The Effect Of Sodium Hydroxide On The Strength Of Kirkuk Soil – Cement Mixtures

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ABSTRACT.

In this study the effect of sodium hydroxide on the strength of clayey soil-cement mixtures was investigated. Clay soils from three various locations of Kirkuk governorate namely Erbil, Laylan and Hawija check points were used.
The effect of cement content, curing age, curing temperature and concentration of sodium hydroxide on the strength of soil-cement mixtures were investigated, through carrying out unconfined compressive strength, Triaxial compression and C.B.R tests.
It was found that the use of sodium hydroxide markedly improves the strength of soil-cement mixtures. The addition of about 1% of sodium hydroxide by weight of soil could reduce about 5% of cement content by weight of soil required to stabilize the soils effectively.

Keywords: Clay soil, cement, sodium hydroxide, unconfined compressive strength, cohesion, angle of internal friction, triaxial compression test and C.B.R. test.

1. INTRODUCTION.

Engineering properties of soil can be improved by mechanical, chemical, electrical, thermal and other methods [1,2 and 3]. Mechanical and chemical methods are the best means used for highways and airfields construction in which Portland cement is used as soil-stabilizer.

Compressive strength is the characterized factor of soil-cement mixtures which indicate the degree of reaction of the soil-cement-water mixture, setting time, rate of hardening and durability of the products. The compressive strength of soil-cement mixture is usually increased with increasing density and curing age [1, 2, 3, 4, 5, 6 and 7].

Primary and secondary processes take place when cement is added to the clay soil [7]. The major hydration products are basic calcium silicate hydrates, calcium aluminates hydrates and hydrated lime. Clay soil contains a small fraction of silica and alumino-silicate in a highly reactive hydrous state on the particles surface [8]. The solubility of the soil silica is greatly increased by alkalis, while alumina dissolved by high PH environment. In the secondary process, the calcium cations Ca^{++} produced by cement hydration will replace the exchangeable cations on the surface of the clay particles, and tend to intensify the flocculation initiated by the increase in total electrolyte content [7]. The dissolved silica and alumina in the pore water will be mixed with calcium ions, and additional cementations material is formed [7, 8 and 9].

It is reported that the addition of sodium hydroxide for soil-cement mixtures, increase and enhance the effectiveness of Portland cement as a stabilizer by reducing the required quantity of cement [1, 8, 10, 11 and 12], and also reduce the shrinkage cracks [13], and volumetric changes [8], and increase the durability and resistance to sulphate solutions [9].

Lamb, Micheals and Moh [8] reported that with two silty - clay soils, the addition of about 1% sodium hydroxide or sodium carbonate, about 5% cement could be saved. Ibrahim and Madhov [14], reported that the use of sodium hydroxide, sodium carbonate and sodium sulphate as an additives were ineffective with silty - loam.

In this paper the effect of sodium hydroxide as an additive to Kirkuk clay soil when stabilized with cement was investigated. Unconfined compressive strength, triaxial compression and C.B.R tests were carried out. Factors such as curing age, curing temperature, cement content and amount of sodium hydroxide on the strength of clay-cement mixtures were investigated.

2. MATERIALS USED.

Soils

Three clay soils from different locations in Kirkuk governorate (Erbil, Laylan and Hawija check points) were used in this study. The physical and chemical properties of the soils used are given in **Table (1) and (2). Fig. (1)** shows the grain size distribution of the soils used.

Cement

Portland cement obtained from Kirkuk cement factory was used throughout this investigation.

Water

Distilled water was used for specimen preparation, while ordinary tap water was used for socking the samples.

Sodium Hydroxide

Water soluble sodium hydroxide regent was used with concentrations varied from 0.5 N to 2.0 N.

3. SPECIMENS PREPARATION AND TESTS.

All clayey soil samples were air dried, pulverized and passed through U.S sieve No. 10. The required amount of cement based on dry weight of the soils was hand mixed. The amount of water and sodium hydroxide solution required to provide the optimum moisture content is added and hand mixed. The required specimen was prepared as following:

1. Specimens For Unconfined and Triaxial Compression Tests

The specimens prepared were 50 mm dia. and 100 mm height. The compactive energy used was equivalent to standard proctor compaction test. The molded specimens when removed from the mold were warped in cellophane, waxed and stored in the curing room at a temperature of 25 ºC and constant humidity for the required period. The unconfined compressive strength was carried out according to ASTM-D2166-66 [15] using constant strain compression machine with a loading rate of 1.5% strain per minute. The unconfined stress ($\sigma_1 - \sigma_2$) was applied at a loading rate of 1% strain per minute. The triaxial compression tests were unconsolidated undrained tests.

2. Specimens For C.B.R Tests

The C.B.R specimens were molded in a standard C.B.R mold utilizing a standard proctor hammer where 34 blows per each of 5 layers were used to give a compaction energy equivalent to standard proctor compaction test. After the required curing age, the specimens were soaked for 4 days under a surcharge weight of 90 kN. The C.B.R tests were carried out according to ASTM-D1883-73 [16].

