

Stabilization of Soft Soils Using Salts of Chloride

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Abstract

The research aims to investigate the effect of adding chloride salts including (NaCl , MgCl_2 , and CaCl_2) on the engineering properties of silty clay soil. Three amount percentage of salt (2%, 4%, and 8%) were added to the soil to study the effect of salts on the compaction characteristics, atterberg limits, and unconfined compressive strength.

The results showed that the increase in the percentage of each of the chloride salts increased the maximum dry density and decreased the optimum water content. The liquid limit, plastic limit, and plasticity index decreased with increasing salt content. Also the results showed that the unconfined compressive strength increased when the salt content increased too.

الخلاصة

يهدف البحث الى دراسة تأثير اضافة مركبات مختلفة لمادة الكلور وهي (NaCl , MgCl_2 , CaCl_2) على الخواص الهندسية لتربة ناعمة (Silty Clay). تم استخدام نسب مختلفة لكل مركب من مركبات الكلور اعلاه (2% و 4% و 8%) لمعرفة تأثير هذه النسب على خواص الرص للتربة (الكثافة الجافة العظمى والمحتوى الرطوبي الامثل) وكذلك تأثير الاملاح على حدود اتبرك (حد السيولة و حد اللدونة و مؤشر اللدونة)، و مقاومة التربة للضغط اللامحصور. تم تحضير ثلاث تراكيز لكل ملح من املاح الكلور اضافة الى الماء المقطر و اضافتها الى التربة وتركها لمدة يوم واحد لغرض الانضاج. بينت النتائج انه بزيادة نسبة مركب الكلور المضاف للتربة تزداد الكثافة الجافة العظمى و يقل المحتوى الرطوبي الامثل. وكذلك يقل حد السيولة وحد اللدونة و مؤشر اللدونة بزيادة نسبة مركب الكلور. اما بالنسبة لمقاومة التربة للضغط اللامحصور فانها تزداد بزيادة مركب الكلور، وبينت ان الزيادة في حالة اضافة مركب كلوريد الكالسيوم هي اكبر مما عليه في حالة اضافة باقي المركبات للكلور.

1-Introduction

Soil stabilization refers to the procedure in which a special soil, cementing material, or other chemical materials are 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 (Perloff. W. 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 Q. and et. al. (2004)).

A difficult problem in civil engineering works exists when the sub-grade is found to be clayey soil. Soils having high clay content have the tendency to swell when their moisture content is allowed to increase (Chen, F. H. (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 cheaper additives which may be used to alter the soil properties.

In this research there is an investigation into the effect of addition of chloride salts (NaCl , MgCl_2 , and CaCl_2) on the engineering properties of silty clay soil. The soil used in this study is obtained from middle of Iraq.

