

## A Laboratory Evaluation of Stabilization of Silty Clay Soil by Using Chloride Compounds

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### ABSTRACT

Large areas of Iraq consist of soils with high clay contents which have low strengths and bearing capacity. This problem has an influence on construction of road and highway, if adequate support does not exist, the road will rapidly deteriorate. The solution to these construction problems is by soil treatment with chemical additives. The main objective of this study is to investigate effectiveness of salts used as an additive in stabilization of silty clay soil. Three types of salts used which are sodium chloride (NaCl), magnesium chloride (MgCl<sub>2</sub>) and calcium chloride (CaCl<sub>2</sub>). Various amounts of salts (2%, 4%, and 8%) were added to the soil to study the effect of salts on the consistency limits, compaction characteristics and CBR value. The test results indicated that the liquid limit, plastic limit and plasticity index decreased as the salts content increased. The addition of salts to the soil increased the maximum dry density and reduced the optimum moisture content. The addition of (2 %) salt to the soil causes increases the CBR value between (8 to 28 %), while, in samples containing large amount of salt (4 and 8 %) the increase was between (55 to 80%). The CBR value increased as the salt content increases for different type of salt and the greatest value is found in the soil treated with (4%) calcium chloride which was equal to (80 %).

**Keywords:** Soil Stabilization, Silty Clay Soil, Chloride Compounds, CBR

### تقييم مختبري لتثبيت تربة طينية زيتية باستخدام مركبات الكلوريدات

#### الخلاصة

يتضمن العراق مساحات واسعة من الترب بمحتوى طين عالي والتي تكون مقاومتها وقابلية تحملها واطنة. إن هذه المشكلة لها تأثير على انشاء الطرق السريعة حيث انها ستتعرض للتشوه السريع عند عدم وجود المسند الملائم وان الحل لهذه المشاكل الانشائية هو بمعالجة التربة باستخدام المضافات الكيميائية. الغرض من هذه الدراسة هو لبيان تأثير استخدام الاملاح كمادة مضافة لتثبيت تربة طينية غرينية. تم استخدام ثلاثة انواع من املاح الكلوريدات وهي كلوريد الصوديوم, كلوريد المغنسيوم وكلوريد الكالسيوم. تمت اضافة كميات مختلفة من الاملاح (2 % , 4 % و 8 %) لدراسة تأثير هذه الاملاح على حدود القوام, خصائص الرص وقيمة نسبة تحمل كاليفورنيا. بينت نتائج الفحوصات التي اجريت ان حد السيولة, حد اللدونة و دليل اللدونة تتناقص بزيادة نسبة الاملاح المضافة للتربة كما بينت النتائج انه بزيادة نسبة الاملاح تزداد الكثافة الجافة

العظمى ويتناقص المحتوى الرطوبي الأمثل. ان اضافة (2%) من الاملاح الى التربة سببت زيادة قيمة نسبة تحمل كاليفورنيا بين (8-28%) بينما في النماذج التي تحتوي كمية اعلى من الاملاح (4 و 8%) فان الزيادة كانت بين (55 الى 80%). ان قيمة نسبة تحمل كاليفورنيا تزداد بزيادة نسبة الملح لكل انواع الاملاح واعلى نسبة كانت بالتربة المعالجة ب(4%) كلوريد الكالسيوم حيث بلغت (80%).

## INTRODUCTION

Large areas of Iraq consist of soils with high clay contents which have low strengths and bearing capacity. This problem has an influence on construction of road and highway, if adequate support does not exist, the road will rapidly deteriorate. The solution to these construction problems is by soil treatment with chemical additives. Improving an in-situ soil's engineering properties is referred to as soil stabilization. Soil stabilization is the alteration of soil properties to improve the engineering performance of soils. The properties most often altered are density, water content, plasticity and strength.

The soil stabilization includes both physical stabilization (such as dynamic compaction) and chemical stabilization (such as mixing with cement, fly ash, lime, and lime by-Products, etc) [1].

Nearly every road construction project utilizes one or both of these stabilization techniques due to improvement in technology which make soil stabilization is most economical method and has been widely used today.