4. RESEARCH PROGRAM.

The main parameters concerned in this research were:

a. Effect of amount of cement content.
b. Effect of curing temperature.
c. Effect of curing age.
d. Effect of amount of sodium hydroxide content and concentration.

For this purpose the testing program is divided into two groups, as shown in **Table (3)**.

5. RESULTS.

5.1. Results of The Unconfined Compression Tests

A. Soil-Cement With No Sodium Hydroxide.

Fig. (2) shows the effect of cement content on the unconfined compressive strength for all the investigated soils at curing temperature of 35 ̊ C and curing age of 7 days. The following results were obtained:

1. The unconfined compressive strength for all the investigated soil cement-mixtures increased with increasing cement content.
2. Higher rate of gain in unconfined compressive strength noticed with the increase in cement content ranged between 5 and 10% by weight of soil.
3. Cement content of 12.5% by weight of soil was chosen to produce acceptable soil-cement mixtures with unconfined compressive strength of more than 1500 kPa. [1, 17 and 18].
4. The soil-cement mixtures from Hawija check point produced higher rate of gain in strength than the other two soil-cement mixtures. This could be attributed to lower soluble salts, organic matter and sulphate content presented in the soil from Hawija check point as compared to other two soils, as shown in **Table (2)**.
5. The soil-cement mixture from Erbil check point showed lower rate of gain in strength due to higher sulphate content of the soil.

Fig. (3) shows the effect of curing temperature on the unconfined compressive strength of all the investigated soils at curing age of 7 days and cement content of 12.5% by weight of soil. Linear relationship between unconfined compressive strength and curing temperature was observed.

Fig. (4) shows the effect of curing age on the unconfined compressive strength of all the investigated soils at curing temperature of 35 ̊ C and cement content of 12.5% by weight of soil. It is noticed that unconfined compressive strength increased rapidly up to curing age of 7 days, and then the rate of gain in strength will be lower.

B. Soil-Cement Mixtures Treated With Sodium Hydroxide.

Fig. (5) shows the effect of sodium hydroxide content with (1.0 N concentration) on the unconfined compressive strength for all the investigated soils at curing temperature of 35 ̊ C, curing age of 7 days and cement content of 12.5% by weight of soil. It is noticed that for all the investigated soils the addition of trace amount of sodium hydroxide to the soil-cement mixtures increased the unconfined compressive strength. This is due to the formation of more cementation gels than those formed in soil-cement mixtures alone [8 and 9].

Fig. (6) shows the effect of sodium hydroxide concentration on the unconfined compressive strength for all the investigated soils at curing temperature of 35 ̊ C, curing age of 7 days, and cement content of 12.5% by weight and 1% sodium hydroxide content. It is noticed that the unconfined compressive strength of the soil-cement mixtures for all the investigated soils treated with sodium hydroxide increased to a maximum value at certain sodium hydroxide concentration and then decreased with the increase in the sodium hydroxide concentration. Hence there is optimum concentrations that produce maximum strength. The optimum sodium hydroxide concentration for the soil-cement mixtures from

Erbil, Laylan and Hawija check point were 1.5 N, 1.0 N and 1.0 N by weight of soils respectively. The relatively high optimum concentration required for the soil from Erbil check point could be attributed to relatively high organic concentration and cations exchange capacity of the soil [10 and 17].

On the bases of an arbitrary 7 days compressive strength of 1750 kPa, the results present in **Table (4)** indicate that sodium hydroxide could reduce the amount of cement used by 5% for the soils from Laylan and Hawija check points and up to 7.5% for the soil from Erbil check point.

5.2. Results of The Triaxial Compression Tests.

From the unconsolidated undrained triaxial compression tests on all the investigated soils stabilized with cement content of 12.5% by weight, curing temperature of 35 ° C and curing age of 7 days, **Fig. (7) and (8)** shows the following:

1. The incorporation of sodium hydroxide with the clay-cement mixture for all the investigated soils increased the cohesion value of the soil-cement mixtures to a maximum value and then decreased.
2. The cohesion of soil-cement mixtures for all the investigated soils treated with sodium hydroxide increased to a maximum value at certain sodium hydroxide concentration and then decreased with the increase in the sodium hydroxide concentration.
3. The angle of internal friction of the soil-cement mixtures for all the investigated soils was decreased by the addition of sodium hydroxide. This agrees with previous finding by Laguros and Davidson [10].
4. The effect of sodium hydroxide concentration on the cohesion and angle of internal friction for Erbil check point soil-cement mixture respectively, at curing temperature of 35 ° C, curing age of 7 days, cement content of 12.5% by weight and 1% sodium hydroxide content. The optimum concentration of sodium hydroxide that produces maximum cohesion was 1.0 N, which is the same as the optimum concentration obtained from the unconfined compressive strength test.

