Effect of Aluminium Chloride on the Geotechnical Properties of Expansive Soil

Prof. V. Giridhar [#1], Mahendrakar Mahendra Kumar [*2]
[1]Professor, Department of Civil Engineering, KSRM College (Autonomous), Kadapa, A.P, India
[2]PG Scholar, Department of Civil Engineering, KSRM College (Autonomous), Kadapa, A.P,India

Abstract

Expansive soils in India are God's boom to formers but susceptible to detrimental volume changes because of their potential to react to changes in moisture regime, which may causes distortions to the civil engineering structures constructed on these soils, which poses the challenges to the Geotechnical engineers. Block cotton soils are chemically active, their nature and behavior can be controlled through the application of chemical agents, the main advantage by the use of the chemical agents is setting time and curing time can be controlled. This paper emphasizes the effect of $AlCl_3$ *on Atterberg's limits, compaction, soaked CBR and strength characteristics tests of black cotton soil mixing with different percentages, with a view to determine the optimum percentage. In this paper, the test results such as Atterberg limits, Differential Free Swell Index, Compaction characteristics, California Bearing Ratio Values, Strength characteristics and SEM analysis on expansive soils mixed with Aluminum Chloride (*$AlCl_3$*) in varying percentages of 0.5%, 1.0%, 1.5%, 2.0%, 2.5%, 3.0% and 3.5% of the expansive soil. It is observed that at optimum percentage, i.e., 2.5%* $AlCl_3$*, there is a marked development in the strength of soil.*

Keywords — *Atterberg limits, Aluminum Chloride ($AlCl_3$), Soaked CBR, Unconfined Compression and SEM analysis.*

I. INTRODUCTION

Expansive soils always pose challenge to foundation engineering. In India, these soils occupy around 20% of the total area. When Geotechnical engineers are faced with swelling type of soils, it is great challenge to foundation engineers. The design of foundations and pavements founded on swelling soils always involve a certain degree of risk and damage. The characteristics that are of concern to the design engineers are permeability, compressibility and durability. Aluminum Chloride exhibits high shear strength which is highly beneficial for its use as a geotechnical material, the main advantage of it is that setting time and curing time can be controlled, the test results such as Atterberg limits, compaction, California Bearing Ratio, strength characteristics and Differential Free Swell obtained on expansive soils admixed with Aluminum Chloride ($AlCl_3$) in varying percentages of 0.5%, 1.0%, 1.5%, 2.0%, 2.5%, 3.0% and 3.5% of the expansive soil. The purpose of this study is to investigate the influence of a specific chemical, Aluminium Chloride ($AlCl_3$) on the geotechnical properties of an expansive soil. An attempt made to check the advantage application of additives into soil, which may results in permanent physical and chemical alterations. This paper focus on experimental test plan was to investigate the effect of $AlCl_3$ on strength improvement expansive soil. The laboratory test matrix in each test plan included variations additive content, curing period, and moisture condition. A study made to know $AlCl_3$ addition to expansive soils, its effect on the Index and Engineering properties. The commercial grade Aluminium Chloride is added as a stabilizer to the expansive soil.

II. LITRERATURE REVIEW

T Yamini Devi et al (2016) have studied the stabilization of expansive soil using $AlCl_3$ and fly ash .the expansive soils mixed with $AlCl_3$ in varying percentages of 0.5%, 1.0%, 1.5%, 2.0% of the expansive soil and at each percentage of chemical, addition of fly ash in percentage of 5%, 10%, 15%, and 20%. They concludes optimum percentage i.e., 1.0% $AlCl_3$ and 10% fly ash, there is marked improvement in the results. G D N Santhoshi et al (2017) their works reveals Black Cotton Soils combining with different proportion of Barite powder and AlCl3, increases the geotechnical properties and the optimum percentage are 1.5% and 20% of $AlCl_3$ and fly ash.

Durotoye T.O and Akinmusuru J.O (2016) studied on "effects of sodium chloride on the engineering properties of expansive soils". They added Sodium Chloride in the natural soil with varies percentages and concluded that the optimum percentage obtained at the 1.5% percent of sodium chloride. The soaked and un- soaked CBR values are 15.38 and 31.78. Also, the unconfined compressive strength at 1.5% percent of NaCl is 86.17 kN/m^2 and the natural soil is 67 kN/m^2.

