Tensile Strength of Natural and Lime Stabilized Mosul Clay

Al-Layla M.T. **Al-Dabbagh A.W.** **Jaro M.N.**

Professor **Assistant Lecturer**
Assistant Lecturer

Civil Engineering Department, College of Engineering, Mosul University

Abstract

The Purpose of this study is to investigate mainly the tensile stress properties of natural and stabilized clayey soil selected from Mosul area .The tensile strengths of compacted specimens of natural soil and lime stabilized soil are obtained using the flexural test (third-point loading). The tensile and the compressive stress-strain curves of both soils are evaluated. The compressive strength on a portion of the beam is determined for both soils. The results reveal that both the tensile and compressive strengths increase with the addition of lime and with the increasing the curing time .Furthermore ,the results show that the tensile strength is more sensitive to lime stabilization than the compressive strength .The stress-strain curves of the stabilized specimens are rather irregular .All specimens, natural and stabilized show sudden type of failure .The method of analysis used for determining the tensile stress-strain curves are the direct method of analysis.

Keywords:Tensile Strength, Lime Stabilization, Flexural Test, Mosul Clay, Irregular Stress Strain Curves

قوة الشد للتربة الطينية الطبيعية والمثبتة بالنورة في مدينة الموصل

محمد طيب الليلة **أيمن وليد الدباغ** **محمد ناظم جارو**

أستاذ مدرس مساعد
مدرس مساعد
قسم الهندسة المدنية, كلية الهندسة ,جامعة الموصل

الخلاصة

إن الهدف الرئيسي من هذه الدراسة هو إيجاد خصائص الشد لتربة طينية أخذت من مدينة الموصل وعوملت بنسب مختلفة من النورة .تم إيجاد مقاومة الشد لنماذج التربة الطبيعية المرصوصة وكذلك التربة المثبتة بالنورة وذلك باستخدام فحص الانثناء .ومن ثم تم أيجاد منحنيات الإجهاد-الانفعال للشد والضغط .بالإضافة لذلك تم إيجاد مقاومة الانضغاط للتربة الطبيعية والمثبتة بالنورة باستخدام جزء من النموذج المفحوص بالشد .إن النتائج تدل على إن كل من مقاومة الشد ومقاومة الضغط تزداد بزيادة نسبة النورة وكذلك بزيادة فترة الإنضاج .كذلك فان النتائج تبين إن مقاومة الشد أكثر حساسة للنورة المضافة مقارنة مع مقاومة الانضغاط .إن منحنيات الإجهاد_ الانفعال للتربة المعاملة بالنورة كانت غير منتظمة .وان درجة عدم الانتظام هذه تزداد بازدياد نسبة النورة المضافة .إن النتائج التي تم الحصول عليها تم تحليلها بواسطة الطريقة المباشرة للتحليل .إن فشل كافة النماذج التي فحصت كان بشكل فجائي.

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Introduction

Tensile stresses can develop in highway pavement layers, at some distance from the wheel load. When the tensile stresses reach or exceed the tensile strength of the pavement layers, cracking takes place which results in excess deflections and more stresses reaching the sub-grade layer. Therefore, the higher the tensile strength of the pavement layers, the more sound roads.

The natural soils have low tensile strength compared with the compressive strength. To improve the tensile strength properties, the soil may be stabilized.

It is well known that the lime stabilization of a clayey soil improves its strength and other engineering properties [1,2,3]. The tensile strength is one of the main properties which the pavement designer consider and always try to select a material with edquate tensile strength . The tensile characteristics can be measured by direct method, indirect method (Brazilian) and by bending method (flextural). Because of the slab action of the pavement layers, the result of flexural tension test are more appropriate than other methods to evaluate the tensile properties of the pavement materials [4].

Leonards and Narain [3] carried out flextural tension tests to investigate the tensile properties of compacted clays. They reported that the tensile strain decreased with the increase of compactive effort at comparable moisture contents. For a fixed compaction energy, the tensile strain increased with increasing moisture content up to the optimum.

Addanki et al [5] performed indirect tension test on a compacted well graded granular soil to study the effect of water content and compactive effort on the tensile strength. They concluded that the tensile strength decreased with an increase in water content, while the tensile strength increased with increasing the compactive effort for water content below the optimum and decreased slightly for water content above the optimum.