5.3. Results of The C.B.R Tests.

From the C.B.R. tests on all the investigated soils stabilized with cement content of 12.5% by weight, curing temperature of 35 ° C and curing age of 7 days, **Fig. (9)** shows the following:

1. The addition of sodium hydroxide to the clay-cement mixture for all the investigated soils increased the C.B.R. value of the soil-cement mixtures to a maximum value and then decreased.
2. The C.B.R. for all the investigated soil-cement mixtures treated with sodium hydroxide increased to a maximum value at certain sodium hydroxide concentration and then decreased with the increase in the sodium hydroxide concentration.

6. CONCLUSIONS.

From the results presented the following may be concluded, limited to the soils tested and test conditions mentioned:

1. The unconfined compressive strength of soil-cement mixtures with or with out sodium hydroxide increased with the increase in cement content, curing age and curing temperature.
2. The incorporation of sodium hydroxide increases the strength of soil-cement mixtures.
3. There is an optimum concentration for sodium hydroxide that produces maximum strength.

4. The cement content required to stabilize the soils could be reduced by adding sodium hydroxide.
5. The C.B.R and cohesion improved in a similar manner to that of the unconfined compressive strength when the soil-cement mixture is treated with sodium hydroxide
6. The angle of internal friction of the soil-cement mixtures decreased when they treated with sodium hydroxide.

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NOMENCLATURE.

C.T = Curing Temperature
C.A = Curing Age
C.C = Percentage of Cement Content

Table (1): Physical Properties of the Investigated Soils.

Soil Location	**Erbil Check Point**	**Laylan Check Point**	**Hawija Check Point**
Specific Gravity	2.70	2.68	2.71
Atterburg Limits Liquid Limit % Plastic Limit % Plasticity Index	 49 20 29	 45 21 24	 50 24 26
Standard Proctor Compaction Maximum Dry Density (gm/cm^3) Optimum Moisture Content %	 1.58 21	 1.65 19	 1.60 20
Unified Soil Classification	CL	CL	CH
AASHO Soil Classification	A-7-6	A-7-6	A-7-6
Soil Description	Reddish Clay	Grayed Clay	Brown Silty Clay

Table (2): Chemical Properties of the Investigated Soils.

Soil Location	**Erbil Check Point**	**Laylan Check Point**	**Hawija Check Point**
pH at Saturation	6.83	6.65	7.05
Organic Matter Content %	1.10	0.85	0.55
Cation Exchange Capacity Meq/100 gms	21.00	25.50	23.10
Total Soluble Salts %	3.95	2.85	0.74
SiO_3 %	34.50	41.20	40.50
P_2O_3 %	15.46	16.10	18.85
CaO %	18.50	16.20	13.25
MgO %	5.32	5.16	5.38
SO_3 %	2.75	1.65	0.50
Fe_2O_3 %	3.75	5.12	4.85
Al_2O_3 %	11.95	10.85	15.05
Na_2O %	0.42	0.52	0.15

Table (3): Research Program.

Group I 27 tests done for the investigated soils with No-NaOH added			Group II 48 tests done for the investigated soils with addition of NaOH		
Details	**No.**	**Test**	**Details**	**No.**	**Test**
1. Values of cement content of 0, 5, 10, 15 and 20 %, with curing temperature of 35 °C and curing age of 7 days.	15	UCS	1. Values of NaOH content of 1 and 2% with cement content of 12.5%, curing temperature of 35 °C and curing age of 7 days.	6	UCS
2. Values of curing temperature of 25 and 45 °C, with cement content of 12.5% and curing age of 7 days.	6	UCS	2. Values of NaOH concentration of 0.5, 1, 1.5 and 2%, with cement content of 12.5%, curing temperature of 35 °C and curing age of 7 days.	12	UCS
3. Values of curing age of 1 and 28 days, with cement content of 12.5% and curing temperature of 35 °C.	6	UCS	3. Values of NaOH concentration of 0, 0.5, 1, 1.5 and 2%%, with cement content of 12.5%, curing temperature of 35 °C and curing age of 7 days.	15	Trixial compression (to find cohesion and angle of internal friction)
			4. Values of NaOH concentration of 0, 0.5, 1, 1.5 and 2%%, with cement content of 12.5%, curing temperature of 35 °C and curing age of 7 days.	15	C.B.R

Table (4): Reduction in Cement Content Obtained by the Addition of Sodium Hydroxide, to Gain a 7 - Day Unconfined Compressive Strength of 1750 kPa.