Chemical stabilization involves mixing or injecting the soil with chemically active compounds such as Portland cement, lime, fly ash, calcium or sodium chloride or with viscoelastic materials such as bitumen. Chemical stabilizers can be broadly divided into three groups, Traditional stabilizers such as hydrated lime, Portland cement and Fly ash; Non-traditional stabilizers comprised of sulfonated oils, ammonium chloride, enzymes, polymers, and potassium compounds; and By-product stabilizers which include cement kiln dust, lime kiln dust etc. Among these, the most widely used chemical additives are lime, Portland cement and fly ash. Although stabilization with fly ash may be more economical when compared to the other two, the composition of fly ash can be highly variable [2].

The Engineers often faced the problem of constructing roadbeds on or with soils (especially soft clayey and expansive soils). These problematic soils do not possess enough strength to support the wheel loads upon them either in construction or during the service life of the pavement. These soils must be, therefore, treated to provide a stable sub-grade or a working platform for the construction of the pavement.

Many researches 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.

Many attentions have been also paid to the effect of salt on soil properties. Moore (3) concluded that salt treatment generally produces higher maximum dry

density at lower moisture content. He found that greatest increase in strength at 1.5% salt treatments for calcareous and 0.5% for non-calcareous soils.

Singh and Ali (4) studied the effects of up to 5% salt content, in rock and brine forms, on a soil-aggregate mixture. The predominant clay mineral was montmorillonite. They concluded that the maximum dry density is increased in all cases, and the optimum moisture content is decreased in all except the lowest salt content of 0.5%.

Petrukhin (5) reported that the presence of soluble salts in loess soil causes increase the maximum dry density up to 10 % and the optimum water content decreases between 8 to 16 %.

Singh and Das (6) study the potential of sodium chloride as a stabilizer in soil-aggregate mixtures. They concluded that CRB values, unconfined compression strength, and indirect tensile strength are greatly improved with the inclusion of sodium chloride as a stabilizing agent.

#### **OBJECTIVE OF THE STUDY**

The objectives of this study are to:

1. Evaluate the effectiveness of soil stabilization by using chloride compounds for silty clay soil.
2. Determine the percentage of strength improvement for silty clay soil obtained for different chlorides compounds used at different concentration.

#### **MATERIALS AND METHODS**

##### **Characteristics of soil used**

Soil used in this study was obtained from middle of Iraq from the area of Altagy which lies the north of Baghdad city. The soil is brown 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 Figure (1). The soil lies above the A-line (shown in Figure 1), thus the soil is classified as, low plasticity clay, (CL) soil according to the unified classification system.

##### **Preparation of Specimens**

This research will determine the effectiveness of soil stabilization using three types of chloride compounds, namely, NaCl, MgCl<sub>2</sub>, and CaCl<sub>2</sub>. Each one of these salts was dissolved in water and then mixed with soil then left for one day for curing. The soil specimens were prepared by a (6) inch inside diameter and (4.58) inch height mold according to ASTM (American Society for Testing and Materials) (D1557).

#### **LABORATORY TESTS**

##### **Atterberg test**

Atterberg tests were carried out based on ASTM (D4318-98) these tests were conducted to investigate the effect of addition of salt on the consistency limits. Figure (2) shows the effect of salt content on the Atterberg limits.

### Compaction test

Laboratory compaction was performed according to ASTM (D1557-02). A (6) inch inside diameter and (4.58) inch height mold was used with a (10) pound rammer dropped from a height of (18) inches.

The soil was compacted in (5) layers with (56) hammer blows applied per lift. The relationships between dry density and water content at different salt with different percentage were obtained is shown in Figure (3).

### California bearing ratio tests (CBR-tests)

CBR-test was conducted according to BS (1377-1990), it was conducted to characterize the strength and the bearing capacity of the studied soil and their mixtures with chloride. The preparations of the specimens were achieved according to the procedures in ASTM (D1557-02). A (6) inch inside diameter and (4.58) inch height mold was used with a (10) pound rammer dropped from a height of (18) inches. The soil was compacted in (5) layers with (56) hammer blows applied per lift.

$$\text{CBR} = P/P_s * 100 (\%)$$

Where: P is plunger-load in kN for tested soil.