Lushnikov et al [6] conducted a series of direct tension and unconfined compression tests on compacted loams and clay soils. They showed that the moisture content have a significant effect on the values of modulus of elasticity in tension and compression.

Ajaz and Parry [7] reported that the values of the initial tangent modulus from the flextural test of clay is greater in tension than in compression and their values are influenced by the moulding moisture content. Thus the use of identical values for tension and compression in analysis of soil structure is not justified.

Jaro [8] measured the tensile strength of sub-base material stabilized with cement. He found that the tensile strength of stabilized material with 4% cement increased as the fine material increased up to 14% and then decreased. For 8 and 12 percent of cement, the maximum strength occurred at 6% of fine material then decreased.

In this study, the tensile strength characteristics of natural and lime stabilized clayey soil selected from Mosul city were determined. The clay was stabilized with 2, 4 and 6 percent lime and cured for 7 and 30 days at room temperature of (25 ± 2 ^{o}C).

The tensile properties were obtained using the simple beam with third-point loading. The results of the tests were analyzed using the direct method of analysis.

Materials

Soil :

The soil used in this study is a clay obtained from Al-hadbaʾa District in Mosul city. Table (1) shows some of the index properties of the soil obtained using the relevant tests according to the ASTM standards

Table (1) Index Properties of Soil

Liquid Limit	51
Plastic Limit	23
Plasticity index	28
Percent Passing No.10 (2.0 mm) No.40 (0.42 mm) No.200 (74 micron) % of clay	 100% 90% 87% 40%

Unified Classification	CH
Specific Gravity	2.72
Clay Material	Kaoliniate, Chlorite and Attapulgite*
pH	8.5

*The results were obtained from Al-Sangary [9].

Lime :

The lime used in this study was obtained from Meshrag Sulphur Factory. The chemical analysis of the lime is shown in table (2).

Table (2) Chemical Analysis of the Lime [10]

Composition	$Ca(OH)_2$	CaO	$CaCo_3$	Al_2O_3	Fe_2O_3	SiO_2	MgO	H_2O
Percent	71.3	6.1	6.2	0.17	0.04	11.1	4.19	0.09

Procedures of Testing

The compaction characteristic of the soil was established using modified compactive effort. The soil was stabilized using 2, 4 and 6 percent lime, and the compaction curves of soil lime mixture were obtained.

Flextural test :

The flextural test was conducted on untreated and stabilized soil using prismatic beam (50.8 * 50.8 * 305 mm). The specimens were prepared by compacting the soil at the optimum moisture content in four layers using special square base hammer weighing (17.1)N and falling from (28)cm. to obtain the modified compactive effort. The compacted specimens were wrapped in serval plastic bags to secure constant water content during the curing periods.

The specimens were cured at room temperature of (25 ± 2 ^{o}C) for 7 and 30 days. At the end of curing periods the specimens were weighted and it was found that the weight was almost constant with variation not more than 2 gm. out of about 1600 gm.

The specimen was mounted in the compression machine as shown in Fig.(1) and a load was applied at rate of 0.127 mm/min (0.005in/min). The deflections at the center of the beam (top and bottom) with applied load were recorded every (1min.) and the flextural strength properties were evaluated.

In addition to the evaluation of the flextural strength, the compression strength was determined using a portion of the beam which was free from cracks or any seen defect. This test was performed according to (ASTM D 1634-631997) [11].