Soil Location		**Erbil Check Point**		**Laylan Check Point**		**Hawija Check Point**	
Cement Content %		16	8.5	15	10	12	7
NaOH	Concentration N	-	1.5	-	1.0	-	1.0
	Content %	-	1.35	-	1.0	-	1.0
Reduction in Cement Content %		-	7.5	-	5	-	5

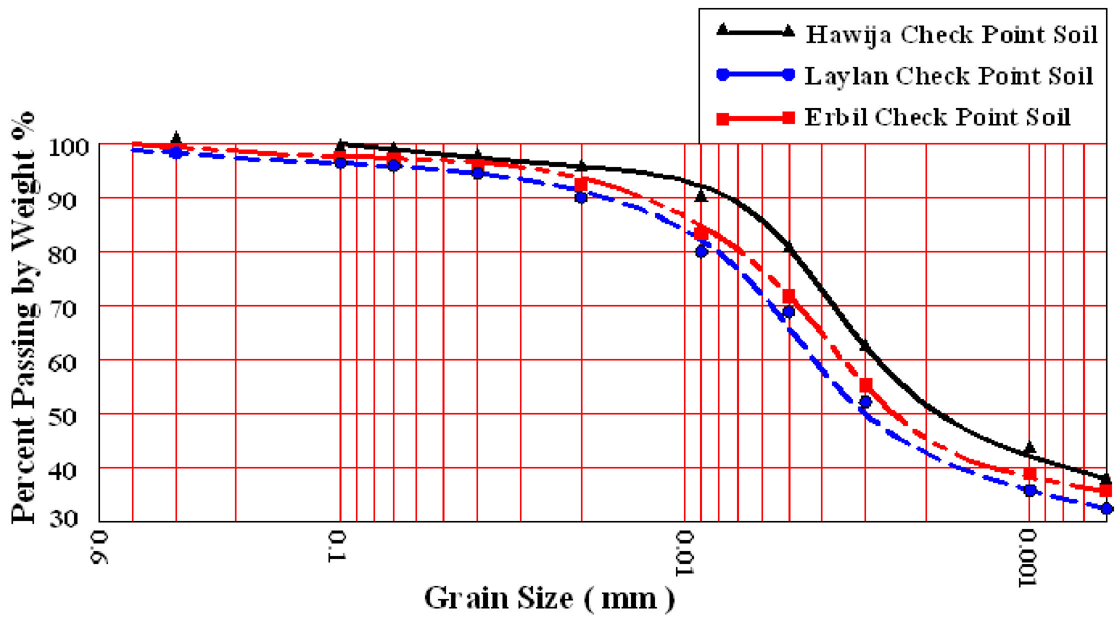

Figure (1) : Grain Size Distribution of the Investigated Soils

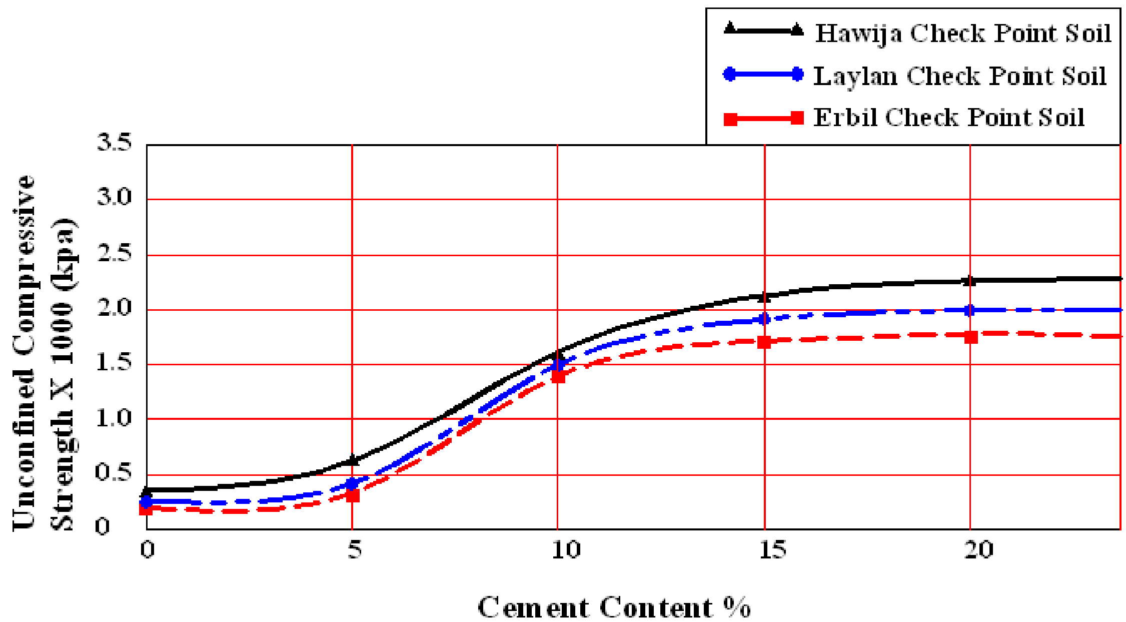

Figure (2) : Effect of Cement Content on the Unconfined Compressive Strength for the Investigated Soils with [C.A=7 Days, C.T=35 °C and No NaOH]