III.MATERIAL INVESTIGATION

A. Expansive Soil:

The soil used in this investigation the expansive soil collected from the Thadigotla village area, near Krishnapuram, Kadapa, A.P, India. The

pebbles and vegetative matter present at the site are removed by hand. The soil is collected at 1.0m depth below the natural ground level. It is dried and pulverized and sieved through a sieve of 4.75 mm size to eliminate gravel fraction, if any. This dried and sieved soil is stored in airtight containers ready for use for mixing. The soil is classified as 'CH' as per I.S. classification (I.S. 1498:1978) indicating that it is Inorganic Clay of High Plasticity. Its degree of expansiveness is very high as the Differential Free Swell Index (DFSI) is 140 per cent.

TABLE 3.1.PROPERTIES OF EXPANSIVE SOIL

Properties of soil	Values
Specific Gravity	2.58
Grain size distribution	
Sand	17%
Silt	19%
Clay	64%
Atterberg Limits	
Liquid Limit	83%
Plastic Limit	39%
Plasticity Index	44%
IS Classification	CH
Differential Free Swell Index	140%
Standard Proctor Compaction	
OMC	24.57%
MDD	1.50 g/cc
California bearing ratio	2.48%
Unconfined compression strength	1.36 kg/cm2

B. Aluminium Chloride ($AlCl_3$):

Aluminium chloride ($AlCl_3$) is compound of Aluminium and Chlorine. The solid has a low melting and boiling point, and is covalently bonded. When $AlCl_3$ reacts with wet soils, it alters the nature of the adsorbed layer. Aluminium ions replace the sodium or iodine ions. The double layer is usually depressed due to an increase in the cat ion concentration. Hence, in Aluminium Chloride stabilization, the liquid limit and plastic limit of the soil decreases. Thus, the plasticity index of the soil decreases, the soil becomes more friable and workable. The reactions can be simplified as: $[Al(H_2O)_6]^{3+} + H_2O \rightleftharpoons [Al(OH)(H_2O)_5]^{2+} + H_3O^+$.

TABLE 3.2 CHEMICAL COMPOSITION OF ($ALCL_3$)

Contents	Details
Other Name	Aluminium Trichloride
Molar Mass	133.34 g/mol
Appearance	Pale yellow solid, hygroscopic
Density (Solid)	2.48 g/cc
Melting Point	192.6°C
Boiling Point	182.7 °C

IV. EXPERIMENTAL PROGRAMME

The following tests are conducted in this investigation as per standard specifications:

1. Index Properties (IS:2720 Part-5-1985)
2. Specific Gravity (IS:2720 Part-3-1980)
3. Differential Free swell Index (IS:2720-Pt-40-1977)
4. Compaction Characteristics (IS:2720-Part-7-1980)
5. California Bearing Ratio (IS:2720 Part-16-1979)
6. Shear Strength (IS:2720 Part-10-1973)
7. SEM analysis.

A. Mixed Proportion Details:

Here, the commercial grade Aluminium Chloride ($AlCl_3$) is used as a stabilizer. $AlCl_3$ added at 0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 and 3.5 precent by weight of soil. The quantity of chemical computed corresponding to the above percentage is directly mixed to the soil before water adding to it, in order to obtain even distribution of the chemical

B. Effect of Curing:

In unconfined compressive strength, soil specimens are prepared and tested after curing period of 0, 3 and 7 days. To find the gradual variation of different in engineering properties by increasing the quantity of chemical to determine the optimum percentage at which the properties are improved. The curing is done with the help of desiccators which maintain water content of the specimens and maintain high humid conditions. As a result, the specimens could be cured at high relative humidity with moulded water content without any appreciable loss of moisture.