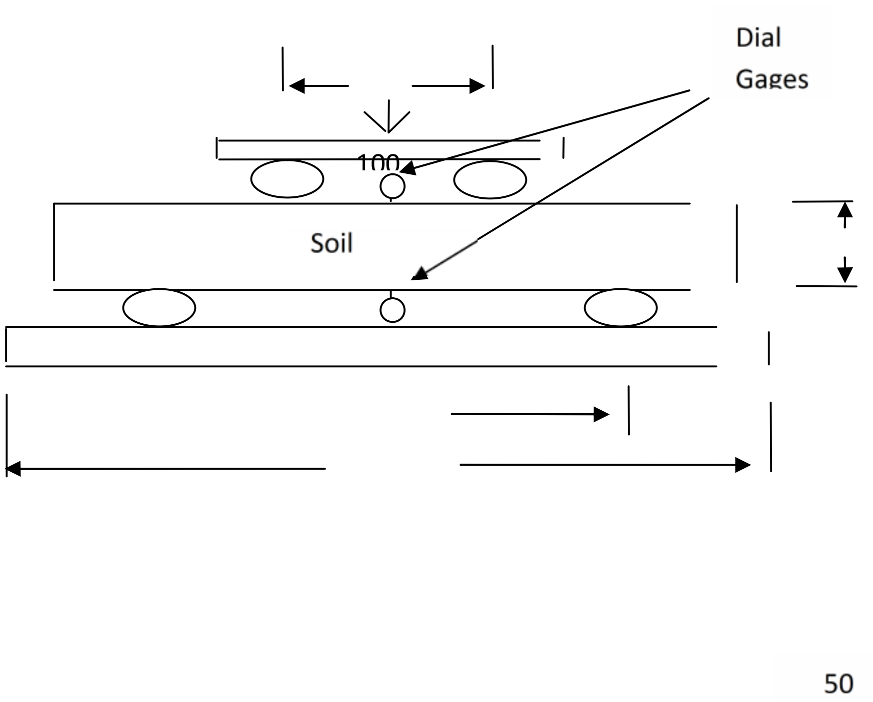


Fig.(1). The mounting of specimen (dimensions in mm)

Method of Analysis

The direct method of analysis is used to calculate the tensile stress at the bottom and the compressive stress at the top of the beam from the applied bending moment. In this method it is assumed that the plane section remain plane after bending, that is the elongation and contraction of longitudinal axes are proportional to their distances from the neutral axis. The value of deformation modulus in tension may differ from that in compression (hence the neutral axis is not necessarily at the mid-height of the beam) and no creep occurs during bending.

Duckworth [12] derived the following Equations for tensile stress (σ_t) and compressive stress (σ_c)

$$\sigma_t = \frac{3M}{bd^2}\frac{\varepsilon_c + \varepsilon_t}{\varepsilon_t} \qquad \text{----------1}$$

$$\sigma_c = \frac{3M}{bd^2}\frac{\varepsilon_c + \varepsilon_t}{\varepsilon_c} \qquad \text{----------2}$$

The Strain of the beam is found from the following Equations:-

$$\varepsilon_t = \frac{48\delta_t MC}{Pb(3L^2 - 4b^2)}$$ ----------3

$$\varepsilon_c = \frac{48\delta_c MC}{Pb(3L^2 - 4b^2)}$$ ----------4

Where :-

M=Applied bending moment

$\delta =$ Observed deflection at the center of the beam which can be obtained directly
from the dial gauges fixed at top and bottom of the beam .
P=Applied load

L=Length of the beam

d=Depth of beam

b=Width of the beam

C=d/2

Results and Discussions

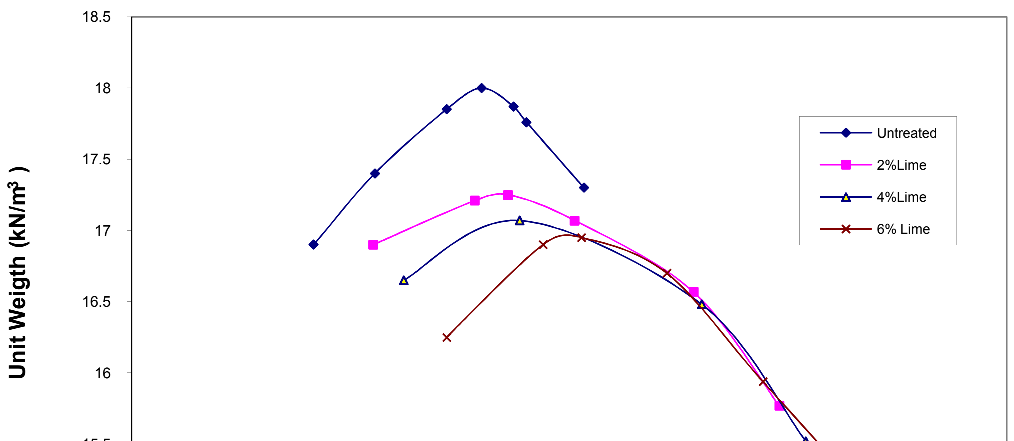
The compaction characteristics of untreated and the treated soil with different percentage of lime is shown in Fig.(2). The maximum dry unit weight decreases with the addition of lime and the optimum water content increases. This behavior of the lime treated soils have been reported by several investigators and is due to agglomeration of soil particles and the affinity of lime to water [2,13,14].