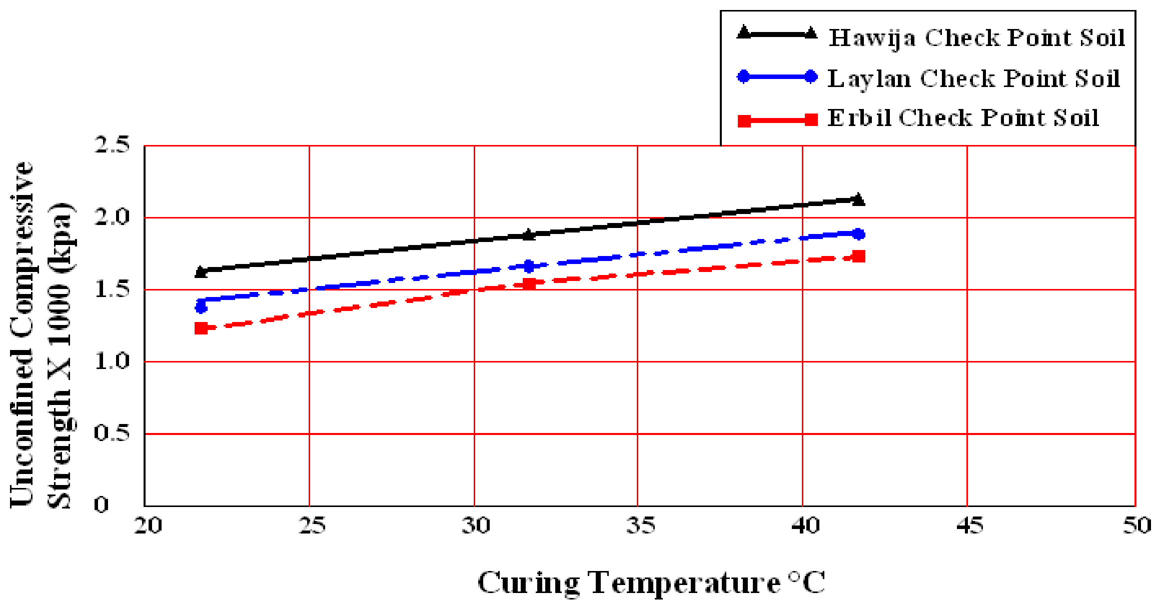

Figure (3) : Effect of Curing Temperature on the Unconfined Compressive Strength for the Investigated Soils with [C.C=12.5%, C.A=7 Days and No NaOH]

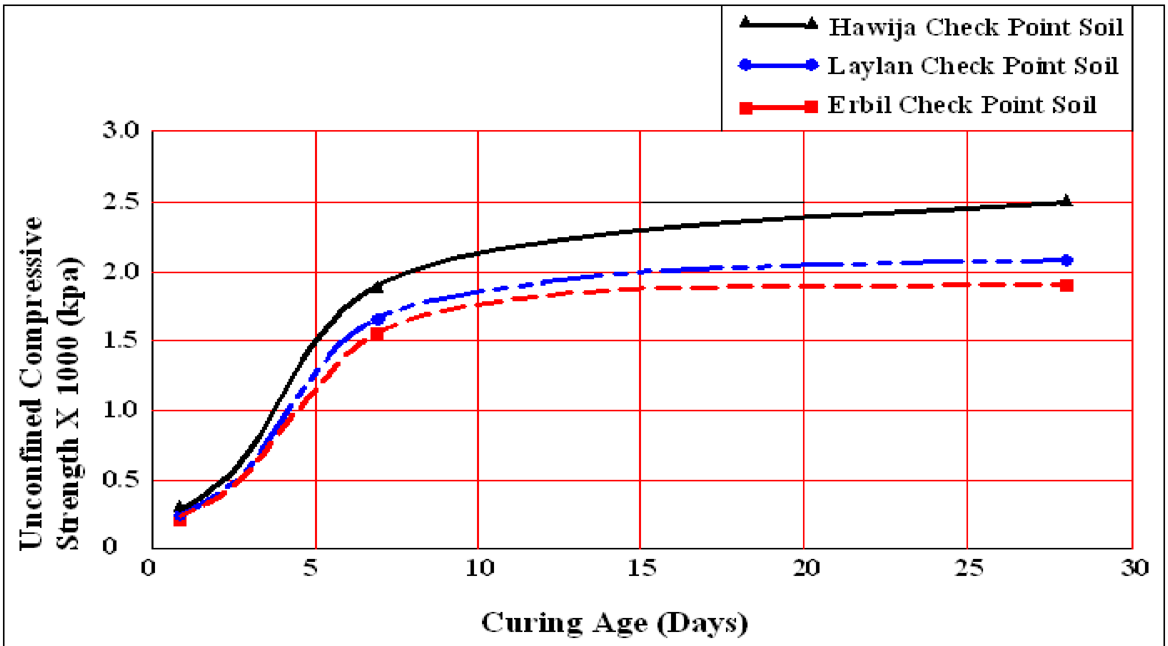

Figure (4) : Effect of Curing Age on the Unconfined Compressive Strength for the Investigated Soils with [C.C=12.5%, C.T=35 °C and No NaOH]