$P_s$  is plunger-load in kN for standard soil (which is equal to 13.2 kN for 2.5mm and 20 kN for 5 mm penetration).

Figure (4) shows the relationship of load-penetration curve of CBR test for different salts.

## RESULTS AND DISCUSSION

### Effect of salt on consistency characteristics

Figure (2) shows the effect of salts content on Atterberg limits. The liquid limit, plastic limit and plasticity index decreased as the salts content increased. Similar results were reported by Venkatabor and Rechi (7), Mesri and Olsen (8) and Abelev (9). They attributed this behavior to the fact that the liquid limit and plastic limit is controlling by shearing resistance and inter particle level as also the thickness of diffused double layer. The shearing resistance in the case of plastic limit is found to be higher than in the case of the liquid limit and the diffuse double layer thickness is much lower.

### Effect of salt on compaction characteristics

The relation between dry density and water content for different salts used (NaCl, MgCl<sub>2</sub>, and CaCl<sub>2</sub>) and different salt percentages (2%, 4%, and 8%) are plotted in Figure (3). The addition of salt to the soil increases the dry density on the dry side of optimum moisture content while it causes no significant change in the dry density on the wet side of optimum moisture content.

Figure (5) shows the relation between maximum dry density and salt content for different salts used. This figure and Table (2) show that the additions of salts to the soil increase the maximum dry density and reduce the optimum moisture content as the salt content increase. Similar results were reported by Frydman and Ehrenreich [10] and Wood [11]. They attributed this behavior to the fact that at low water 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 [12].

Consequently under the influence of 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 water 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.

#### **Effect of salt on CBR value**

The relationship of load-penetration curve of CBR test for different salts are shown in Figure (4), and CBR values of untreated and treated specimens are given in Table (2), it can be seen, that the addition of salts led to an increase in the CBR values for the three salts used. 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 [13].

Figure(6) shows the effect of salt content on percentage of increase in CBR value, from this figure it can be noted that the addition of (2 %) salt to the soil causes increases the CBR value between (8 to 28 %), while, in samples containing large amount of salt (4 and 8 %) the percentage of increase was between (55 to 80%).

In general, the percentage of increase in CBR value of the soil treated with calcium chloride ( $\text{CaCl}_2$ ) is higher than other salts and the greatest value equal to (80%) which was found in the soil treated with (4%  $\text{CaCl}_2$ ).

The addition of calcium chloride to the soil causes hardening and more strength as compared to the soil specimens containing other salts additives.

#### **CONCLUSIONS**

Based on the laboratory tests result, the following conclusions can be drawn:

1. The liquid limit, plastic limit and plasticity index decreased as the salts content increased.
2. The additions of salts to the soil increase the maximum dry density and reduce the optimum moisture content.
3. The addition of chloride as a stabilizing agent produces a marked increase in CBR value.
4. The addition of (2 %) salt to the soil causes increases the CBR value between (8 to 28 %), while, in samples containing large amount of salt (4 and 8 %) the percentage of increase was between (55 to 80%).
5. The results indicate that the percentage of increase in CBR value of the soil treated with calcium chloride ( $\text{CaCl}_2$ ) is higher than other salts and the greatest value equal to (80%) which was found in the soil treated with (4%  $\text{CaCl}_2$ ).

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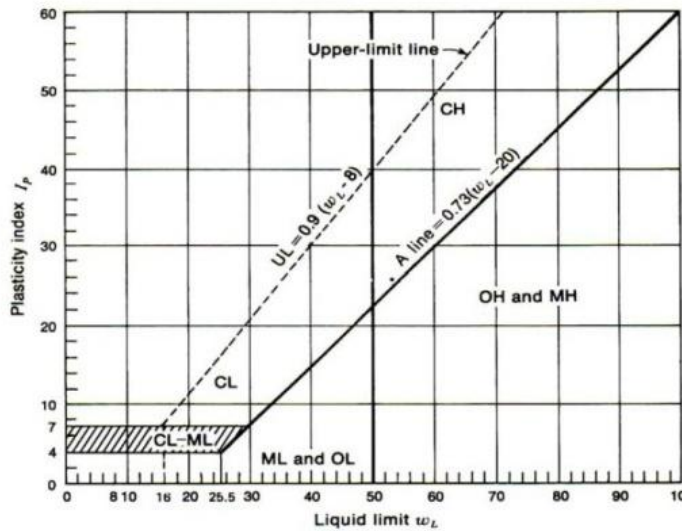
**Table (1) Properties of the Soil Used in this Study.**