The results of the tensile and compressive strength of the compacted specimens, at the optimum water content, are presented in Table (3) and in Figures (3 and 4).

Table (3) Results of Tensile Strength and Compressive Strength for Untreated and Stabilized Soil

Lime (%)	Curing Time (days)	Tensile Strength σ_t (kPa)	Compressive Strength σ_c (kPa)	Tens. Strength/ Comp. Strength σ_t/σ_c(%)
0*	/	180	1200	15
2*	7	218	1510	14.5
	30	233	1980	11.8
4*	7	430	1840	23.4
	30	504	2980	16.9
6*	7	328	1400	23.4
	30	560	3480	16.1

* The results are the average of at least two tests.



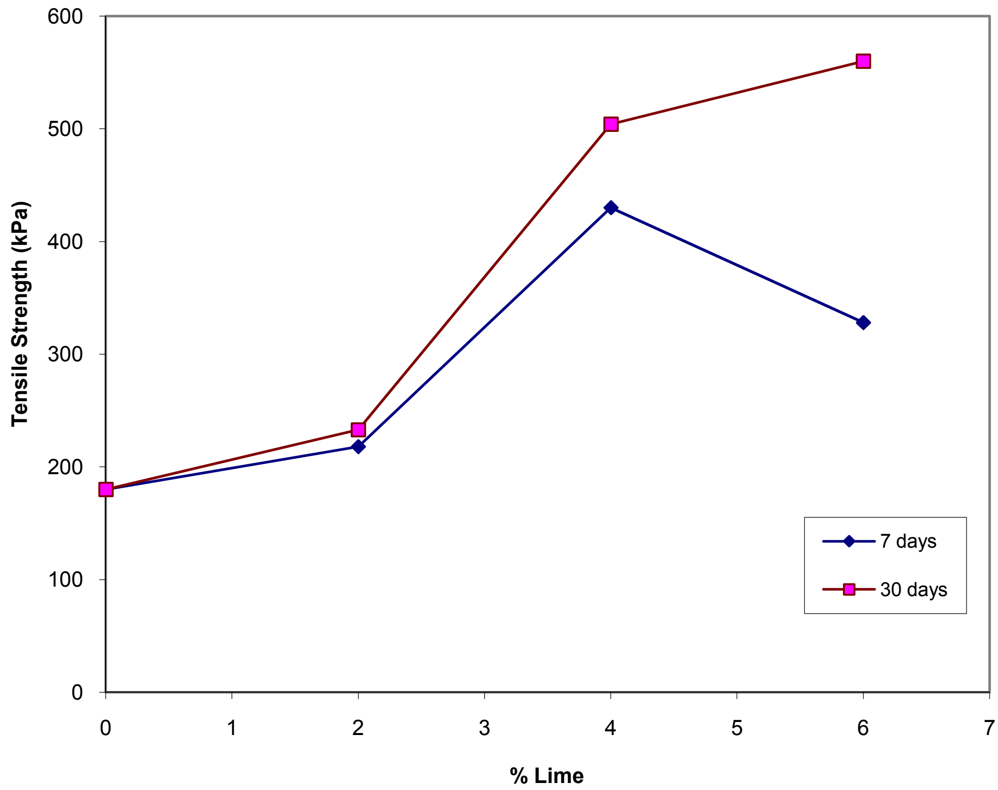


Fig.(3) Effect of Lime on Tensile Strength

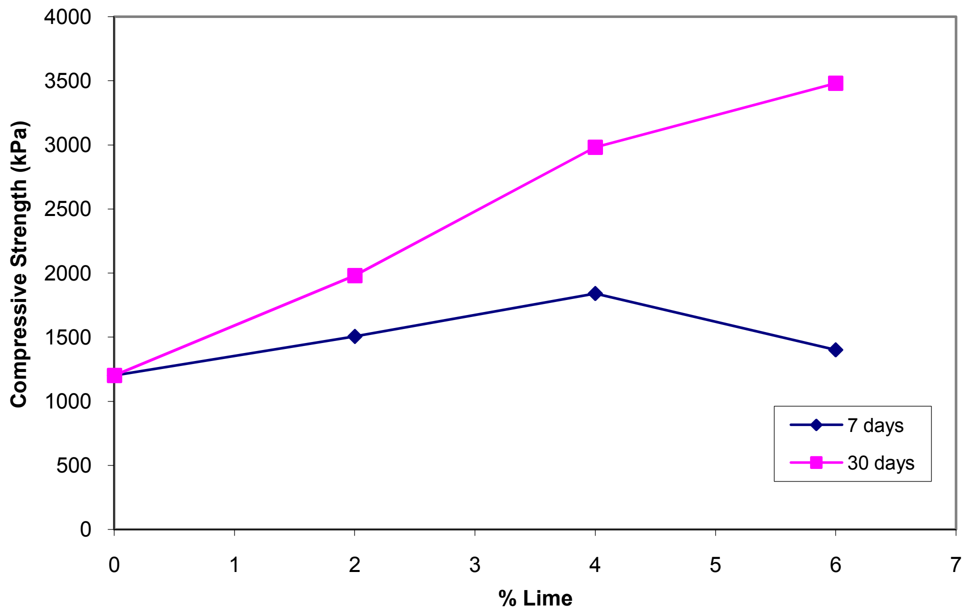


Fig.(4) Effect of Lime on the Compressive Strength

The tensile strength of the untreated soil is 180 kPa. When 2% and 4% of lime was used and the specimens cured for 7 days, the tensile strength increased to 218 and 430 kpa respectively, then decreased to 328 kpa at 6% lime.

On the other hand, when the soil cured for 30 days, the tensile strength increased to 233, 504 and 560 kPa when 2, 4, and 6 % lime was used respectively.

The increase in the tensile strength with the increase of the percentages of lime is due to the reaction between lime and clay which is a function of the amount of lime, type of the clay minerals and curing conditions.

