making writing chalk, soil conditioning for agriculture, making moulds for pottery, as an additive in the manufacture of Ordinary Portland Cement (OPC)

M Sand is nothing but artificial sand made from crushing of rock or granite for construction purposes in cement or concrete. M sand differs from natural river sand in its properties.

II.REVIEW OF LITERATURE

Burcu Taufo, et al., [1] in their investigation of e ancient Roman buildings located Xanthos (Antalya), found that the binder of the mortars composed of lime and fine aggregates have compact and uniform structure. The mortars are of low density and high porosity were produced from high calcium lime containing magnesium and natural aggregates. The lime and aggregate ratios were between 3/4 – 5/2 by weight and the aggregates with particle sizes greater than 1mm. composed the largest fraction of the aggregates. Lime composed of small size of micritic crystals due to use of aged lime putty. Aggregates were natural and mainly composed of quartz, albite, diopside and amorphous silica that may derived from the use of volcanic ash as pozzolans.

Md Azree Othuman Mydin [2]Prepared Five mortar mixtures were designed by maintaining a constant lime/sand/water ratio of 1:2:0.035. The control mixture comprised only lime putty while various percentages of egg albumen in the range of 2–10% were used to prepare the remaining mixtures. The results indicated that the compressive and flexural strength of increases with the increasing percentage of egg albumen added into lime mortar until the mixture reaches 6% of egg albumen.

B. Middendorf et al., [3] devised methods for disaggregating or separating a mortar sample by dissolving the binder using dilute acids, and the subsequent chemical analysis that can be applied to the dissolved binder.

Özlem ÇİZER [4] investigated ratios of lime as the binder and aggregates as the filling material in mortars. Ratios were determined by treatment of mortar samples with dilute hydrochloric (HCl) acid. Two samples of 50-60g in weight from each mortar were prepared, dried and weighed (Msam) by a precision balance. Then, the mortar samples

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were left under the solution of dilute hydrochloric acid (5 %) until all carbonated lime ($CaCO_3$) in the samples entirely dissolved. Aggregates remaining insoluble were filtered through a filter paper, rinsed with water.

Adil Binal[5] studied Khorasan mortar made by using aggregate and lime exhibits a more flexible structure than the concrete. This feature allows the historic building to be more durable. The Khorasan mortar shows the highest compressive strength in mixtures with water/lime ratio of 0.55 and lime/aggregate ratio of 0.66. The samples with low lime/aggregate ratio, there was an increase in the strength values depending on the curing period. As the cure duration increases, a chemical reaction takes place between the lime and the brick fracture, and as a result of this reaction, the strength values are increased.

Andrew[6] suggests Selenitic lime made by incorporating calcium sulphate into the material, either by introducing sulphur dioxide into the kiln during lime burning or by adding sulphuric acid to the slaking water or by the addition of gypsum to a feebly hydraulic lime and grinding the mixture. The calcium sulphate promoted a rapid set and increased the strength of the mortar. Unfortunately it can result in stone decay in situations where any remaining free calcium sulphate, which was more readily soluble than calcium carbonate, was transferred to adjoining stones. Selenitic limes are not readily differentiated from pure calcium limes except by chemical analysis.

Winterkorn HF[7] in his Introductory remarks says that Phosphoric acid reacts with free iron and aluminum oxides present in the soil environment, producing heat and rapid formation of insoluble hard cementitious product

Amin Eisazadeh[8] observed that the phosphoric acid-stabilized lateritic soil showed the highest degree of improvement with an approximately threefold strength increase in comparison with the natural soil over an 8-month curing period.

B. Sengupta[9] explains that the reaction between acidic gases in the atmosphere and the products of cement/lime hydration is degradation of concrete. Normal air contains 0.3% CO_2 in low concentration. When the level of CO_2 in industrial atmosphere becomes higher, it penetrates into the pores of concrete by diffusion and reacts with calcium hydroxide. As a result pH level is reduced and consequently concrete protection of reinforcing steel is lost

III.EXPERIMENTAL PROCESS

Take Lime to M-Sand ratio as 1:5, and 5% Gypsum is added to mix to prevent drying shrinkage, Water to lime ratio is kept at 0.5.Dry the cast specimen after 24 hours from moulding.. Cure cast specimen for 7 days by sprinkling water in open atmosphere. Conduct required test after curing in diluted acid.

For Acid attack studying 2%, 4% and 6% of Sulphuric acid and Hydrochloric acids solutions were used.