<b>Property</b>	<b>Value</b>
Liquid limit	48 %
Plastic limit	27 %
Plasticity index	21 %
Specific gravity	2.71
Sand (0.06 to 2 mm)	6 %
Silt (0.005 to 0.06mm)*	31 %
Clay(less than 0.005mm)*	63 %

\* According to the ASTM specifications(2002)

**Table (2) Properties of Untreated and Treated Specimens.**

Case	O.M.C %	maximum dry density kN/m <sup>3</sup>	CBR (at 25 mm penetration)	CBR (at 50 mm penetration)	CBR
Untreated-soil	12.7	19.31	13.2	14.1	14.1
Soil + 2% NaCl	12.1	19.50	14.3	15.2	15.2
Soil + 4% NaCl	11.7	19.67	19.8	21.8	21.8
Soil + 8% NaCl	11.3	19.71	23.1	21.8	23.1
Soil + 2% MgCl <sub>2</sub>	11.8	19.52	14.8	16.7	16.7
Soil + 4% MgCl <sub>2</sub>	11.0	19.86	23.1	22.5	23.1
Soil + 8% MgCl <sub>2</sub>	11.1	19.90	23.1	23.2	23.2
Soil + 2% CaCl <sub>2</sub>	11.9	19.60	15.4	18.1	18.1
Soil + 4% CaCl <sub>2</sub>	11.7	19.82	22.0	25.4	25.4
Soil + 8% CaCl <sub>2</sub>	10.4	20.08	21.4	21.8	21.8



