ISSN 1991- 8690 الترقيم الدولي ٨٦٩٠ - ١٩٩١
Website: http://jsci.utq.edu.iq Email: utjsci@utq.edu.iq

Shear Strength characteristics of gypseous Soil with Lime

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ABSTRACT

Gypseous soils are abundant in Iraq, constitute over 33% of total surface area in Iraq. The structures that founded on these soils could face large damages due to dissolving of gypsum when saturated in water.This study investigates the shear strength characteristics of gypseous soil with lime. The soil used was fetched from Al-Dour region (66% gypsum content). This soil was treated with different percentages of Lime (0.5, 1.5, 2.5 and 5%). Test results pointed out that the best treatment percentage to be 1.5.shear strength tests (direct shear tests) conducted in order to study the shear strength characteristics of gypseous soil with Lime and to find the suitable percentage of Lime to improve the shear strength characteristics of gypseous soil against the effect of soaking water, in order to attain a sort of simulation with the field conditions; both the unit weight and the water content of the natural soil are kept equal to the field values. All treated specimens were cured at 37^0C for 7 days before performing these tests.

The results of shear strength tests show that the addition of Lime to the gypseous soil increases their strength to an optimum value and then decreases.

Introduction

Many problems relating to construction on gypseous soils were observed. There are three main sources of these problems: firstly, the dissolution and transport of gypsum through soil profile, causes a continuous loss of soil mass and increasing voids, a large reduction in shear strength and an increase in compressibility are the main results of this phenomenon, secondly the variation of shear strength and compressibility characteristics of gypseous soils upon wetting to saturation, thirdly the volume change accompanying the dehydration of gypsum or hydration of anhydrite. In the first case, a volume decrease of approximately 39% was expected, while in the second case, a volume increased by 63%, **Ismail (1994)**.

This behavior caused wide damages in roads, canals, buildings and dams, which are constructed, on or in gypseous soils. Hence when gypseous soils are exposed to water, especially to moving water, it would be expected to have a severe damage and may face a real disaster.

"When soil is loaded, shearing stresses are induced in it. When the shearing stresses reach a limiting value, shear deformation takes place, leading to the failure of the soil mass; therefore, it can be defined as the resistance to deformation by continuous shear displacement of soil particles or on masses upon the action of a shear stress", **Pumia (1988).**

The shearing resistance of a soil is constituted basically of the following components.

1. The structure resistance to displacement of the soil because of the packing of the particles.
2. The fractional resistance to translocation between the individual soil particles at their contact points, and
3. Cohesion or adhesion between the surfaces of the soil particles .The shear strength in cohesionless soil results from inters granular friction alone, while all other soils it results both from internal friction as well as cohesion. However, plastic undrained clay does not pass internal friction.

Petrukhin and Arakelyan (1985) studied the behavior of two different natural gypseous, clayey and sandy silt soils.

The initial gypsum content of both soils is varied from several percent to fifty percent. For gypseous clayey soils, the cohesion intercept, **c** increases with the increasing gypsum content until gypsum content reaches to 15% then decreases, while the angle of friction, increases with the increase of the gypsum content until gypsum content reaches to 20% then decreases. For gypseous sand silty soils, the angle of friction, ø, increases with increasing of gypsum content until gypsum content reaches to 25% then decreased, while the cohesion intercept decreases with the increasing of gypsum content until gypsum reaches to 35%, then increases markedly.

Ramiah (1982) studied the effected of adding different gypsum content on shear strength of Baghdad silty clay soil. Unconfined compression test for remolded specimens of (3, 14, 28, and 56 days) duration, with and without gypsum, soaked and unsoaked revealed that the strength versus time exhibited cyclic behavior and the peak strength occurred after a period of 20 or 30 days of preparing specimens, also with addition of gypsum (3%, 6%, and 10%) the unsoaked compacted specimens showed an increase in strength (qu), while soaked specimens exhibited lower strength increase.

Subhi (1987) studied the effect of gypsum content on the unconfined compression strength of the remolded Baghdad soil. Specimens were compacted at their modified AASHTO optimum moisture content using various levels of gypsum content. She noticed a considerable increase in the strength of the soil with increase of gypsum content.

Seleam (1988) also concluded that the strength parameters increased with the increasing in gypsum content, when she studied the shear strength of gypsiferous sandy soil, gypsum content ranging between (26-80%). The high value of the cohesion (**c**) was related to the effect of gypsum cementation between soil particles.

Mikeev and et. al. (1973) reported that the experiments for determining the soil strength under field conditions revealed that the initial value of the angle of internal friction ($ø = 37^\circ$) and initial value of cohesion (**c** = 0.99 kg/cm^2) of a loam with 20% gypsum content were reduced to ($ø = 31^\circ$) and (**c** = 0.99 kg/cm^2) after 30 days of wetting.

Sirwan and et. al. (1989) selected a site 150 km north of Baghdad, triaxial tests, penetration tests, and plate bearing tests were established at different moisture contents, by which they concluded that the angle of internal friction of dry gypsiferous soil was $(40)^0$ dropping upon wetting to $(29)^0$.