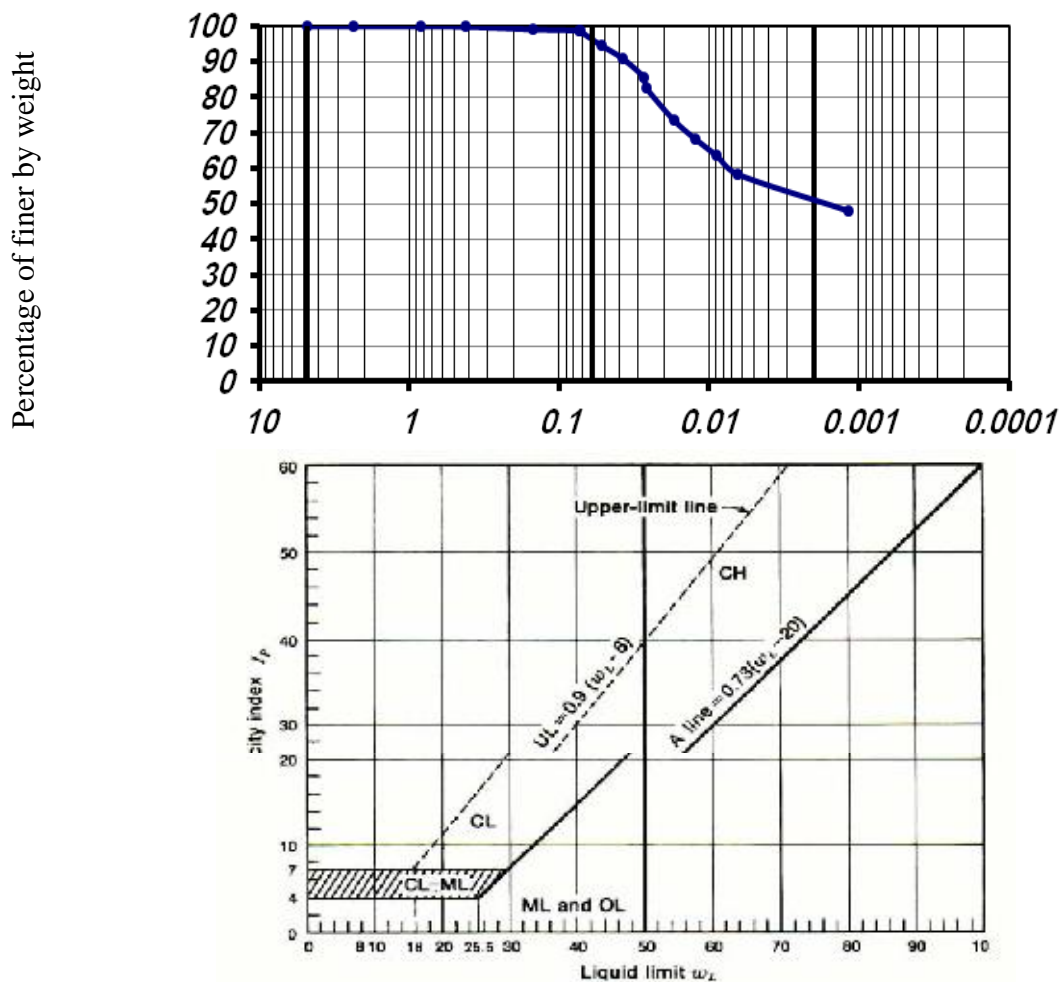
2- Material Used

2-1 Soil

The soil used in this paper was a silty clay soil, which was brought from Al-Midhatia town laying about 30 km to the south of Al-Hilla city. This type of soils represent a widely spread typical soil in the middle and southern of Iraq. The soil samples were taken at a depth of about (1 m) below the ground surface. The properties of the soil, and atterberg limits are given in table (1) while the classification and the grain size distribution of the soil are shown in Fig. (1) and Fig. (2) respectively, the soil lies above the A-line (Fig.1), thus the soil is classified as high plasticity clay soil (CH) according to the unified classification system.

Table (1) properties of the soil used in this research

Property	Value
Liquid limit	51
Plastic limit	27
Plasticity index	24
Specific gravity	2.70
Clay fraction	51
Silt fraction	46.6
Sand fraction	2.4

Fig. (1) Plasticity chart (Bowles, J. E. (1982))**Fig. (2) Grain size distribution by kerosine method**

2-2 Soaking Solutions

2-2-1 Distilled Water: Distilled water was used in all tests.

2-2-2 Chlorides Solutions

The concentration of each chloride salt (NaCl , MgCl_2 , and CaCl_2) was obtained by dissolving in distilled water to obtain the specific concentration for each type of salt in ppm, 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). Three different concentrations for each chloride salt (2%, 4%, and 8%) were prepared.

3-Soil Tests: -

3-1 Compaction Test

The modified proctor compaction test was carried out to determine the moisture-dry density relationship according to ASTM (D 1557). Each chloride salts (NaCl , MgCl_2 , and CaCl_2) were dissolved in water and mixed with soil then left for 1 day. The soil was compacted into 929.75 cm^3 mould in five layers. Figure 3 shows the dry density-moisture content relation for different type and percentages of salts compared with that relation in the natural soil.

