A Laboratory Evaluation of Stabilization of Salty Clay Soil by Using Chloride Compounds

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Abstract: The object of this paper is to investigate the effect of adding different chloride compounds including (NaCl, $CaCl_2$, $MgCl_2$) on the engineering properties of silty clay soil. Various amount of salts (2%, 4%, and 8%) were added to the soil to study the effect of salts on the compaction characteristics, consistency limits and compressive strength. The main findings of this study were that the increase in the percentage of each of the chloride compounds increase the maximum dry density, decrease the optimum moisture content. The liquid limit, plastic limit and plasticity index decreased with the increase in salt content. The unconfined compressive strength increased as the salt content increased.

***Keywords**:* Soil Stabilization, Silty Clay Soil, Consistency Limit, Unconfined Compressive Strength.

Nomenclatures:

σ = compressive stress (kPa)

P = corresponding force (kN)

Є = axial strain for the given load

ΔL = length change of specimen (mm)

L_o = initial length of test specimen (mm)

A = corresponding cross-sectional area (mm²)

A_o = initial cross-sectional area of the specimen (mm²)

CH = high plasticity clay

X.R.D = X-ray diffraction

ASTM= The American society for testing and materials

1. INTRODUCTION

Soil stabilization refers to the procedure in which a special soil, a cementing material, or other chemical material is added to a natural soil to improve one or more of its properties. One may achieve stabilization by mechanically mixing the natural soil and stabilizing material together so as to achieve a homogeneous mixture or by adding stabilizing material to an undisturbed soil deposit and obtaining interaction by letting it permeate through soil voids (William, H. 1976).

Where the soil and stabilizing agent are blended and worked together, the placement process usually includes compaction. Soil stabilizing additives are used to improve the properties of less–desirable rood soils. When used these stabilizing agents can improve and maintain soil moisture content, increase soil particle cohesion and serve as cementing and water proofing agents (Janathan, et al. , 2004).

A difficult problem in civil engineering works exists when the sub-grade is found to be clay soil. Soils having high clay content have the tendency to swell when their moisture content is allowed to increase (Chen 1981). Many research have been done on the subject of soil stabilization using various additives, the most common methods of soil stabilization of clay soils in pavement work are cement and lime stabilization. The high strengths obtained from cement and lime stabilization may not always be required, however, and there is justification for seeking a cheaper additives which may be used to alter the soil properties.

This paper describes an investigation into the effect of addition chloride compounds (NaCl, $CaCl_2$, and $MgCl_2$) on the engineering properties of silty clay soil. The soil used in this study was brought from south of Iraq.

2. METHODOLOGY AND EXPERIMENTS

2.1 The soil:

Light brown silty clay soil was brought from south of Iraq representing a widely spread typical soil in the middle and southern parts of Rajasthan (India).

The soil sample was taken at a depth of a bout (1 meter) below the top surface. It was found to be stiff silty clay. The properties of the soil and the results of the consistency limits were shown on table (1). The classification of the soil was given in figure (1). The soil lies above the (A) line, thus the soil is classified as (CH) soil according to the unified classification system. The x–ray diffraction test was shown in table (2).

TABLE 1: Properties of the Soil

Property	Value
53 %	Liquid limit
28 %	Plastic limit
25 %	Plasticity index
37.2	Specific gravity
84 %	Clay fraction
05 %	Silt fraction
3 %	Sand fraction

TABLE 2: Mineralogical Composition of Soil (X.R.D)

Non – clay minerals	**clay minerals**
Montmorillonite	Quartz
Polygorskite	Dolomite
Kaolinte	Calcite

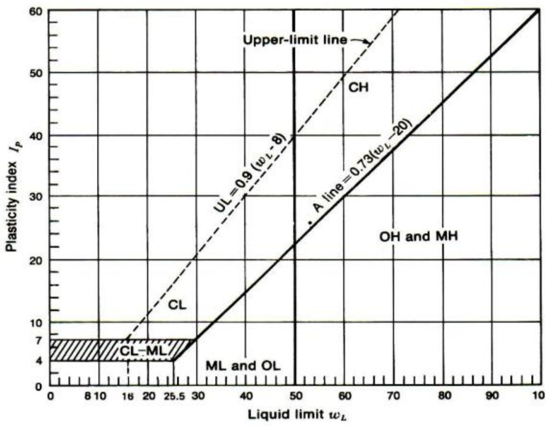

Fig 1. Plasticity Chart (Joseph E. Bowles, 1982)

2.2 Preparation of Specimens:

Three types of chloride compounds were used including (NaCl, $CaCl_2$, $MgCl_2$). Each one of these salts was dissolved in water and then mixed with soil. The soil specimen were prepared by modified proctor test procedures according to ASTM (D 1557).