**Figure (1) Plasticity Chart [14].**

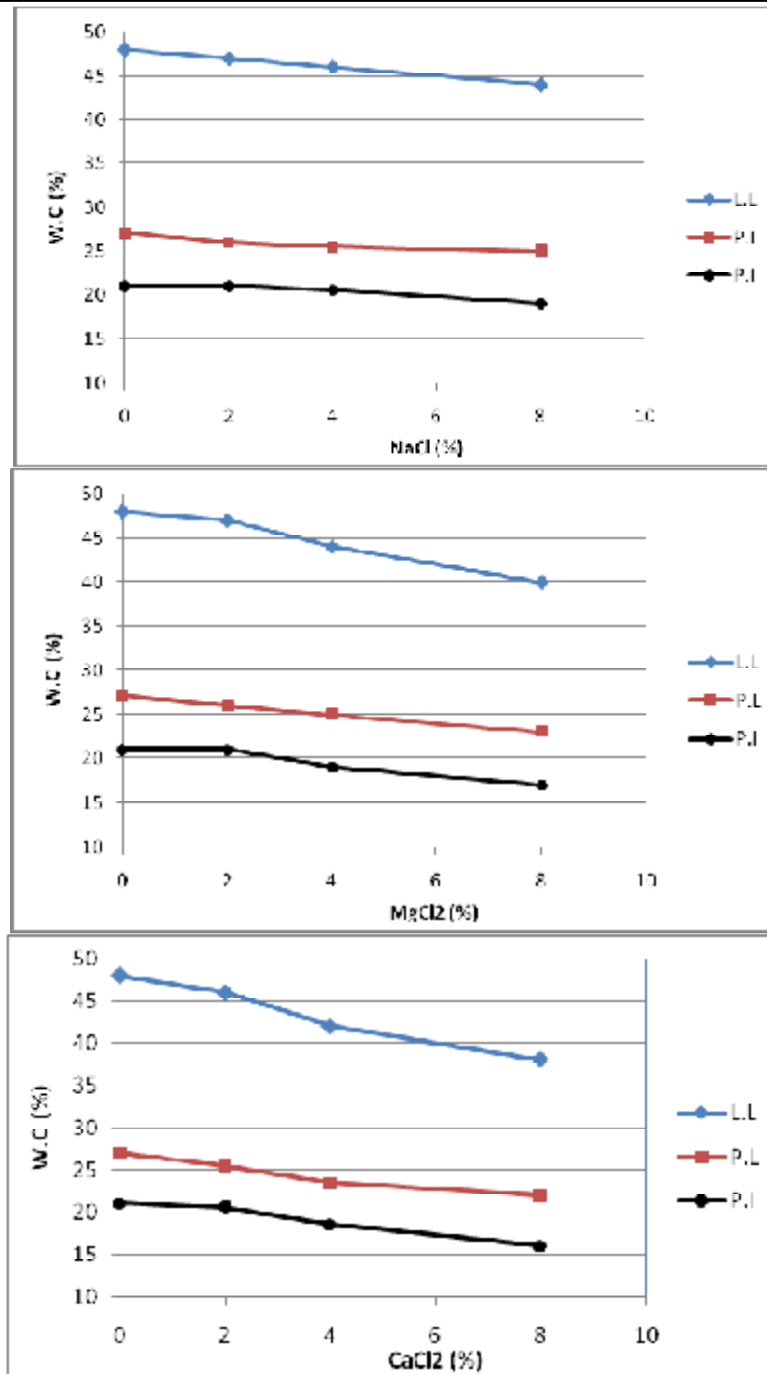


Figure (2) The effect of salt content on Atterberg limits.



