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STABILISATION OF SILTY CLAY SOIL 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, $MgCl_2$, $CaCl_2$) on the engineering properties of silty clay soil. Various amounts 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 increased the maximum dry density and 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.

Keyword: Soil Stabilisation, Silty Clay Soil, Consistency Limit, Unconfined Compressive Strength.

1. Introduction

Soil stabilisation 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 stabilisation by mechanically mixing the natural soil and stabilising material together so as to achieve a homogeneous mixture or by adding stabilising material to an undisturbed soil deposit and obtaining interaction by letting

Nomenclatures

A	Corresponding cross-sectional area [mm²]
A_o	Initial cross-sectional area of the specimen [mm²]
CH	High plasticity clay
L_o	Initial length of test specimen [mm]
P	Corresponding force (kN)
Greek Symbols	
ΔL	Length change of specimen [mm]
σ	Compressive stress [kPa]
ϵ	Axial strain for the given load

it permeate through soil voids [1]. Where the soil and stabilising agent are blended and worked together, the placement process usually includes compaction.

Soil stabilising additives are used to improve the properties of less–desirable rood soils. When used these stabilising agents can improve and maintain soil moisture content, increase soil particle cohesion and serve as cementing and water proofing agents [2].

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 [3]. Many research have been done on the subject of soil stabilisation using various additives, the most common methods of soil stabilisation of clay soils in pavement work are cement and lime stabilisation. The high strengths obtained from cement and lime stabilisation may not always be required, however, and there is justification for seeking cheaper additives which may be used to alter the soil properties.

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

2. Methodology and Experiments

2.1 Characteristics of soil in southern Iraq

Light brown silty clay soil was brought from south of Iraq representing a widely spread typical soil in the middle and southern parts of Iraq. The soil samples were taken at a depth of a bout 1 meter below the top surface. These samples were found to be stiff silty clay. The properties of the soil and the results of the consistency limits are given in Table 1 while the classification of the soil is given in Fig.1. The soil lies above the A-line (shown in Fig. 1), thus the soil is classified as high plasticity clay

(CH) soil according to the unified classification system. The x–ray diffraction test results, of the soil samples, are given in Table 2.

Table 1. Properties of the Soil Used in this Study.

Property	Value
Liquid limit	53 %
Plastic limit	28 %
Plasticity index	25 %
Specific gravity	2.73
Clay fraction	48 %
Silt fraction	50 %
Sand fraction	2 %

Table .2. Mineralogical Composition of Soil (X- Ray Diffraction).

Non – Clay Minerals	Clay Minerals
Quartz	Montmorillonite
Dolomite	Polygorskite
Calcite	Kaolinte
Feldspar	

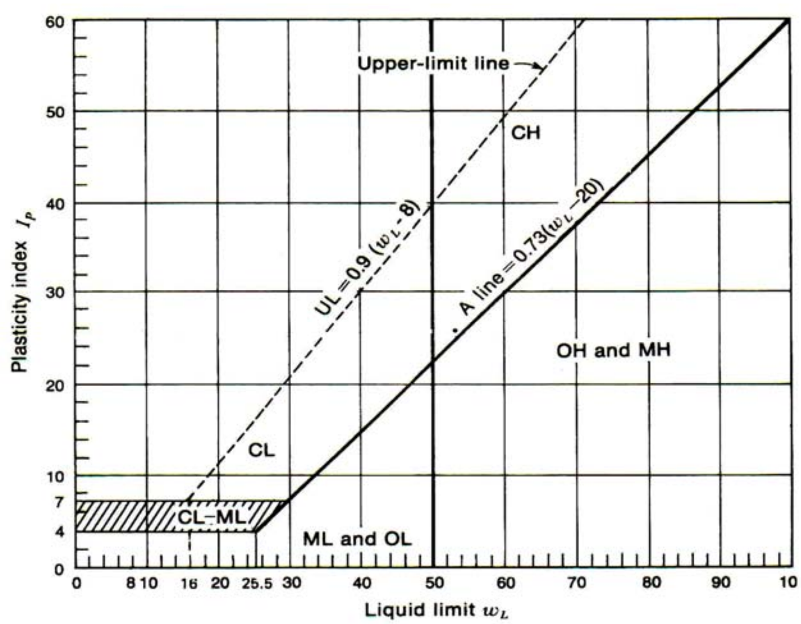

Fig. 1. Plasticity Chart [4].