For 0.05 M citric solution, 48 gms of citric salt in 5 litre of water, For 0.1M citric solution 96gms of citric salt in 5 litre of water, For 0.2M Citric solution, 192 gms of citric salt in 1 litre of water, For 0.1 M Acetic solution, 30 gms of citric salt in 5 litre of water, For 0.2 M Acetic solution, 60 gms of citric salt in 5 litre of water, For 0.3M Acetic solution, 90 gms of citric salt in 1 litre of water

The higher moles of 0.5M or more of citric acid or Acetic acid caused disintegration of cubes within 7 days.

IV.RESULTS AND DISCUSSION

TABLE 1. WATER ABSORPTION CHARACTERISTICS

WATER ABSORBPTION				**% decrease 7d**	**% decrease 14d**	**% decrease 28d**
	7D	14D	28 D			
2% H_2SO_4	8.33	8.1	7.38	4.69	5.70	13.17
4% H_2SO_4	11.44	6.49	6.84	-30.89	24.4	19.52
6% H_2SO_4	7.76	7.45	0	11.21	13.27	100
2% HCL	9.52	8.89	0	-8.92	-3.49	100
4% HCL	8.71	9.4	0	0.34	-9.42	100
6% HCL	15.21	0	0	-74.02	100	100
Ambient	8.74	8.59	8.5	0	0	0

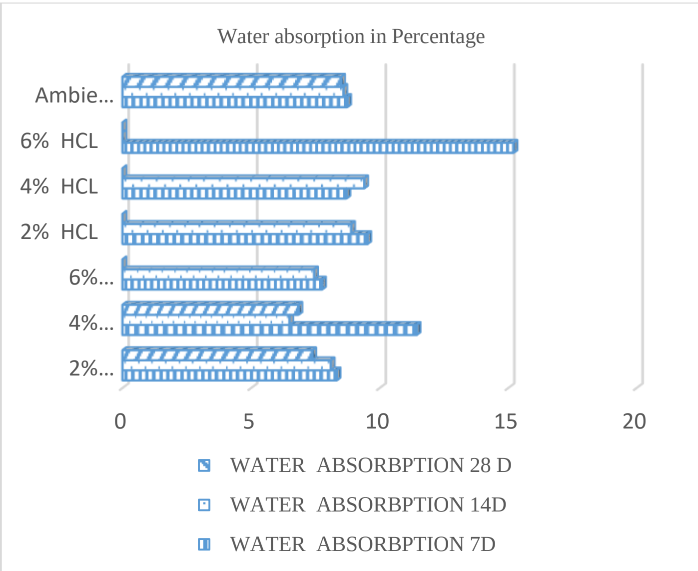

FIGURE 1: WATER ABSORPTION IN PERCENTAGE

TABLE 2. UNIT WEIGHT

Unit weight in gms/cc				**decrease**		
	7D	14D	28 D	% 7d	% 14d	% 28d
2% H_2SO_4	2.15	2.15	2.22	6.19	6.54	3.64
4% H_2SO_4	2.16	2.30	2.30	5.81	-0.12	0.37
6% H_2SO_4	2.13	2.33	0	7.07	-1.13	100
2% HCL	2.08	1.84	0	9.22	19.77	100
4% HCL	2.03	2.05	0	11.50	10.95	100
6% HCL (small size)	1.05	0	0	54.23	100	100
ambient	2.29	2.30	2.31	0	0	0

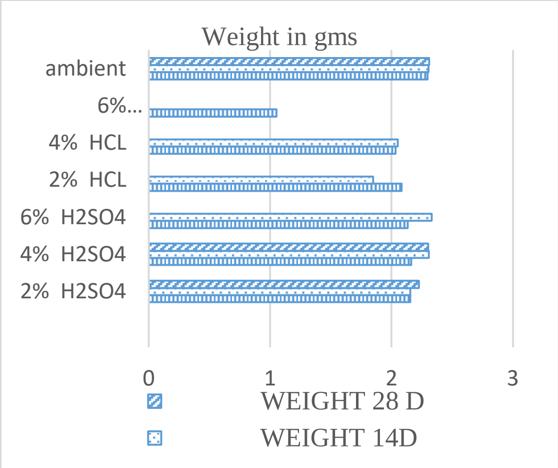

FIGURE 2: UNIT WEIGHT

TABLE 3. COMPRESSIVE STRENGTH IN N/MM2

COMPRESSIVE STRENGTH				percentage decrease in strength		
Method	7D	14D	28 D	7d	14d	28d
2% H2SO4	0.49	0.23	0.14	-25.64	46.51	72.54
4% H2SO4	0.05	0.12	0.07	87.17	72.09	86.27
6% H2SO4	0.28	0.12	0	28.20	72.09	100
2% HCL	0.29	0.39	0	25.64	9.30	100
4% HCL	0.3	0.26	0	23.07	39.53	100
6% HCL	0.28	0	0	28.20	100	100
Ambient	0.39	0.43	0.51	0	0	0

