IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 1 Ver. IV(Jan. - Feb. 2016), PP 57-60
www.iosrjournals.org

Influence of Chloride Compounds on the Swelling and Strength Properties of Expansive Subgrade Soil

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Abstract: *The engineering properties of expansive soil containing montmorillonite clay mineral are highly sensitive to moisture variations. The cyclic wetting and drying process in the expansive subgrade soil leads to the failure of pavements constructed on them. In order to improve the properties of subgrade soils and the pavement system performance, stabilization of subgrade soil is only the alternative. In the process of stabilization, usage of chemicals has gained prominence due to their easy applicability and adaptability. In general, lime is a conventionally used chemical for the last two decades and investigations reveals that chloride compounds could also be used instead of lime, because of their active contribution towards the cation exchange with soil and also their solubility in water causes easy application to soil grains. In the present study the performance of different chloride compound chemicals like Ammonium chloride (NH_4Cl), Magnesium Chloride ($MgCl_2$) and Aluminum Chloride ($AlCl_3$) on the swelling and strength properties expansive soil were studied. Evaluation is based on the laboratory test results on the soil collected from coastal area of Andhra Pradesh, India. Chemicals were added to in varying percentages ranging from 0% to 2% of dry weight of the soil. Laboratory testing for DFS, swell pressure and UCS were carried out on specimens at different curing periods. Results show that the selected chemicals played a significant role in reducing the swelling properties and improving the strength properties of soil and out of which aluminum chloride was found to be more effective.*

Keywords: *Stabilization, Expansive subgrade soil, Chloride Chemicals, Swell Pressure, UCS*

I. Introduction

In the process of transportation network development, sometimes the alignment may have to be finalized on expansive subgrade soils, which causes poor pavement performance and increased maintenance costs. The clayey soils, along the coastal area of Andhra Pradesh, India contains montmorillonite mineral content having peculiar chemical makeup which shows alternative high swelling and shrinking due to seasonal moisture fluctuations. These soil deposits are expected to cover nearly twenty percent of the geographical area. Continued investigations have been going on throughout the world countries to devise ways and means to solve the problems caused by expansive subgrade soils. Out of different stabilization methods available, chemical stabilization is an alternative to alleviate the problems posed by expansive subgrade soils [1]. Stabilization of soil by blending lime is a conventional method and is in practice for the last two decades [2]. But the main problem with lime is its uniform application to the soil grains which is not possible as it is added in dry powdered form. Various researchers tried the effectiveness of strong electrolytes with the idea of applying the required concentration in the form of chemical solution. Calcium chloride could be used as an alternative to the conventionally used lime due to its dissolvability in water and exchange of cations [3]. The studies made by [4] shows the effect of addition of $CaCl_2$ on the properties of construction materials used for base and subbase courses. Laboratory and field testing were conducted by [5] to determine the effect of potassium hydroxide on the geotechnical properties of soil and also evaluated of effect of addition of lime, cement and their combination on UCS, bearing capacity, shear strength, durability and flexural characteristics of various soils. Similarly the effectiveness of trivalent cations like Fe^{+3} and Al^{+3} were investigated by [6] and found that the addition of these cations increases the shear strength of soil and soil becomes low compressible with reduced plasticity. Stabilization of silty clay using different chloride compound chemicals like NaCl, $MgCl_2$ and $CaCl_2$ were tried by [7] by mixing these chemicals in varying percentages of 2%, 4% and 8% of dry weight of soil. Results have shown the increased MDD, reduced OMC, increased UCS and reduced plastic properties of the soil. In the present work, an attempt is made to understand the effect of different chloride chemicals on the behavior of expansive soil. The variation of geotechnical properties particularly the swelling and strength properties are presented and discussed.

II. Materials Used

2.1 Soil

Black cotton soil was collected from Amalapuram town area of Andhra Pradesh, India. Soil is collected from a depth of nearly 1.5 meter from the ground level and it is black in color. Soil has high swelling nature, indicated by high value of DFS and swell pressure. From the laboratory grading it is classified as clays of high compressibility (CH). The geotechnical properties are as shown in table 1.

Table 1 Geotechnical properties of the expansive soil

Sl.No	Property	Value		Sl.No	Property	Value
1	DFS (%)	140		6	MDD (g/cc)	1.55
2	LL (%)	83		7	OMC (%)	25
3	PL (%)	28		8	SP (kPa)	290
4	PI (%)	55		9	CBR (%)	2
5	SL (%)	12		10	UCS (kPa)	94

2.2 Chemicals

Chloride compound chemicals like Ammonium Chloride (NH_4Cl), Magnesium Chloride ($MgCl_2$) and Aluminum Chloride ($AlCl_3$) were used in this study. All the chemicals are of laboratory grade.