V. RESULTS AND DISCUSSIONS

A. Plasticity characteristics and Deferential Free Swell Index:

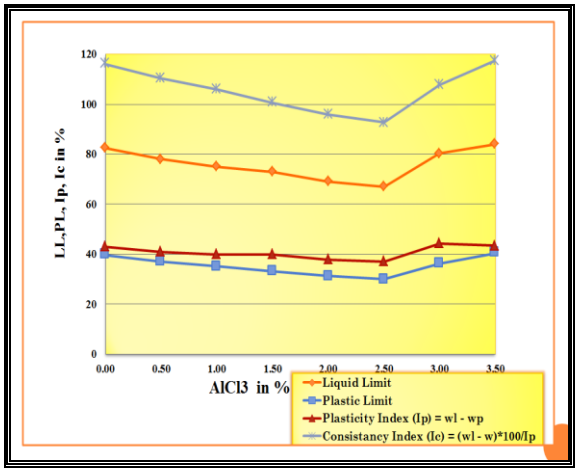
There is reduction in Liquid limit and plastic limit of soil with addition of $AlCl_3$up to the incremental percentage of 2.5% it is clearly appears in fig 4.1.Beyond this percentage it has been observed that there is increase in both Liquid limit and plastic limit. The influence of $AlCl_3$ on Plasticity Index of soil is considerable up to the 2.5% $AlCl_3$ admixed soil. The differential free swell index value of the natural soil is 140%. The maximum reduction in differential free swell index is observed at 3.0% addition of $AlCl_3$ in tested range. Therefore, 3% addition of $AlCl_3$ is more effective in reducing the swelling characteristics in the tested range.

TABLE 5.1 PLASTICITY AND COMPACTION CHARACTERISTICS FOR CORRESPONDING $ALCL_3$ % IN SOIL

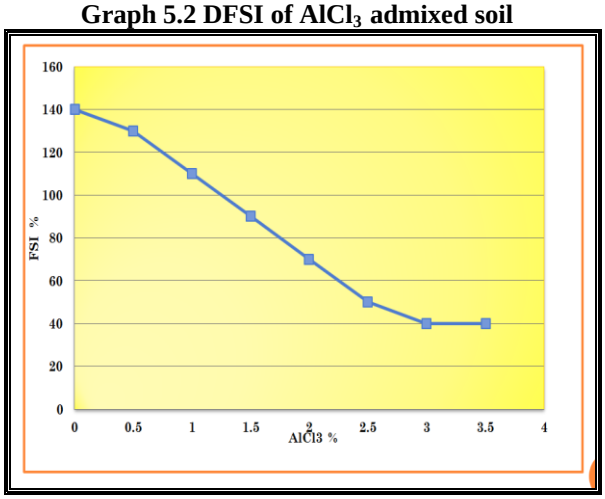
% of AlCl3	LL (%)	PL (%)	Pl (%)	OMC in (%)	MDD (g/cc)

0.0	83	39	44	24.57	1.5
0.5	78	37	41	23.90	1.53
1.0	75	35	40	22.61	1.64
1.5	72	33	39	21.72	1.65
2.0	69	32	37	19.57	1.68
2.5	66	30	36	18.30	1.72
3.0	80	36	44	18.32	1.71
3.5	84	39	45	19.72	1.68