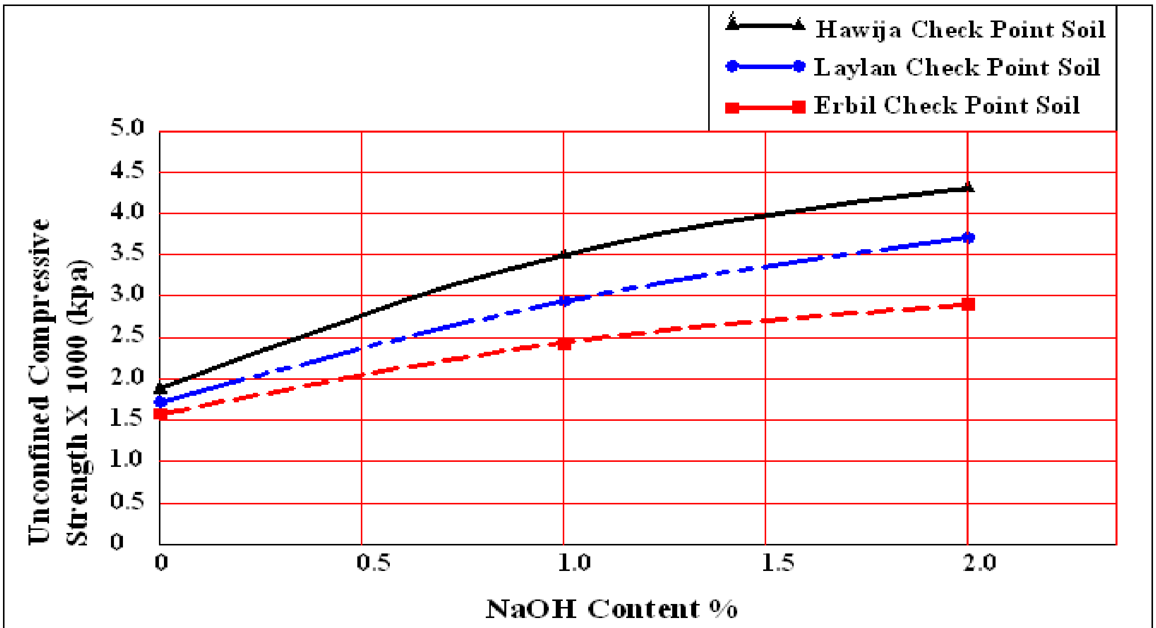

Figure (5) : Effect of NaOH Content on the Unconfined Compressive Strength for the Investigated Soils with [C.A=7 Days, C.T=35 °C and C.C=12.5%]

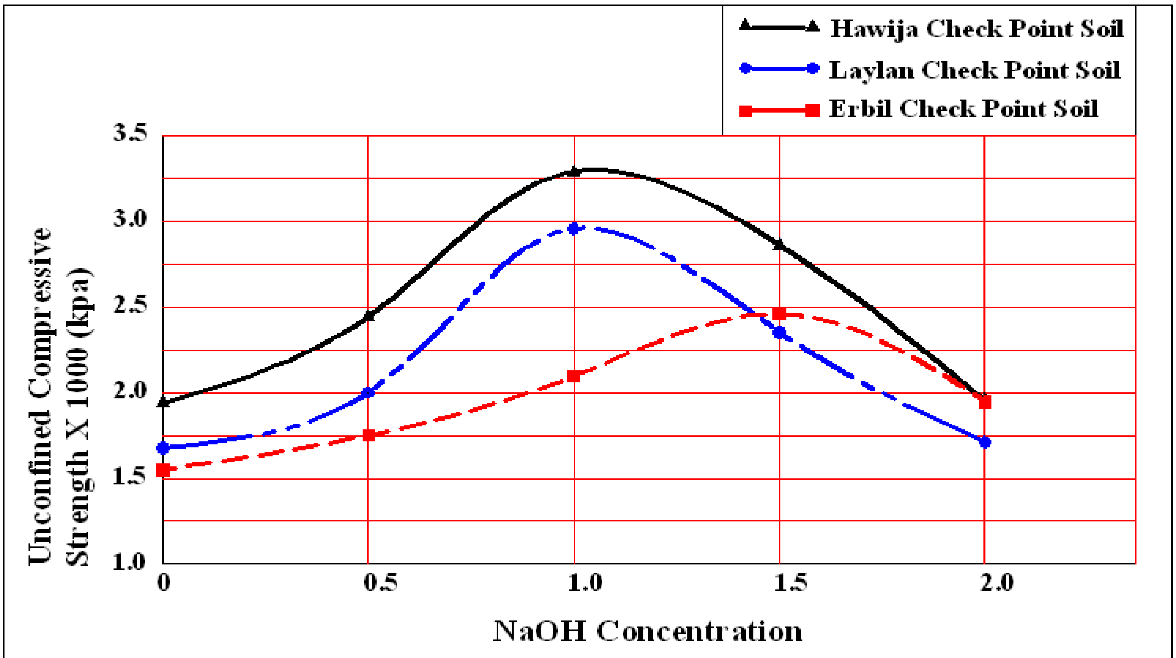

Figure (6) : Effect of NaOH Concentration on the Unconfined Compressive Strength for the Investigated Soils with [NaOH=1%, C.A=7 Days, C.T=35 °C and C.C=12.5%]