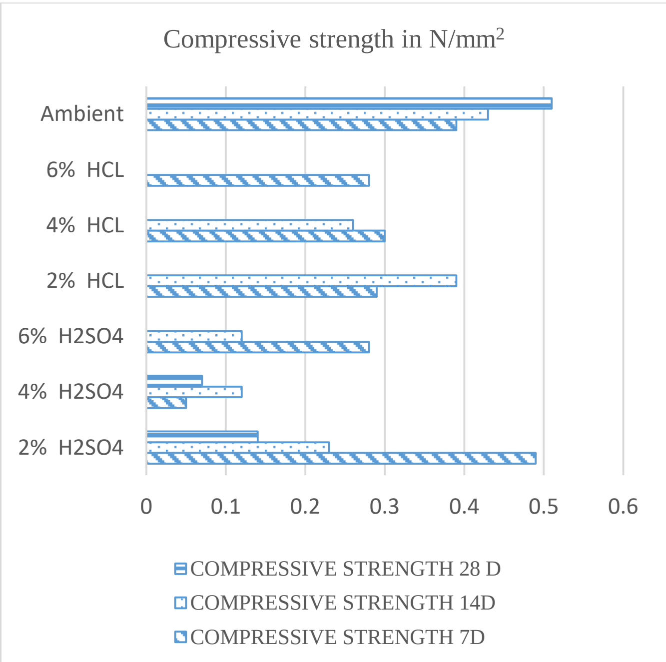

FIGURE 3. COMPRESSIVE STRENGTH IN N/MM2

TABLE 4. WATER ABSORPTION CHARACTERISTICS CITRIC AND ACETIC ACIDS

CURING TYPE	PERCENTAGE
cit0.05	5.77
cit0.1	9.11
cit0.2	5.5
ace0.1	5.3
ace0.2	5.4
ace0.3	5.05
Ambient	8.85

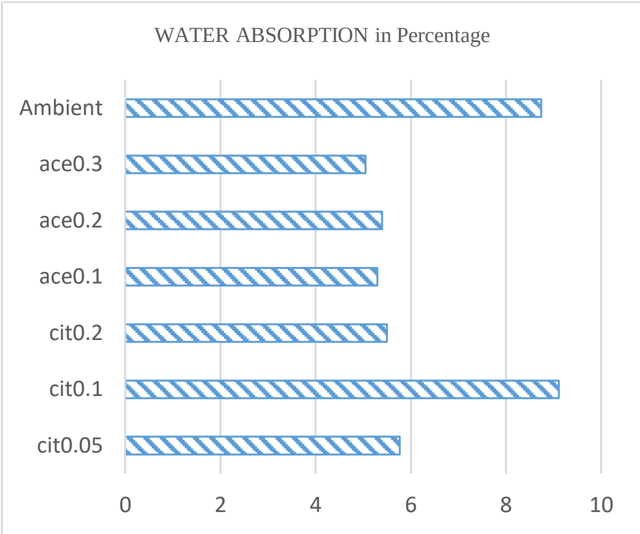

FIGURE 4. WATER ABSORPTION CHARACTERISTICS CITRIC AND ACETIC ACIDS

TABLE 5: UNIT WEIGHT CHARACTERISTICS CITRIC AND ACETIC ACID ATTACK

CURING TYPE	UNIT WEIGHT gm/cc
cit0.05	2.01
cit0.1	2.01
cit0.2	1.91
ace0.1	2
ace0.2	2.16
ace0.3	2.09
Ambient	2.29

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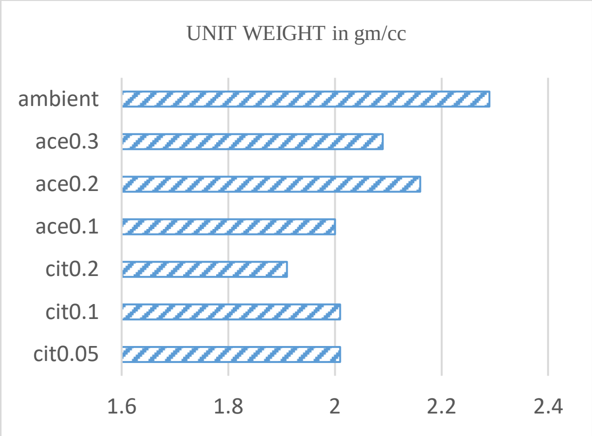