Graph 5.1 Plasticity Characteristics of $AlCl_3$ admixed soil



Graph 5.2 DFSI of $AlCl_3$ admixed soil



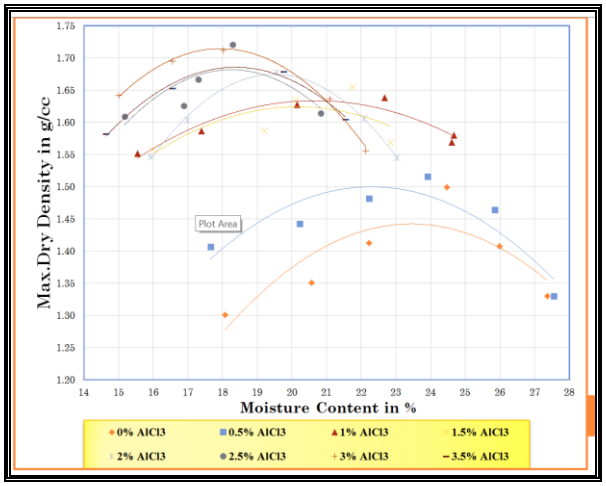
B. *Compaction characteristics:*

From Graph 5.1 & 5.3 the increase in dry density with incremental increase in chemical precent as usual the water contents may be decreases with respect to percentage of chemical admixed soil Up to 2.5% of $AlCl_3$ admixed soil. The maximum dry density is 1.72g/cc at 2.5% of $AlCl_3$, excess percentage of the AlCl3 the dry density value may be decreasing for 3.0%, and 3.5% due to the basic nature of used chemical may converts in soluble form when exposed to atmosphere the dry density values is 1.71 and 1.68 respectively. Hence, it is concluded that the 2.5% of $AlCl_3$ is gives the maximum dry density i.e., 1.72 g/cc. water content is 18.30%.

C. *California Bearing Ratio & Unconfined Compressive Strength:*

It is observed from the Table 5.3 & Graph 5.3 CBR value of soil samples admixed with AlCl3 increase with increase in percentages of $AlCl_3$ up to 2.5% $AlCl_3$ admixed soil and It is found that the excess of $AlCl_3$ more than 2.5% causes decrease in CBR value.

Graph 5.2 Compaction Characteristics of $AlCl_3$ admixed soil



Graph 5.2 $AlCl_3$ % Vs MDD & OMC

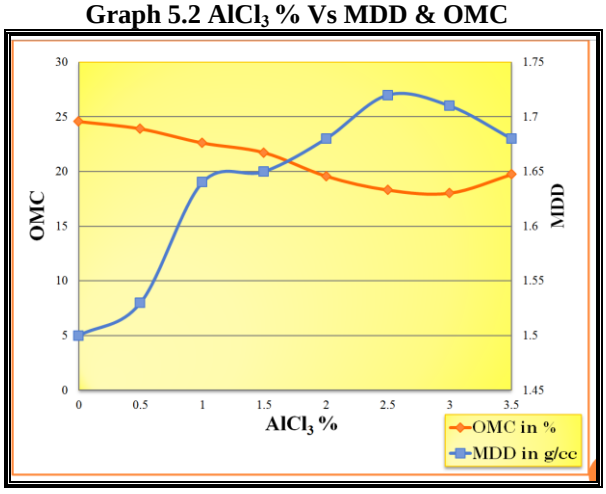


Table 5.4 & Graph 5.4 shows the influence of $AlCl_3$ on Unconfined Compressive Strength was observed In terms of additive percentage better shear strength observed at 2.0% for all the curing periods. Index properties and compaction characteristics reveals 2.5% $AlCl_3$ admixed soil is better strength achieving percentage. But, the external forces or size of specimen also affects the test results.

TABLE 5.3.CBR TEST RESULTS

% of AlCl3	CBR at 2.5mm penetration			
	Unsoaked CBR	% increase in CBR	Soaked CBR	% increase in CBR
0.0	2.48	0.00	2.48	0.00
0.5	3.24	15.15	3.07	24.14
1.0	5.55	96.97	4.95	100.00
1.5	7.51	166.67	6.92	179.31
2.0	9.73	245.45	8.71	251.72
2.5	11.95	324.24	10.07	306.90
3.0	10.16	260.61	9.48	282.76
3.5	9.31	230.30	8.79	255.17

Graph 5.3. CBR Values for Soaked & Un-soaked Conditions for $AlCl_3$ admixed soil