III. Method Of Testing

Air dried soil was pulverized into small pieces and stored in air tight dry gunny bags. Chloride chemicals were used in varying percentages of 0.5%, 1.0%, 1.5% and 2.0% by dry weight of soil. Chemical solution is prepared by dissolving the chloride chemicals in the required quantity of water and added to the dry soil. The blended soil material is stored in gunny bags and left for curing at room temperature. Laboratory testing was performed according to the recommendations given in the Indian Standard Codes. Testing of Atterberg's limits were done using the procedure recommended in Indian Standard codes of 2720 (Part 5)-1985 and 2720 (Part VI) – 1972. Differential free swell testing was done as per IS 2720 (Part XL)-1977. Heavy compaction testing was done for finding MDD and OMC of the soil by following IS: 2720(Part 8)-1983. California Bearing Ratio (CBR) testing was done as per IS: 2720 (Part 16)-1987. Samples for CBR and UCS were prepared at MDD and OMC of the natural soil. In this study most of the testing was limited to swell pressure (SP) and unconfined compressive strength (UCS) testing. IS: 2720(Part 10)-1991 was followed for UCS testing. Cylindrical specimens of diameter 36mm and height 72mm are used for UCS testing. Treated specimens of 16 nos. were prepared with different chemical percentages for each chemical and specimens are placed in polythene covers and is properly labeled and stored in incubator to prevent changes in water content. Cured specimens were tested after a period of 1, 7, 14 and 28 days. During UCS testing, compressive load is applied until the failure surfaces have clearly developed and stress-strain curve is well past its peak or until an axial strain of 20% is reached. Peak value of stress is considered as the required UCS value.

IV. Results And Discussion

The summary of results on the effectiveness of different chemicals in this study on the swelling and strength properties are given in Table 4.1 & 4.2.

Table 4.1 Results of Swelling properties with different chemicals

Chemical Content (%)	DFS			Swell Pressure		
	NH_4Cl	$MgCl_2$	$AlCl_3$	NH_4Cl	$MgCl_2$	$AlCl_3$
0.0	150	150	150	298	298	298
0.5	95	85	75	255	212	185
1.0	80	75	60	170	136	92
1.5	80	60	55	135	120	81
2.0	75	60	50	120	103	73

Table 4.2 Results of UCS testing at different curing periods.

Chemical Content (%)	UCS values in kPa											
	NH_4Cl				$MgCl_2$				$AlCl_3$			
	1day	7days	14days	28days	1day	7days	14days	28days	1day	7days	14days	28days
0.0	94	94	94	94	94	94	94	94	94	94	94	94
0.5	106	145	200	224	115	167	217	242	124	194	246	254
1.0	122	202	261	276	132	220	285	294	142	232	295	306
1.5	103	210	218	226	118	228	236	244	130	240	248	256
2.0	99	181	206	210	115	199	224	228	125	211	236	240

4.1 Effect of additives on Differential Free Swell

The variation of DFS with the addition of different chemical contents to the expansive soil is presented in the Fig. 4.1(A). It is observed that addition of chemicals decreased the DFS value. It is instantaneous in the beginning and is then normalized. All the chemicals are showing instantaneous reduction in the beginning up to 1% chemical content. Chemicals used in this study are showing more or less similar variation but aluminum chloride ($AlCl_3$) is found to be more effective. Considering an optimum value of 1% aluminum chloride chemical content the percentage reduction in DFS value is of the order of 60%.