Diefenthal and et.al. (1980) studied the effects of stress history and relative density on the short term strength and stiffness of a granular soil that was chemically stabilized with a sodium silicate grout. They found that the strength of a grouted specimen under a confining stress is a function of relative density they found little difference in the mechanical behavior between grouted specimens under confining stress and under confine stress and under at rest conditions the angle of internal friction of grouted specimens because of an increase in the cohesion and the initial tangent modulus of grouted specimens similar to that of dense ungrouted specimens.

Borchert and Kirchenbarer (1983) studied chemically stabilized soil using silicate gel. They observed that Young's modulus for compression was up to one third greater than that for tension.

Abood (1994) concluded that the value of **c** and of the treated soil with sodium silicate is more than the natural untreated soil.

This fact necessitates the search for a method of treatment to gypseous soils.

Soil treatment with lime is one of the oldest techniques used to improve the engineering properties of soils.

Lime can be used to treat soils in order to improve their workability and load – bearing characteristics in a number of situations. Lime is frequently used to dry wet soils at construction sites and elsewhere reducing downtime and providing an improved working surface. An even more significant use of lime is in the modification and stabilization of soil beneath road and similar construction projects. Use of lime can substantially increase the stability impermeability and load – bearing capacity of the subgrade. Both Lime and hydrated lime may be used for this purpose.

Treatment by using lime is suitable for Iraqi condition due to the following reasons:

-Hot weather in Iraq during most of the year which accelerates gain in strength of soil – lime mixture.

-Lime is locally manufactured in Iraq and it is less expensive than cement.

-Adaptability of soil – lime to delay compaction.

The increase in strength of clayey soils is normally expected as a result of lime treatment unless the pozzolanic reactions are halted for some reason. Several authors supported this. Additional increase in strength was found if the lime treatment is helped by the addition of a small proportion of gypsum, Holm et.al. (1983) and Kujala and Nieminen (1983).

Thompson (1966) explains that the main effect of lime on the shear strength of a fine-grained soil is producing a substantial increase in cohesion with some minor increase in the angle of internal friction. He found this to be a result of the cementation action of the pozzolanic reactions.

Thompson (1966) studied the effect of lime on the modulus of elasticity of four typical Illinois soils. He found that the modulus of elasticity, "E", of the lime-soil mixture were much greater than the "E" of the untreated soils. He mentioned that the modular ratios, E lime +soil/ E soil were from 3 to 25 folds. These results coincided with the result reported by Abdel-Kader and Hamadani (1989).

George (1987) found that the secant modulus of elasticity (Es) increases with the increase in curing age and temperature. The increase shows similar patterns to that of unconfined compressive strength. He found that the optimum lime content, which gives maximum Es, is equal to that giving unconfined compressive strength at all curing temperatures used in this study.

Materials Methods

The natural gypseous soils are used in the present study was brought from Al-Dour (150km North West of Baghdad).

Disturbed samples were taken from (1-1.5) m below the natural ground surface, taken packed in double nylon bags and transported to the soil mechanics laboratory, University of Technology.

The index properties of the soils are presented in Table (1).

Table (1) Results of Physical Tests

Soil Properties	Al-Dour Soil
Specific Gravity (G.S)	2.39
Liquid limit (L.L)%	30
Plastic limit (P.L)%	24
Plasticity index (P.I)%	6
Gravel Fraction %	0
Sand Fraction %	65.09
Silt Fraction %	34.91
Clay Fraction %	0
Unified Soil Classification System	SM
Field density (gm/cm^3)	1.4
Initial moisture content %	10
Maximum dry density (gm/cm^3)	17.4
Optimum moisture content	14

Lime CaO was used in this study. It was manufacture by the Kerbala lime factory. The chemical composition and other properties of the lime were determined and the results are shown in Table (2).

Table (2) Chemical and Physical Analysis of the Lime

The composition	CaO	MgO	SiO2	Combined oxide 100% passing No. 12
%	96.11	1.39	1.82	0.68

The specific gravity tests were conducted following the procedure of **ASTM designated as D854-58**, except that kerosene was used instead of distilled water as recommended by **U.S. Army Engineer water ways Experiments station (1980)**, due to the solubility of gypsum in water.

The liquid limit and plastic limit tests were performed on the untreated and treated soils following the procedure **ASTM designated as D423-66 and D427-61 respectively.**

The grain size distribution was performed according to **ASTM D422-79**, the natural soils were wet sieved through a No. 200 (0.074mm) sieve, and the sample was oven dried at 45 ºC. then sieve analysis was carried out by a set of sieving. The amount that passing sieve No. 200 was analyzed by the standard hydrometer method.

This test was performed according to **ASTM D1556-82** to find field soil density of the soil in the field by the sand cone method. This test was repeated for two times in the pit, which the soil was brought from locations.