FIGURE 5. UNIT WEIGHT CHARACTERISTICS CITRIC AND ACETIC ACIDS

TABLE 6: COMPRESSIVE STRENGTH CHARACTERISTICS CITRIC AND ACETIC ACID ATTACK

CURING TYPE	COMPRESSIVE STRENGTH
cit0.05	0.467
cit0.1	0.449
cit0.2	0.507
ace0.1	0.707
ace0.2	0.841
ace0.3	0.682
Ambient	0.436

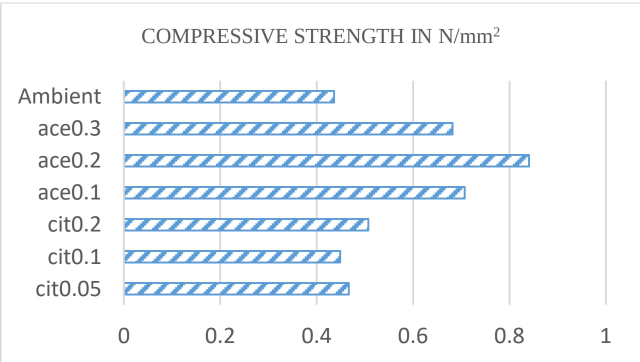

FIGURE 5. COMPRESSIVE STRENGTH CHARACTERISTICS CITRIC AND ACETIC ACIDS

V.CONCLUSION

Hydrochloric And Sulphuric Acids Exposure

1. Water absorption is more in 7 days and less for 14 and 28 days for all acid attacks
2. The 28 day cubes of all percentages of HCL and 6% Sulphuric acid, 14days 6% HCL disintegrated
3. Lowest water absorption is shown in 4% sulphuric acid and next is 6% sulphuric acid, hence it is evident that HCL is more harmful than sulphuric acid in acid attack
4. Highest water absorption is for 6% at 7days, these samples eventually disintegrated
5. Compared to ambient cured cubes 4% and 6% sulphuric acid attack cubes show lower water absorption
6. Maximum weight is shown by ambient curing samples of 28 days and 6% sulphuric acid and 4% sulphuric acid attack cubes, this correlates with water absorption results
7. Lowest weight is shown by 4% and 6% HCL attack samples, this correlates with water absorption results of same
8. Compressive strength of ambient cured cubes are superior in strength than that of acid attack cube, except 2% sulphuric acid cubes
9. From the compressive strength results, it is evident that even though weight increases and water absorption decreases for the 4% and 6% sulphuric acid attack cubes, the strength is less than ambient cured cubes.
10. Only 2% sulphuric acid attack for 7days shows cubes strength of 0.49 which is nearer to results of ambient cured cubes, 14 days and 28 days' exposure decreases the strength by 46% And 72 percent respectively.
11. Even though the water absorption and weight of 2% HCL exposure cubes show negative trend, the compressive strength at 14 days' exposure shows values equal to ambient cured cubes
12. Hence 2% of sulphuric acid and 2% of HCL exposure for 7-14 days is is OK for Lime mortar cubes, other higher percentage of HCL and Sulphuric acids are harmful to lime mortar

Citric and Acetic Acid Acids Exposure

13. Water absorption is maximum for citric 0.1 mole exposure cube
14. Ambient exposure cubes also show water absorption less than citric 0.1 mole exposure cubes
15. Lowest water absorption is shown for acetic acid 0.1mole exposure cubes
16. Lowest unit weight is shown for citric 0.2mole exposure cubes
17. Highest unit weight is shown by ambient cured cubes
18. Acetic acid 0.2 mole exposure cubes show unit weight nearer to but less than ambient cured cubes
19. Acetic acid 0.2 mole exposure cubes show highest strength almost double than that of ambient cured cubes
20. Acetic acid 0.2 mole exposure cubes also show higher unit weight and lower water absorption which is correlating with high compressive strength
21. All the citric acid and acetic acid exposure cubes show higher strength than ambient cured cubes
22. Acetic acid solution are better for exposure than citric acid solutions, because of higher percentage of increase in strength

VI.SCOPE FOR FURTHER WORK

1. Lesser percentages of hydrochloric and sulphuric acids such as 1, 0.75, 0.5,0 .25 can be tried for acid attack exposure
2. The microstructure studies and XRD studies of ingredients and final cubes after acid exposure can be studied

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3. The acetic acid can be used as a admixture in lime mortar in 0.2M, OR 0.1M, OR 0.3M and strength enhancement can be studied

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