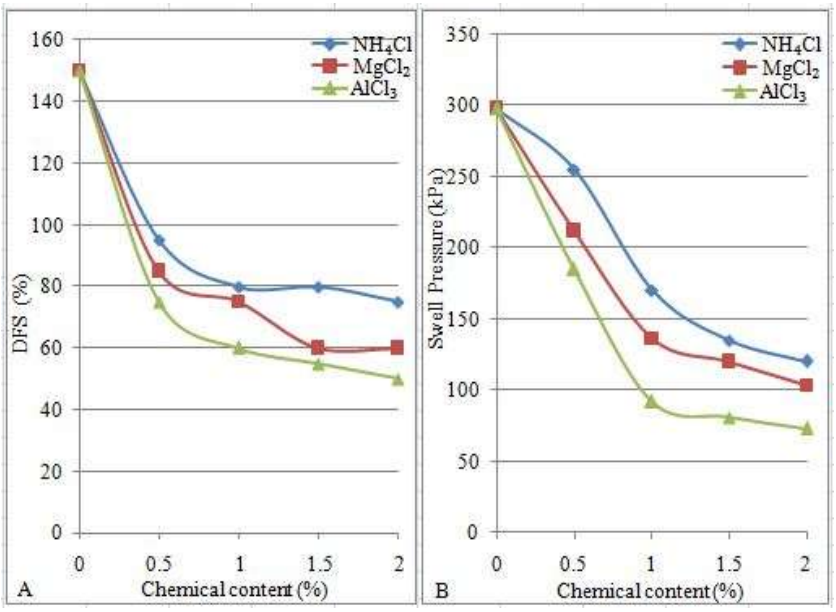

Fig. 4.1 Variation of Swell Properties with different chemical contents

4.2 Effect of additives on Swell Pressure

The chlorides used in this study are more effective in reducing the swelling pressure of natural soil which is having high value of the order of 298 kPa. The variation of swell pressure with the addition of different chemicals is shown in Fig 4.1(B). Swell pressure values have significantly fallen down up to 1% chemical content and thereafter it became nominal. For the addition of 1% NH_4Cl, $MgCl_2$ and $AlCl_3$ contents, the percentage reduction in swell pressure is of the order of 43%, 54% and 69% respectively.

4.3 Effect of additives on Unconfined Compressive Strength

The effect of different chloride compounds on the unconfined compressive strength of untreated and treated samples tested at different curing periods of 1, 7, 14, 28 days are presented in Table 4.2 and its variation is shown in Fig. 4.2. Untreated soil is having an UCS value of 94 kPa, which can be considered as very low value. Addition of chlorides is showing effective improvement in UCS upto some extent and reduced after reaching a peak value. Out of the different chemicals used, aluminum chloride chemical is little bit more effective than other chemicals. Considering an optimum value of 1% chemical, the UCS value increased to 122, 132 and 142 kPa with the addition of NH_4Cl, $MgCl_2$ and $AlCl_3$ contents respectively. Curing period has a noticeable effect on the UCS value. A period of 14 days was found to be most favorable curing period and is showing nearly 2 to 2.5 times higher UCS than that of zero day cured samples. Finally at the optimal stage of 1% chemical content and 14 day curing period the UCS value increased to 218, 236, 248 kPa for NH_4Cl, $MgCl_2$ and $AlCl_3$ chemicals respectively.

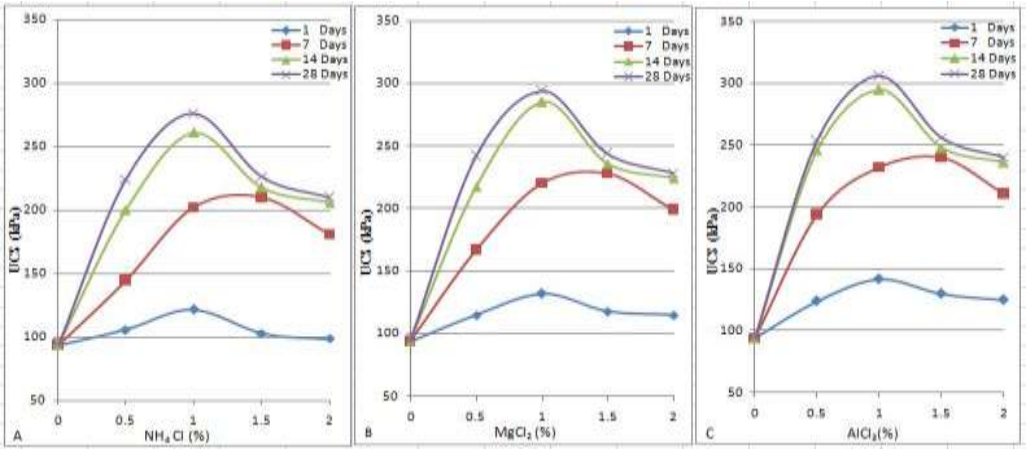

Fig. 4.2 Variation of UCS with chemical contents at different curing periods

V. Conclusions

A few conclusions are drawn from the above discussions. The selected additives are effective in minimizing the swelling nature of the expansive soil. In this study it is indicated by swell pressure and DFS value. For an optimum value of 1% chemical content the percentage reduction in swell pressure is 43%, 54% and 69% for NH_4Cl, $MgCl_2$ and $AlCl_3$ contents respectively. Out of the three chemicals selected in this study, aluminum chloride ($AlCl_3$) is found to be effective in reducing the swelling properties. Similarly all the chemicals are effective in increasing the strength of the soil indicated by UCS value. Curing period has a large effect on the UCS value of soil. Chemical content of 1% with curing period of 14 days was considered as optimum and percentage increase in UCS is of the order of 178%, 203% and 214% for NH_4Cl, $MgCl_2$ and $AlCl_3$ chemical contents respectively. Hence the chloride compound chemicals could be considered as an alternative from the stand point of expansive soil stabilization and out of which aluminum chloride is found to be effective.

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