3. ENGINEERING TEST

3.1 Compaction Test:

The modified proctor compaction test was carried out to determine the moisture content–dry density relationship according to ASTM (D 1557). Each chloride compounds (NaCl, $CaCl_2$, $MgCl_2$) was dissolved in water and mixed with soil then left for one day. The soil was compacted into 1000 cm³ mould in 5 layers. Fig. (2) shows the dry density–moisture content relation for different salts and different percentages.

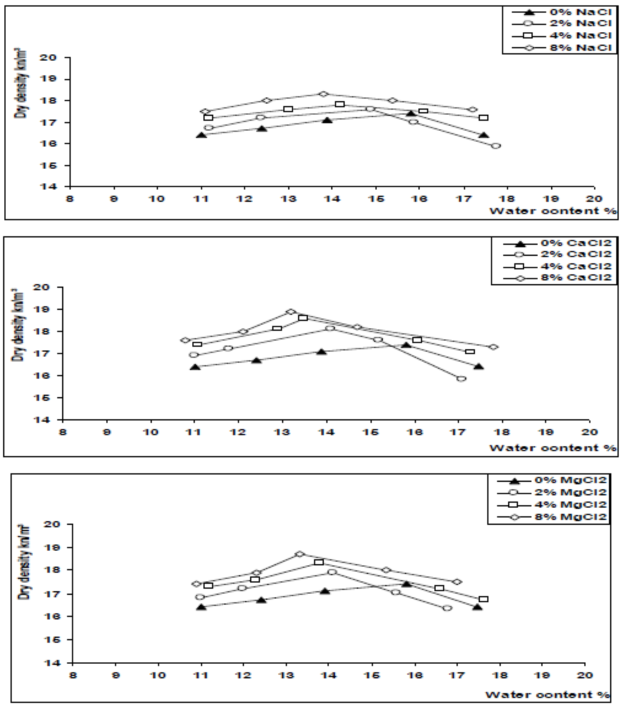

Fig.2. Compaction Test

3.2 Atterberg Limits:

The liquid limit test have been conducted using the Cassagrande apparatus according to ASTM (D423-66). The plastic limits were conducted according to the ASTM (D424-59). These tests were carried out to investigate the effect of addition of salt on the consistency limits fig.(3) shows the effect of salt content on the Atterberg limits.

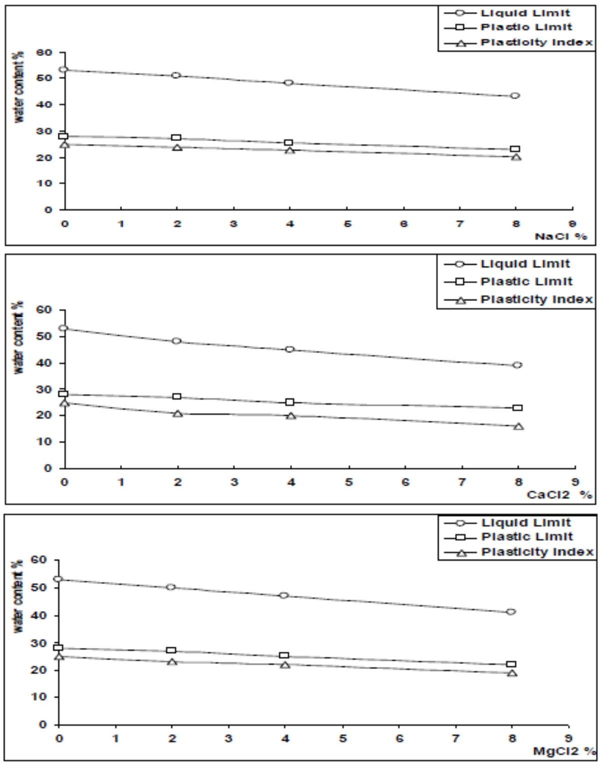

Fig .3. Salt % versus Moisture Content

3.3 Unconfined Compression Test:

The compacted specimens were obtained by pushing the tubes of diameter (38mm) to the soil using compression machine then specimen were extracted from these tubes by an extruder then cut at (89mm) length specimen was then tested immediately after preparation the test was conducted according to ASTM (D2166-65).The rate of strain was 0.9 mm per minutes. The axial strain and axial normal compressive stress are given by the following relations:

$$\sigma = P / A,$$

$$\epsilon = \Delta L / L_o,$$

$$A = A_o / 1 - \epsilon$$

Fig. (4) Shows the relationship of stress-strain of unconfined compressive strength for different salts.