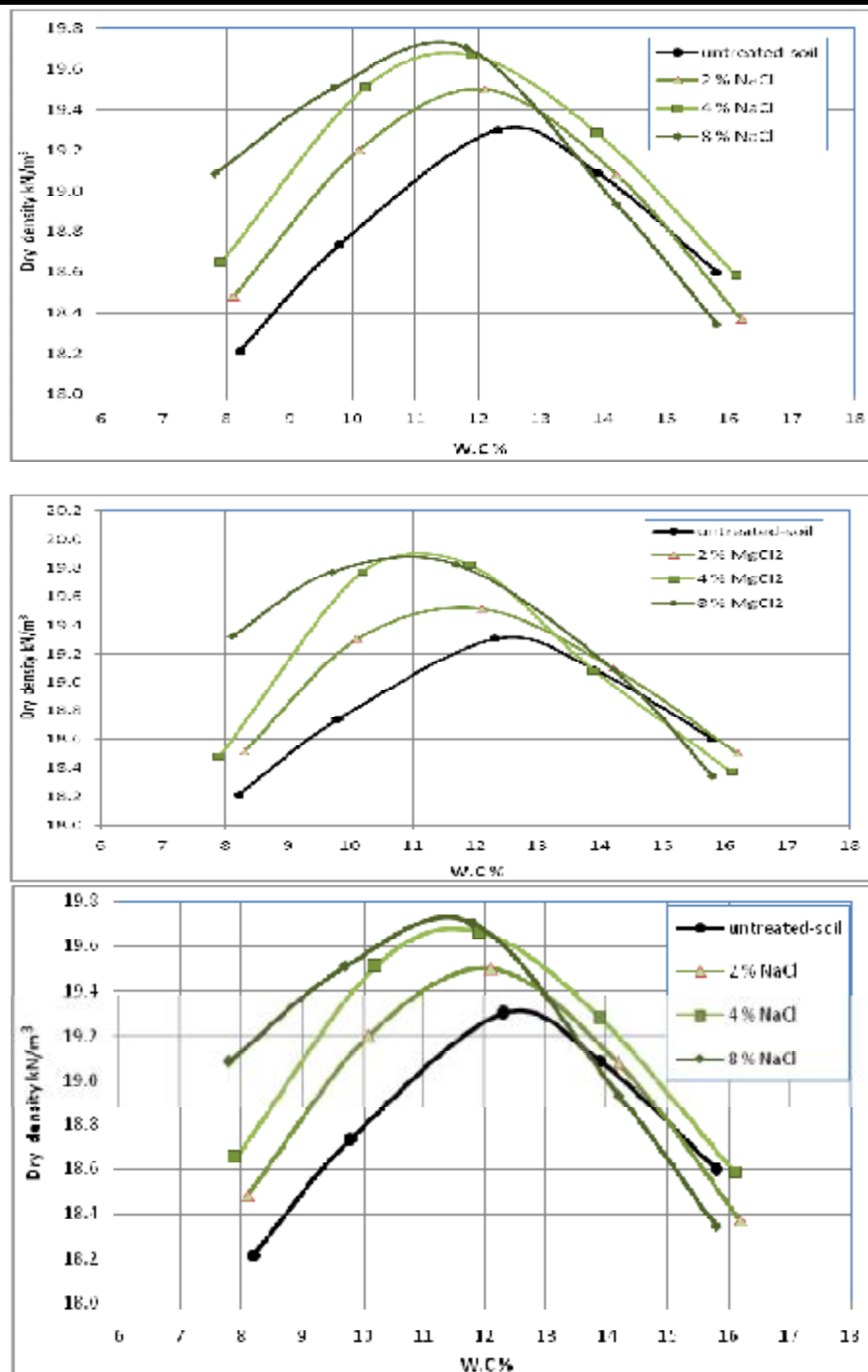


Figure (3) The relation between dry density and water content for different salts used.