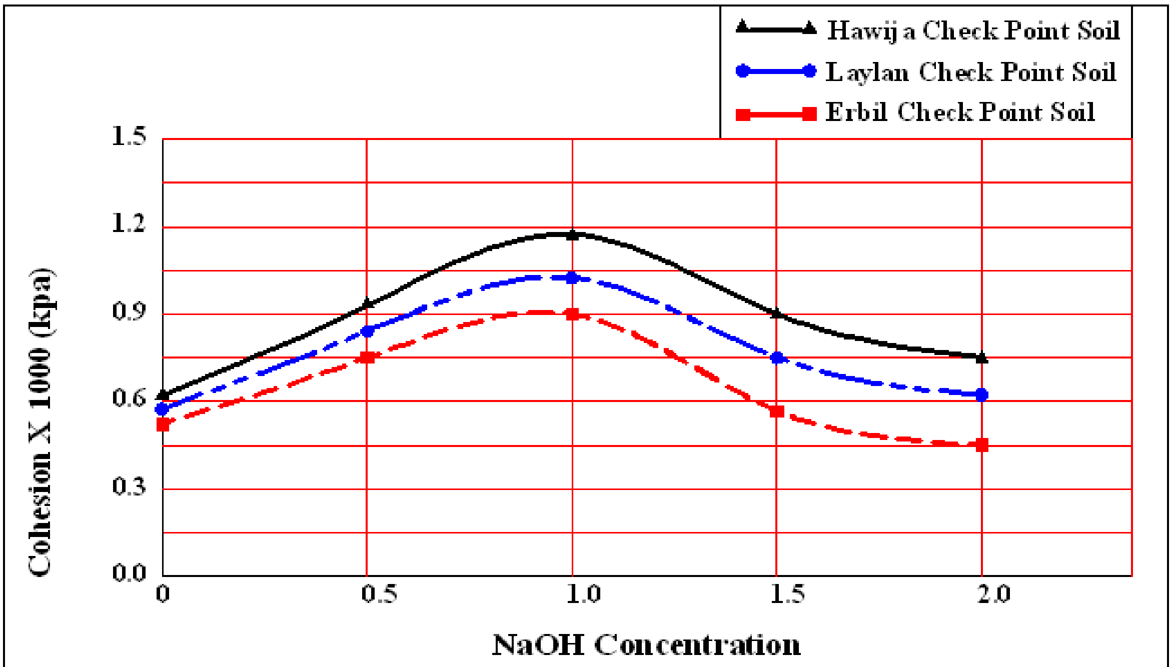

Figure (7) : Effect of NaOH Concentration on the Cohesion for the Investigated Soils with [NaOH=1%, C.A=7 Days, C.T=35 °C and C.C=12.5%]