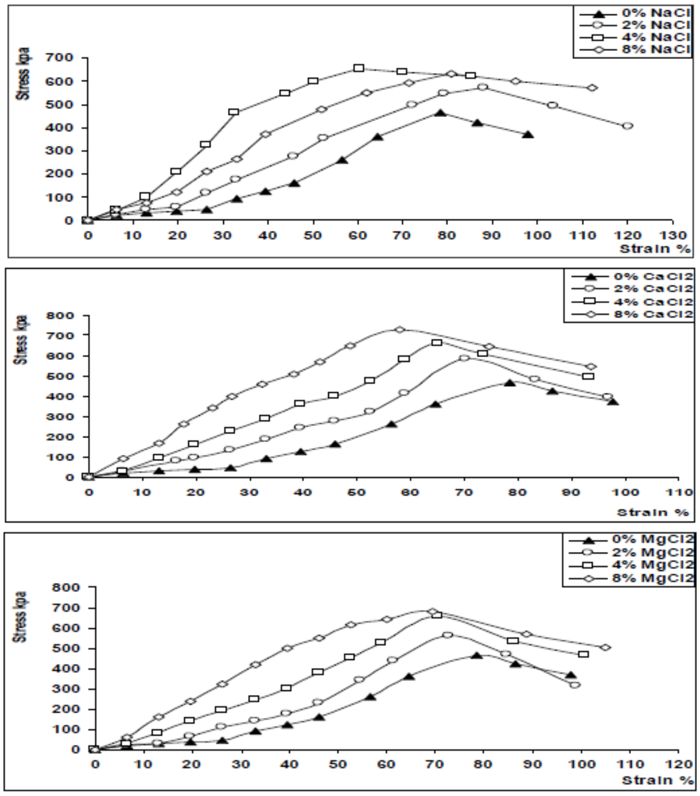

Fig.4. Unconfined Compression Test

4. RESULTS AND DISCUSSION

4.1 Compaction Test:

The relation between dry density and moisture content for different salts (NaCl, $CaCl_2$, $MgCl_2$) and different percentages (2%, 4%, 8%) are plotted in fig.(2). The addition of salts to the soil increased the dry density and the optimum moisture content the same results were reported by (Frydam, et al. , 1977) and (wood 1971). They attributed this behavior to the fact that at low moisture content the soil structure (before compaction) tends to change from edge-to-face type of flocculation to face-to-face flocculation (salt flocculation) with the increase in salt concentration (Lambe 1958). Consequently under the influence of dynamic compaction, the clay particles become more oriented and the compacted dry unit weight increases with the increase in salt content. The decrease in the optimum moisture content as the salt content increased may be explained due to the higher the face-to-face flocculation the lower is the amount of water required for lubrication.

4.2 Atterberg Limits:

Fig. (3) Shows the effect of salts content on the Atterberg limits. The liquid limit, plastic limit and plasticity index decreased as the salts contend increased. Similar results were reported by (Venkatabor and Reach 1977) this behavior is due to the decrease in the thickness of the diffused double layer as the salt content increased.

4.3 Unconfined Compression Test:

The unconfined compressive stress-strain relationship of specimens with different salts and different percentages are shown in fig. (4) it can be seen that the increased in salt contents leads to an increase in the unconfined compressive strength. The addition of salt to the soil cause an increase in the ion concentration of the pore water with concomitant reduction in the double layer thickness and this will cause a reduction in the interparticles repulsion and an increase in the attraction, resulting in the increase in cohesion (William, H. 1976). The compaction effort also effect the strength of the cohesive soil The unconfined compressive strength increase with the increase in the compaction effort .the results indicate that the maximum shear strength is for the soil treated with calcium chloride. The addition of CaCl2 to the soil cause hardening and more strength as compare to the other salts.

5. CONCLUSION

This investigation was conducted to study the effect of adding three chloride compounds (NaCl, CaCl2, MgCl2) on the properties of silty clay soil. The soil was tested for its liquid limit, plastic limit, dry unit weight, and moisture content and shears strength. The addition of each one of the chloride compounds decreased the liquid limit and plastic limit and plasticity index for the soil. The dry density increased and the optimum moisture content decreased with the increased in salts percentage. The compressive strength of the soil increased with the addition of chloride compounds. This could help improving soil strength and other soil properties.

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