The reduction in tensile strength when the soil is treated with 6% lime and cured for 7 days is due to the extra lime which acts as a fill material with the short curing period .This extra lime is the result of uncompleted reaction in 7 days between lime and clay minerals .Similar behavior was found in compressive strength with the same percentage of lime [Table (3) and fig.(4)].

The effect of lime on the tensile strength (σ_t) and compressive strength (σ_c) can be visualized by considering the ratio (σ_t/ σ_c) as shown in table (3). For untreated soil the ratio is 15%. When the lime is added and the specimens cured for 7 days the ratio become 14.5, 23.4 and 23.4% for 2, 4 and 6% of lime respectively. This means that the relative increment of increase in compressive strength is more than that in tensile strength for 2% lime, while for 4 and 6 % lime the relative increment in tensile strength is more than that in compressive strength. The same behavior in the ratio (σ_t/σ_c) was found for the specimens cured for 30 days.

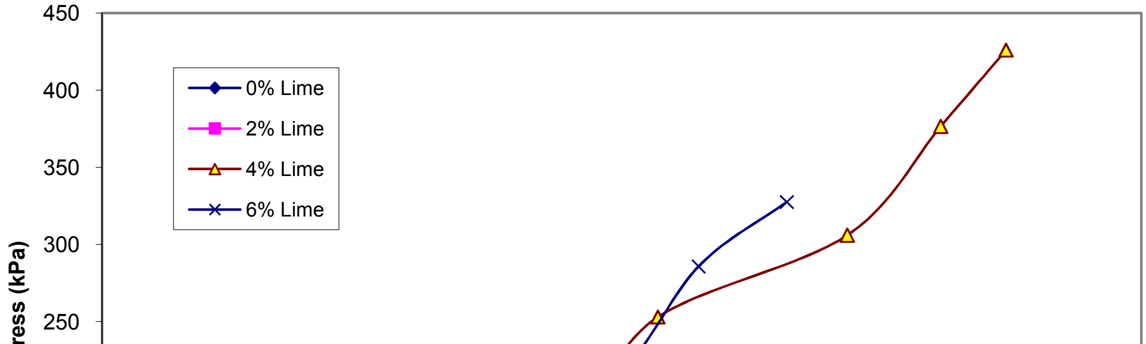
The percent of increase in tensile strength and compressive strength with respect to untreated soil are shown in table (4). This table shows that the tensile strength is generally more sensitive to the lime than the compressive strength.