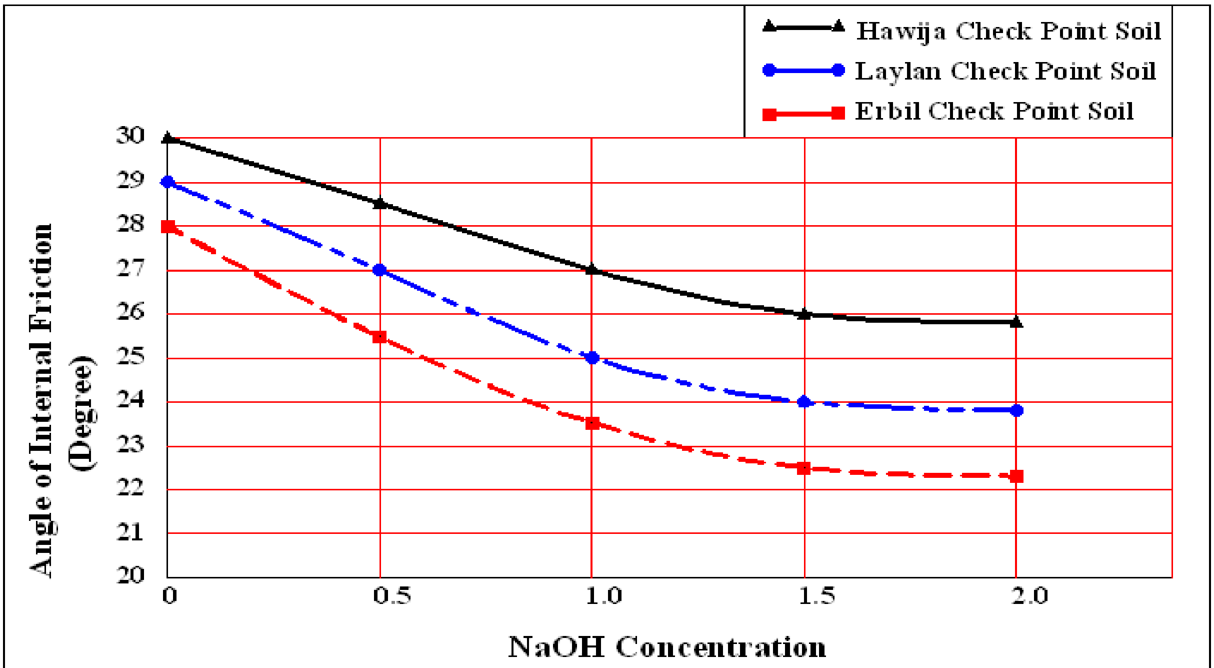

Figure (8) : Effect of NaOH Concentration on the Angle of Internal Friction for the Investigated Soils with [NaOH=1%, C.A=7 Days, C.T=35 °C and C.C=12.5%]

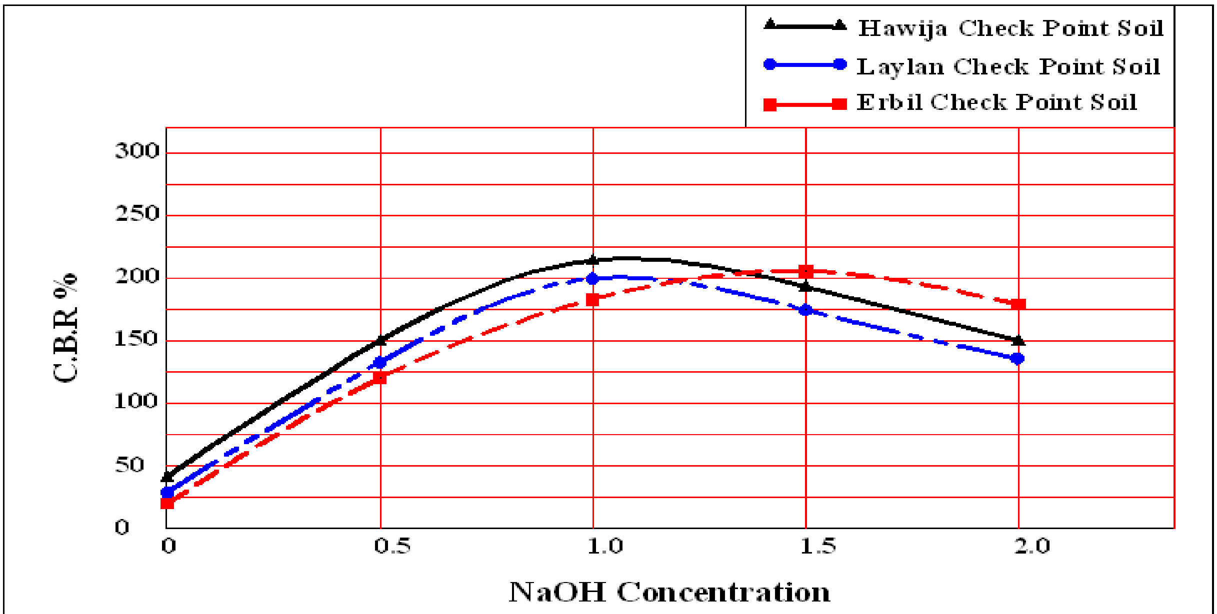

Figure (9) : Effect of NaOH Concentration on the C.B.R for the Investigated Soils with [NaOH=1%, C.A=7 Days, C.T=35 °C and C.C=12.5%]

تأثير هيدروكسيد الصوديوم على مقاومة خليط من تربة كركوك الطينية مع السمنت

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الخلاصة.

في هذه الدراسة تمت التحري عن تأثير هيدروكسيد الصوديوم على مقاومة خليط التربة مع السمنت. استخدمت نماذج من التربة الطينية لثلاثة مواقع مختلفة من محافظة كركوك وهي نقاط تفتيش اربيل، ليلان و الحويجة.
تمت دراسة تأثير محتوى السمنت، عمر الرش، درجة حرارة الرش و نسبة تركيز هيدروكسيد الصوديوم على قوام خليط التربة مع السمنت، من خلال انجاز تجربة الانضغاط الغير المحصور، تجربة الانضغاط ثلاثى المحاور و تجربة C.B.R.

وجد ان استعمال هيدروكسيد الصوديوم كمادة مضافة يؤدي الى تحسين ملحوظ في قوام خليط التربة مع السمنت ، حيث ان اضافة هيدروكسيد الصوديوم بحوالي 1% من وزن التربة، يؤدي الى تقليل محتوى السمنت المطلوبة لتثبيت التربة بحوالي 5% من وزن التربة .

الكلمات الرئيسية: تربة طينية، هيدروكسيد الصوديوم، مقاومة الانضغاط الغير المحصور، تجربة الانضغاط ثلاثى المحاور و تجربة C.B.R