2.2 Preparation of specimens

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

3. Engineering Tests

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, $MgCl_2$, $CaCl_2$) were dissolved in water and mixed with soil then left for one day. The soil was compacted into 1000 cm^3 mould in 5 layers. Figure 2 shows the dry density–moisture content relation for different salts and different percentages.

3.2 Atterberg limits

The liquid limit test has been conducted using the Cassagrande apparatus according to ASTM (D423-66). The plastic limit test was conducted according to the ASTM (D 424-59). These tests were carried out to investigate the effect of addition of salt on the consistency limits. Figure 3 shows the effect of salt content on the Atterberg limits.

3.3 Unconfined compression test

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

$$\sigma = P / A \tag{1}$$

$$\varepsilon = \Delta L \;/\; L_O \tag{2}$$

$$A = A_O / 1 - \varepsilon \tag{3}$$

Figure 4 shows the relationship of stress-strain of unconfined compressive strength for different salts.

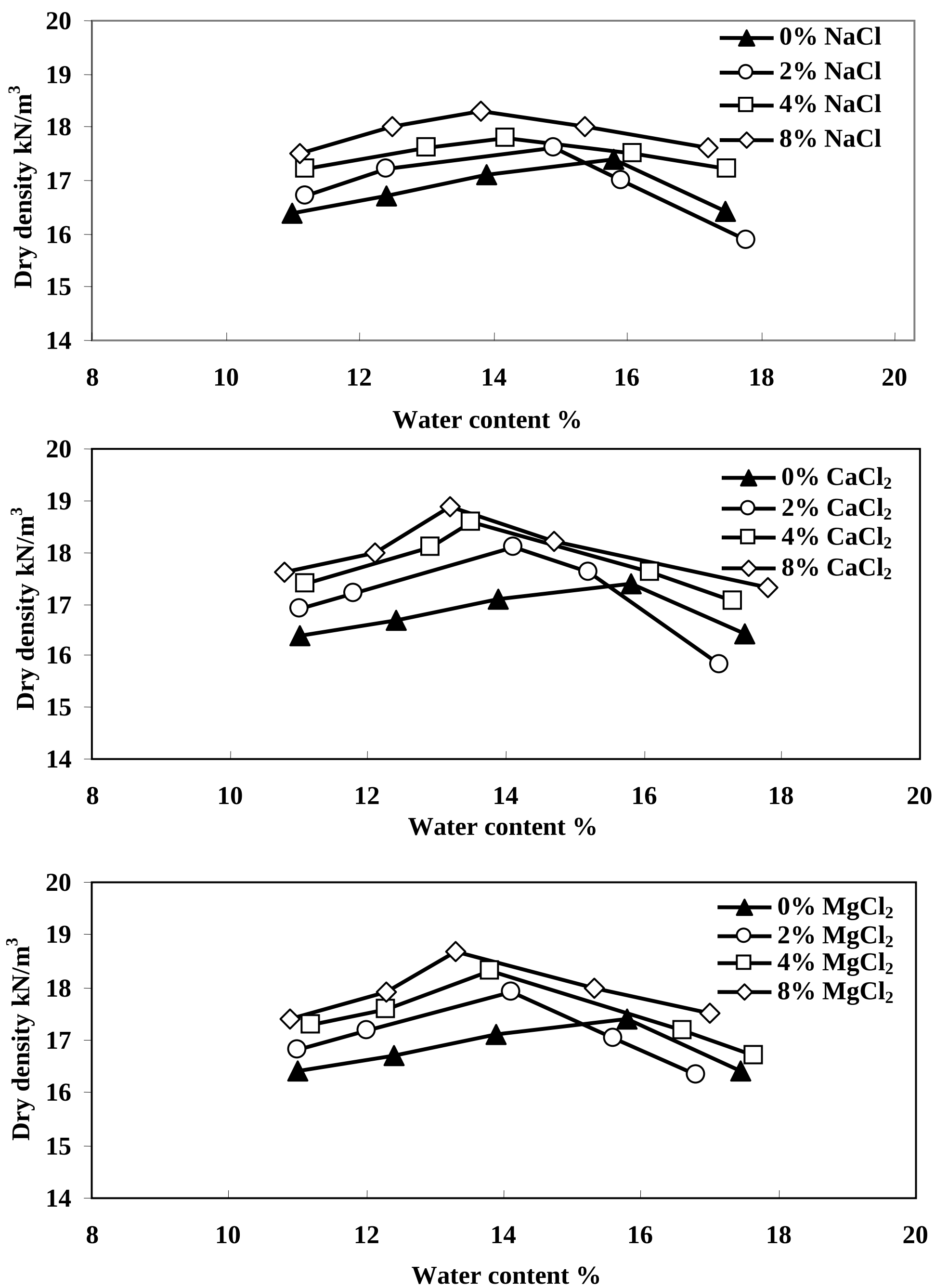

Fig. 2. Unit Weight versus Moisture Content for Different Salts.

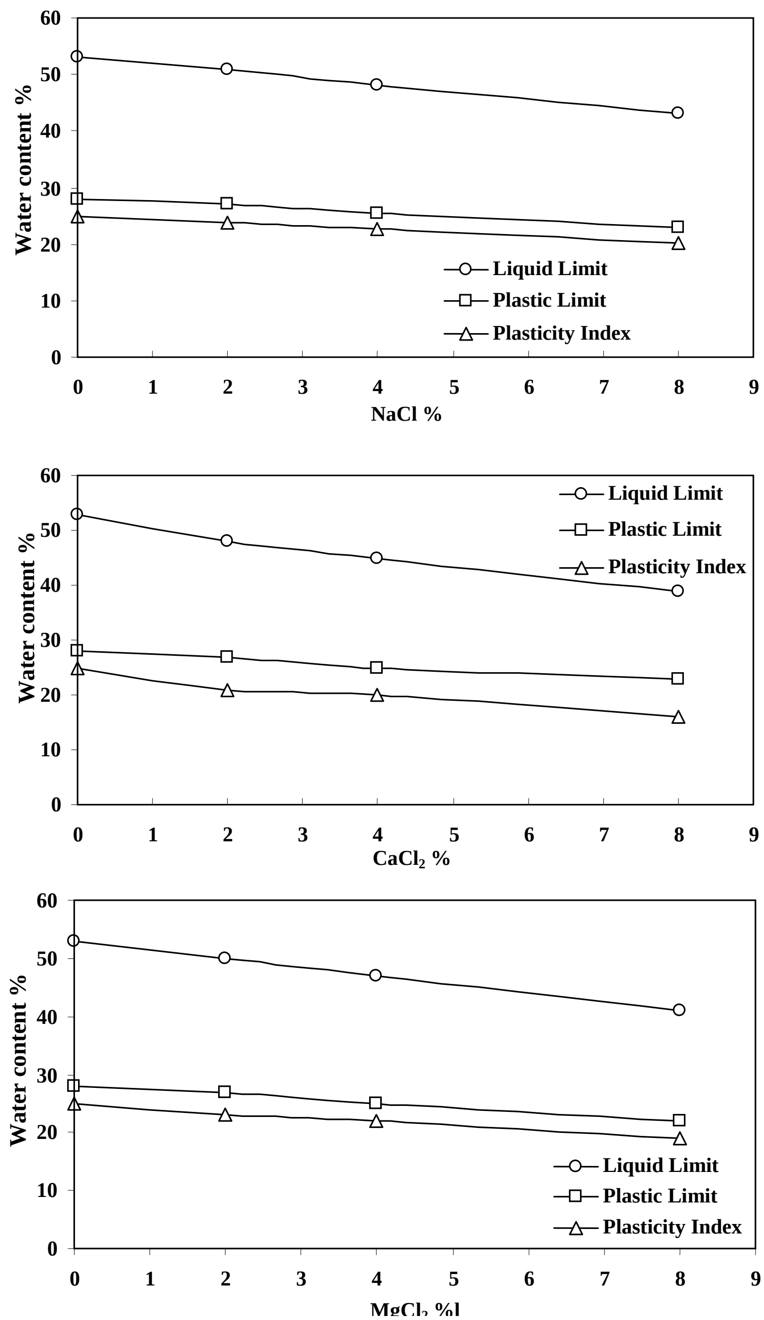

Fig. 3. Effect of Different Salt Percentage and Moisture Content on Engineering Properties of the Soil.