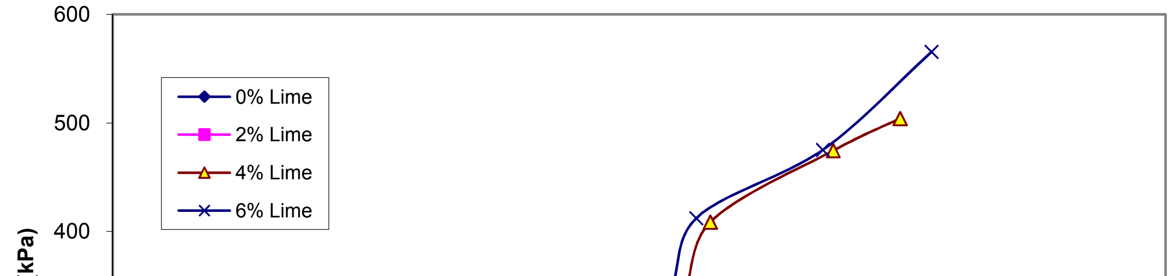
Table (4) Increasing Percentage of Tensile Strength and Compressive Strength of Stabilized Soil under Different Condition

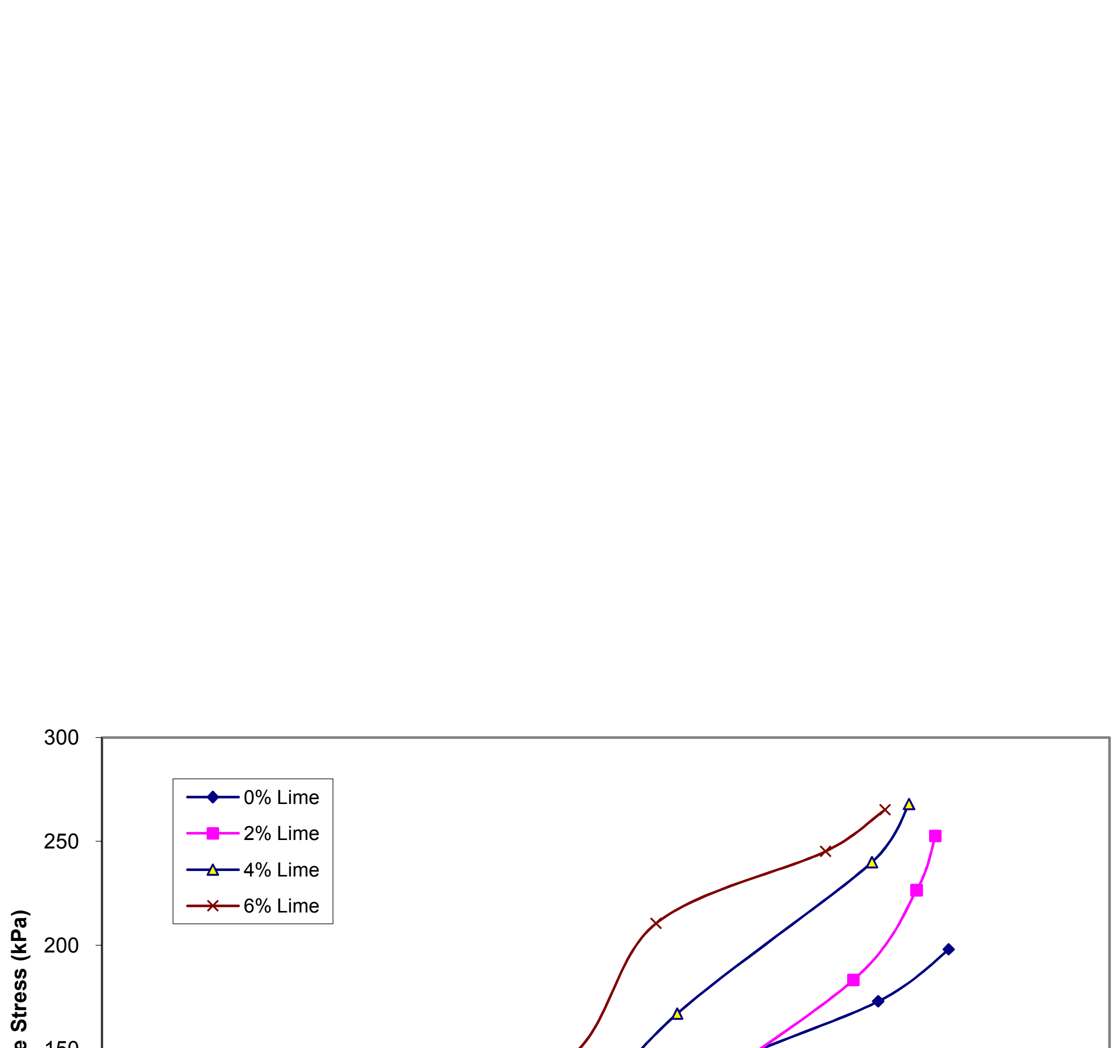
Lime (%)	Curing Time (days)	Tensile strength (Kpa)	Increasing of Tensile Strength %	Compressive Strength (Kpa)	Increasing of Compressive Strength %
0*	/	180		1200	
2*	7	218	21	1510	25
	30	233	29	1980	65
4*	7	430	138	1840	53
	30	504	180	2980	148
6*	7	328	82	1400	16
	30	560	211	3480	190