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 (D424-59). These tests were carried out to investigate the effect of addition of salt on the consistency limits. The effect of salt content on the Atterberg limits is shown in Fig. (4).

3-3 Unconfined Compression Test

The compacted specimens were obtained by inserting tubes of 38 mm in diameter in to the compacted soil (with moisture equal to the optimum moisture content obtained from compaction test for each type of salt) using compression machine. Then 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/min. The axial strain and the axial normal compressive stress are given by the following relations.

$$\sigma = P/A \quad (1)$$

Where: σ is compressive stress (kPa), P is compressive force (kN), and A is corresponding cross-sectional area of the specimen (mm^2)

$$\epsilon = \Delta L/L_0 \quad (2)$$

Where: ϵ is axial strain under the given load, ΔL is length change of specimen (mm), and L_0 is initial length of tested specimen (mm).

$$A = A_0 / (1 - \epsilon) \quad (3)$$

Where: A_0 is initial cross-sectional area of the specimen (mm^2)

The relationship of the stress-strain of unconfined compressive strength for different salts is shown in Figure (5).

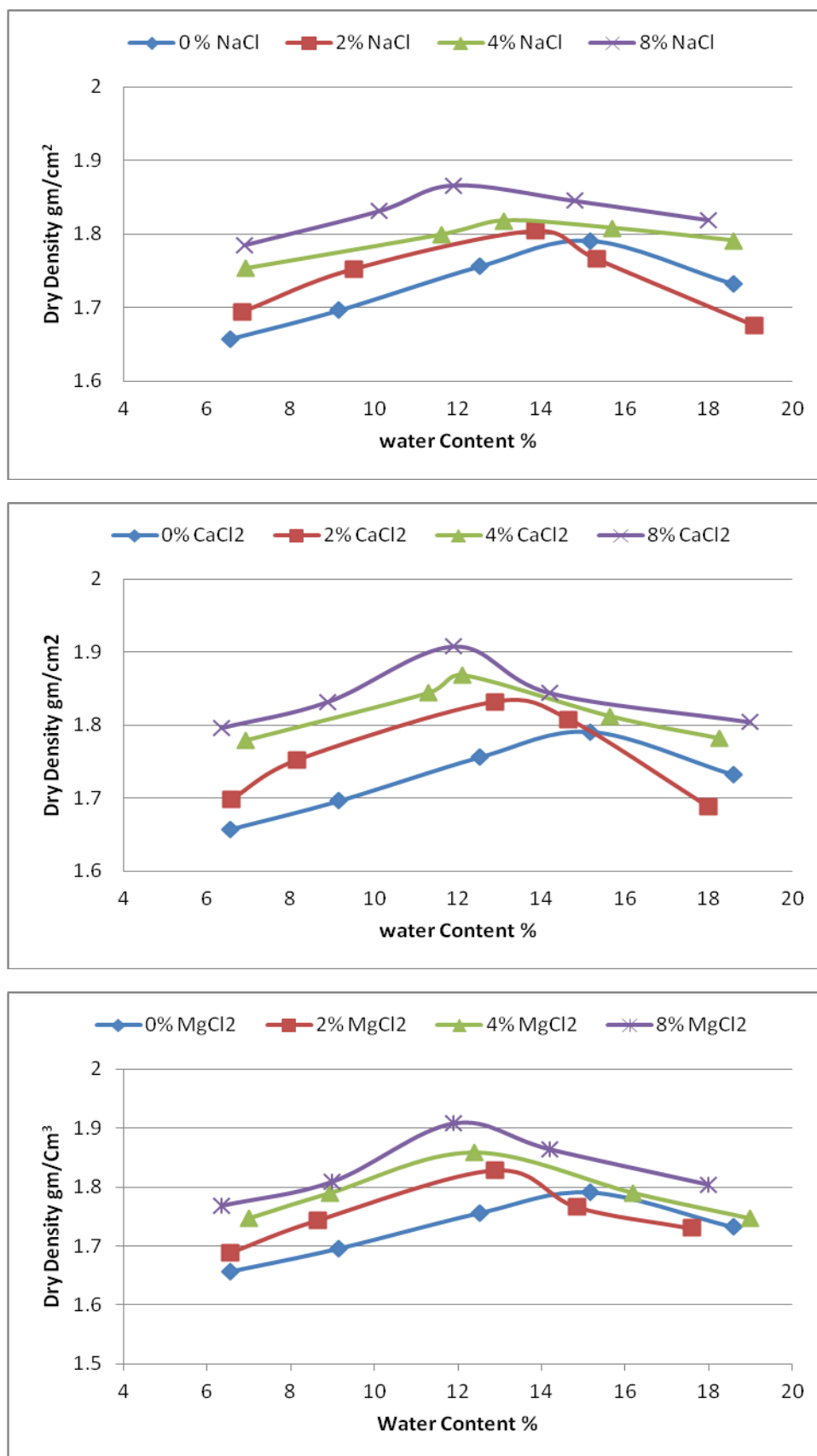


Fig.(3) Dry density versus Water content for different salts content

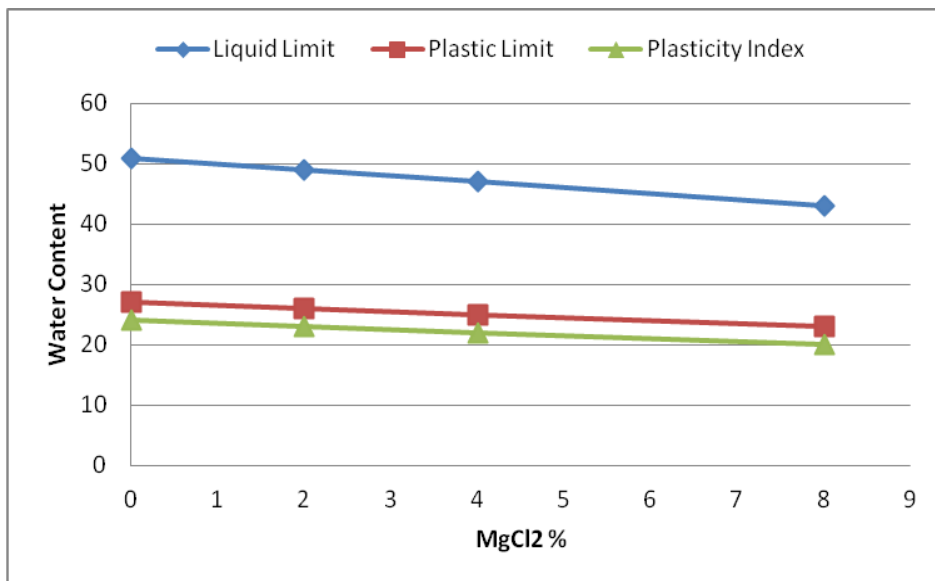
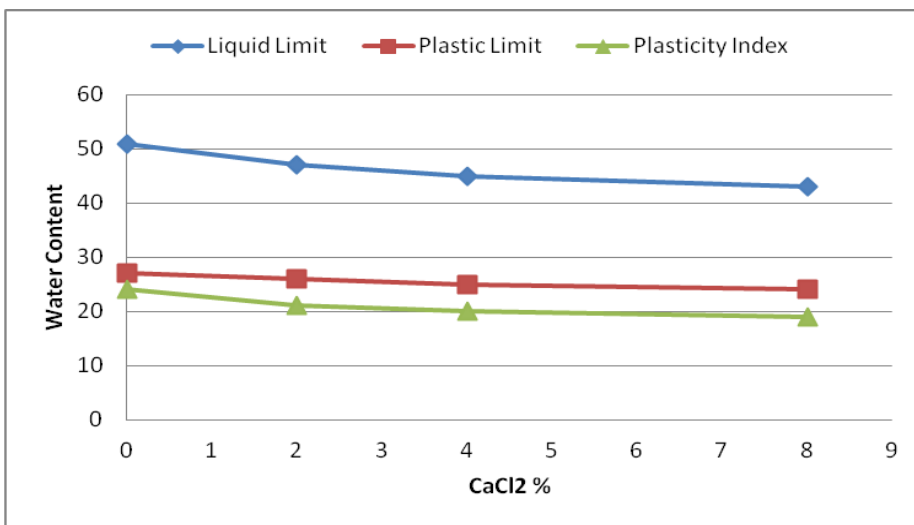
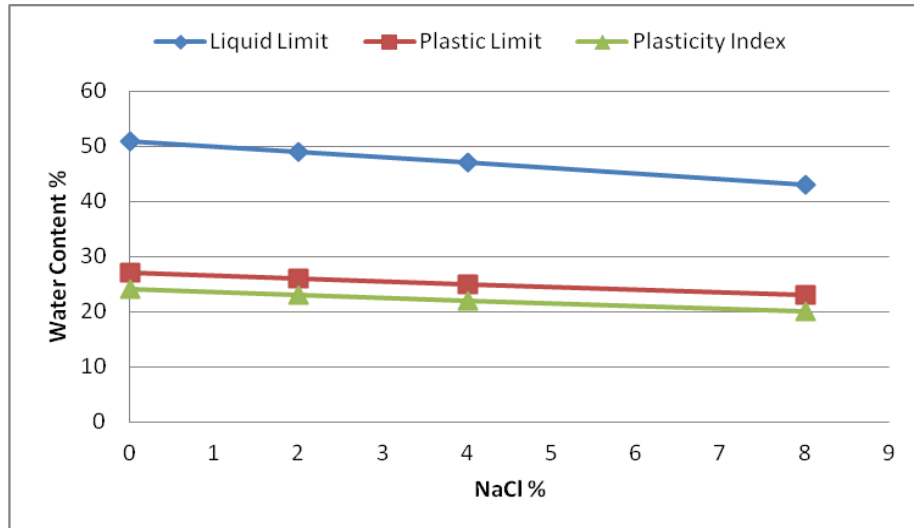