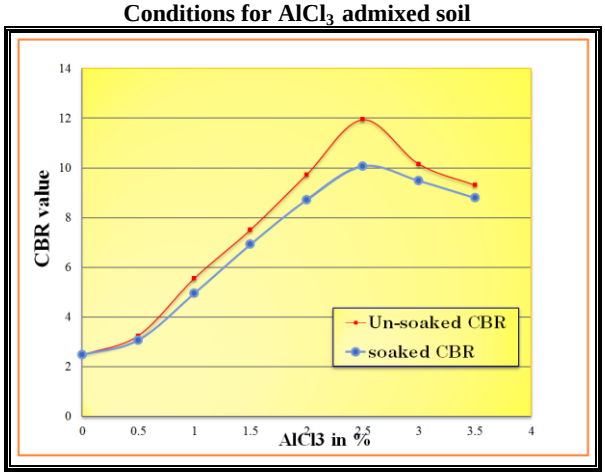
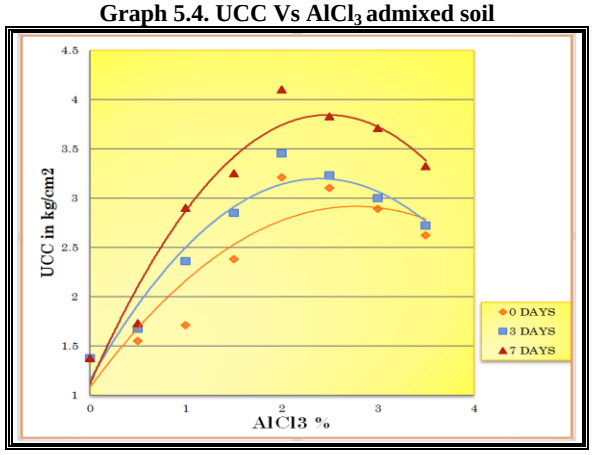


TABLE 5.4. UN-CONFINED COMPRESSIVE STRENGTH TEST RESULTS

% of AlCl3	Un-Confined Compression Strength in kg/cm^2		
	0 DAY	3 DAYS	7 DAYS
0.0	1.36	1.37	1.37
0.5	1.55	1.67	1.73
1.0	1.71	2.36	2.90
1.5	2.38	2.85	3.25
2.0	3.21	3.45	4.10
2.5	3.10	3.23	3.83
3.0	2.89	3.00	3.71
3.5	2.62	2.72	3.32

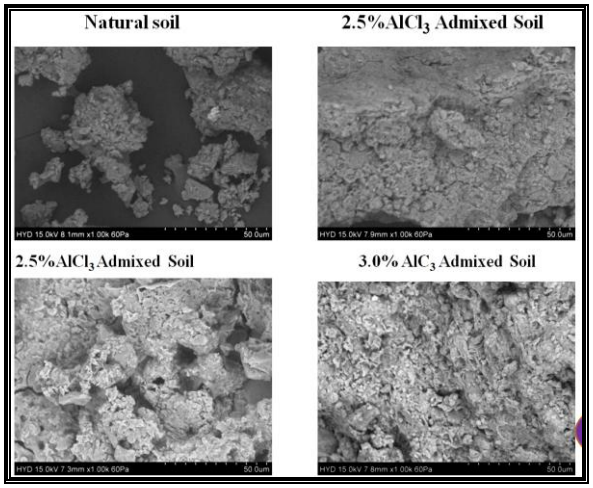
Graph 5.4. UCC Vs $AlCl_3$ admixed soil



D. SEM Analysis:

From the SEM analysis the increase in $AlCl_3$ precent the soil sample changes amorphous structure from crystalline structure of natural soil. By the reaction of chemical with soil and water existed pores in natural expansive soil may be replaced by chemical admixed soil.

Images 5.5 SEM Analysis Images



VI. CONCLUSION REMARKS

1. There is reduction in Liquid limit of soil with addition of $AlCl_3$ up to the incremental percentage of 2.5% beyond this it has been observed that there is increase in Liquid limit.
2. Same trend of effect of $AlCl_3$ observed in case of Plastic Limit values also like as in case of Liquid Limit.
3. The influence of $AlCl_3$ on Plasticity Index of soil is considerable.
4. The admixed soil having 3.0% of $AlCl_3$ is considered to the more effective in reducing the Swelling characteristics in the tested range.
5. There is reduction in optimum moisture content with per cent increase in $AlCl_3$ by weight of the soil up to 2.5%.
6. The maximum Dry unit weight of the admixed soil increase with increase in percentage of $AlCl_3$.
7. The California Bearing Ratio value of the soil is influenced by the addition of $AlCl_3$.
8. The maximum increase in California Bearing Ratio value of soil admixed with $AlCl_3$ which occurs at 2.5% of $AlCl_3$.
9. The strength of soil samples admixed with $AlCl_3$ tested immediately increase with increase in per cent $AlCl_3$.
10. The unconfined compressive strength of the admixed soil increases with in $AlCl_3$ percentage and curing period.

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