* The results are the average of at least two tests

The tensile and compressive stress that occurred at bottom and top of the beam respectively during the flexural tension tests are calculated using equation 1 and 2. These values are used to draw the stress-strain curve for both the untreated and lime stabilized specimens as shown in Figs.(5 and 6). In general the curves of stabilized specimens are irregular in their shape, such relations were observed by Ajaz and Parry [7] for compacted clay and Jaro [8] for sub base material stabilized by cement. It is believed that such irregularities in the stress-strain curves are due to progressive type of failure which took place during the test or due to non uniform distribution of lime in the specimens .All the specimens showed sudden type of failure.




600
500
400
(kPa)
0% Lime
2% Lime
4% Lime
6% Lime


300
250
200
0% Lime
2% Lime
4% Lime
6% Lime
e Stress (kPa)

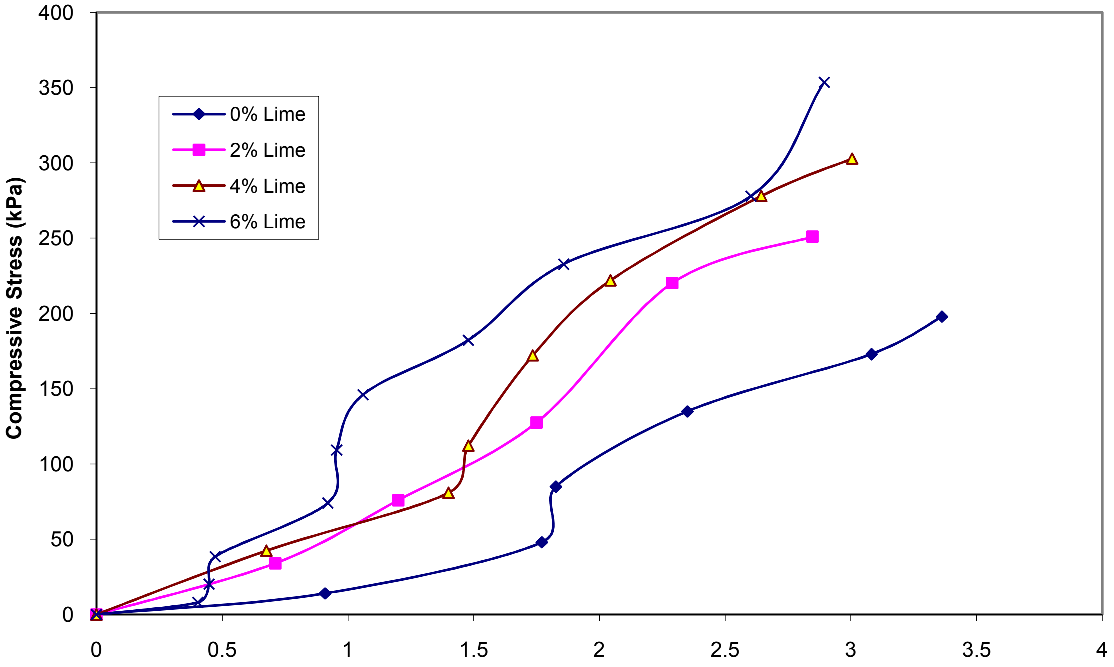


Fig.(6-b) Compressive Stress-Strain Curves of Stabilized Soil for (Curing Time 30 days)

Conclusions

The following conclusions can be drawn from this study:

1. The tensile strength increases with the addition of lime. The increments of increasing ranged from 21 to 211 percents, while the increments in the compressive strength range from 16 to190 percent.
2. Increasing the curing time improves the compressive strength more than the tensile strength.
3. The tensile stress-strain curves of stabilized specimens have irregular shape when direct method of analysis is used .In general The curves became more irregular when the percent of lime increased .

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