Fig. (4) Effect of different salt content on Atterberg limit

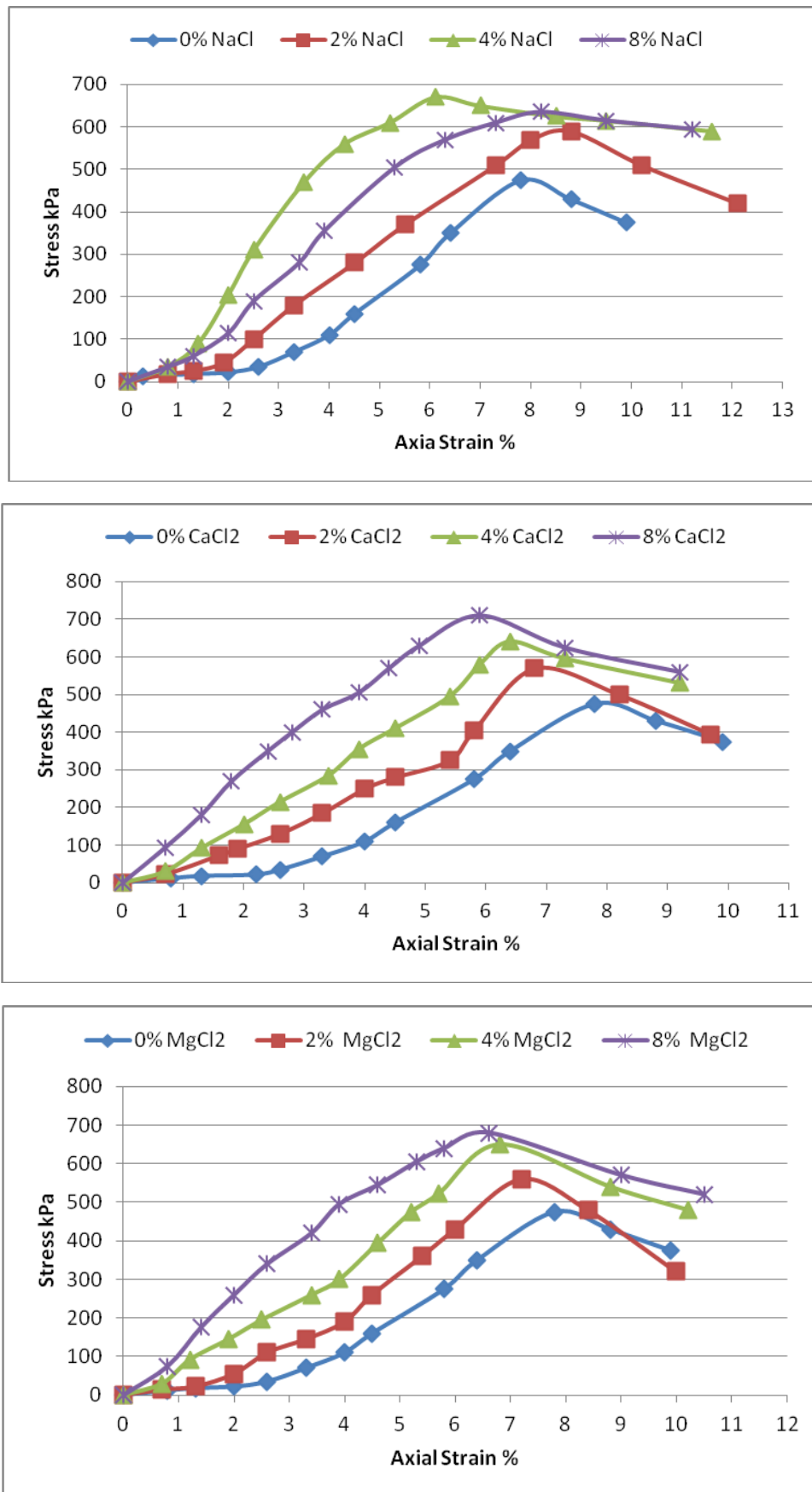


Fig.(5) Effect of different salt content on Unconfined Test

4- Results and Discussion

4-1 Compaction test

The relation between dry density and moisture content for different salts type (NaCl , MgCl_2 , and CaCl_2) and different concentration percentages (2%, 4%, and 8%) are plotted in fig. (3). The result showed that the addition of salts to the soil increase the dry density and decrease the optimum moisture content. (Frydman Frydman, I. R. & Ehrenreich, T. (1977)). 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 increase in salt concentration. Consequently under the influence of dynamic compaction, the clay particles become more oriented and the compacted dry unite weight increases with 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 to 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 decrease as the salts content increased. 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: -

Figure (4) shows the unconfined compressive stress – strain relationships of specimens, with different salts and different moisture percentage. It can be seen that the increase in salt content increase 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 (Sina and et. al., (2010)). The results indicate that the maximum compressive strength is found in the soil treated with calcium chloride. The adding of CaCl_2 to the soil cause hardening and more strength as compared to the soil specimens containing other type of salts additives.

5- Conclusions: -

- 1- The addition of each type of the chloride compounds used in this research decreased the liquid limit, plastic limit, and the plasticity index for the soil.
- 2- The maximum dry density increased and the optimum moisture content decreased with the increase in salt content.
- 3- The compressive strength of the soil increased with the increase in chloride compound percentage.

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