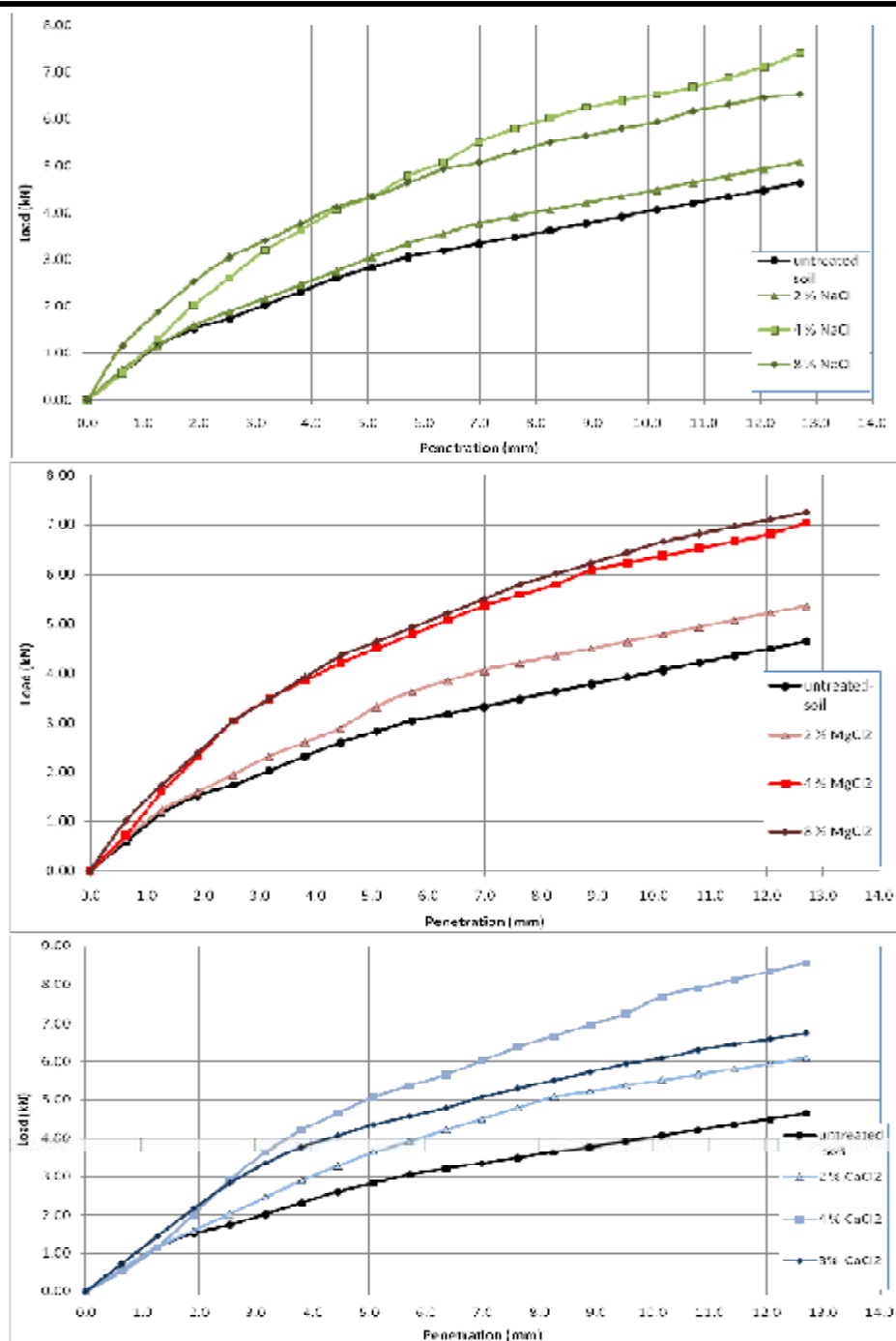


Figure (4) The relationship of load-penetration curve of CBR test for different salts.

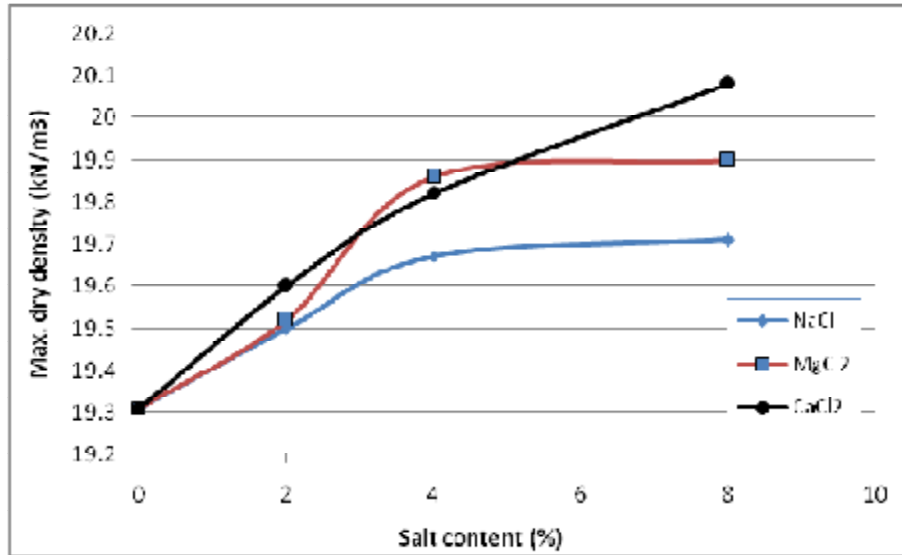


Figure (5) the relation between max. Dry density and salt content for different salts.

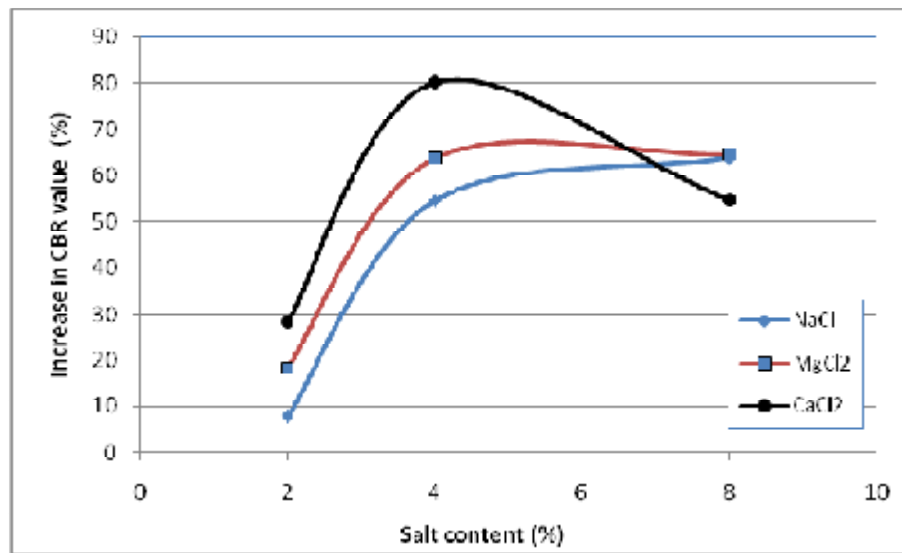


Figure (6) the effect of salt content on the percentage of Increase in CBR value.