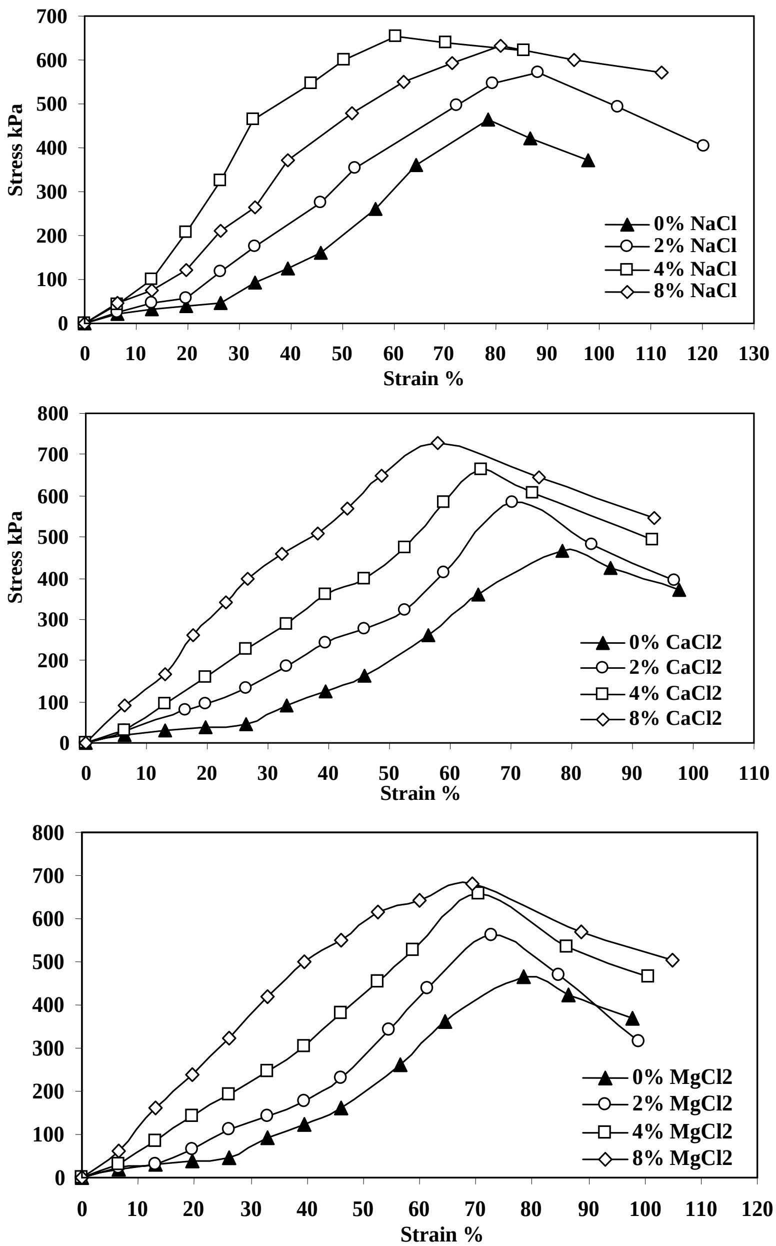

Fig .4. Unconfined Compression Test.

4. Results and Discussion

4.1 Compaction test

The relation between dry density and moisture content for different salts (NaCl, $MgCl_2$, $CaCl_2$) and different moisture 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. Similar results were reported by Frydam et al [5] and Wood [6]. They attributed this behaviour 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 [7]. 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

Figure 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 & Reach [8] this behaviour 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 relationships of specimens, with different salts and different moisture 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 causes an increase in the ion concentration of the pore water with concomitant reduction in the double layer thickness and this, in turn, causes a reduction in the antiparticles repulsion and an increase in the attraction, resulting in the increase in cohesion [1]. 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 found in the soil treated with calcium chloride. The addition of $CaCl_2$ to the soil cause hardening and more strength as compared to the soil specimens containing other salts additives.

5. Conclusions

This investigation was conducted to study the effect of adding three chloride compounds (NaCl, $MgCl_2$, $CaCl_2$) on the properties of silty clay soil. The soil was tested for its liquid limit, plastic limit, dry unit weight, moisture content and shear 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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