This test was performed according to **ASTM D2216-80**. The moisture content was determined at dry temperature between (40-60)ºC to prevent any loss of crystal water above this temperature.

Several chemical tests were performed according to the recommended specifications of the Geological Surrey and Mining Company (Iraqi) for dissolved salts in the soil). Table (3) shows the results of these tests.

Table (3) Chemical Analysis Of The Natural Soil

Constituent	SiO%	$Fe2O_3$ %	$Al2O_3$%	CaO %	MgO %	SO_3 %	Na_2O %	K_2O %	G.C %	pH
Al-Dour Soil	16.94	1.51	3.02	26.36	1.44	30.85	0.5	0.52	66	9

An air-dried pulverized and homogenous soil was used. The required percentage of Lime, expressed as a percentage of total dry weight of soil was added to the dry soil and mixed by hand to insure a uniform distribution of the Lime. The required amount of water was added at room temperature in a slow stream and thoroughly mixed by hand until the water dispersed through the mixture. Then the moist mixture was placed in the closed container for one hour before the compaction process (for curing), **Mitchell and Hooper (1961)**.

The soil mixture was prepared, the oven dry temperature was kept with (45) ºC due to the dehydration of gypsum.

Direct shear test were conducted according to **ASTM (3080-72), (Head (1982) vol.2).**

Using specimens prepared in molds of 60X60X20(mm) thick. All specimens were prepared by pouring the soil inside the mold in layers and compacted by tamping rod to the required field density. Then the treated specimens were weighed wrapped and cured at 37ºC for 7 days.

At the end of curing, the shear test was conducted for treated and untreated specimens in dry condition and soaking condition after 24 hr. the rate of strain were (0.6 mm/min).

Results and Discussion

This study was carried out on soil from Al-Dour region, with gypsum content namely 65 percent. Al-Dour soil was blended in varying percents with Lime, where the Lime was added at several ratios which were (0.5%, 1.5%, 2.5%, and 5%). The samples were oven dried at (40-45 0C) before blending with the specified percents of Lime.

properties are discussed in the following paragraphs:

Direct Shear Test

To study the effect of Lime on shear strength and shear strength parameter, C and ø, at field density and field moisture content, a consolidation drained direct shear test was performed on natural and Lime-treated soil samples.

The first set of tests was conducted without soaking for untreated and treated soil with (0.5, 1.5%, 2.5, and 5%) Lime content for soil. The second set of tests was conducted on untreated and treated soil with soaking in water. Summary of the test results is given in Table (4).

Results of direct shear test conducted on samples are shown in Figures (1) to (10). The shear stress and vertical displacement versus horizontal displacement were plotted for each test, in addition a figure between the maximum shear stress versus normal stress was drawn and the shear strength parameters, the angle of internal friction (ø) and cohesion (C) were calculated.

For untreated soil, the results of specimens for unsoaked and soaked in water are showing in Figures (1) and (2). The engineering properties and the effect of the addition of Lime on these water are showing in Figures (1) and (2). It can be seen that the behavior of stress-strain relationship is not show clear peak, so the tests continued until the sample reached 20% strain.

For treated soil, the soil exhibited similar behavior of all unsoaking and soaked specimens. It can be observed that the soil showed a clear peak value of shear stress at each normal stress, see Figures (3) to (10).

Figure (11) shows the relation between (C) and (ø) with the Lime content respectively for soaked and unsoaked condition. For unsoaked and soaked in water it can be observed that (C) increased as the Lime content increased to an optimum value and then decreased. The angle (ø) was increased with addition of Lime. However, the increments flocculated with the addition of different percentage of Lime. This behavior was probably due to complicated responds of soil to Lime which took place and resulted in flocculation, agglomeration and pozzolanic reaction.

Table (4) Results of Direct Shear tests

	Without Soaking				Soaking in Water		
Lime content %	Normal Stress kPa	τ max kPa	C kPa	ϕ deg	τ max kPa	C kPa	ϕ deg
0	100	98.16	14.67	38.91	65.61	6.30	29.60
	200	172.00			116.75		
	400	339.00			235.29		
0.5	100	108.31	21.925	39.3	87.49	19.10	31.70
	200	174.89			133.31		
	400	307.48			270.03		
1.5	100	179.00	91.47	40.80	146.65	84.50	37.00
	200	262.42			255.86		
	400	437.41			380.14		
2.5	100	158.92	68.54	41.20	133.38	61.80	38.33
	200	239.30			231.24		
	400	420.00			374.37		
5	100	132.00	45.40	41.89	115.46	36.20	39.20
	200	229.57			202.31		
	400	402.81			361.17		

Conclusions

1. The presence of gypsum causes strength increase due to ettringite ($3CaO.Al_2O_3.3CaSO_4.32H_2O$) formation, particularly with Lime.
2. When considering direct shear tests, the following were observed:

I. For treated soil, the soil exhibited similar behavior of all unsoaking and soaked specimens. It can be observed that the soil showed a clear peak value of shear stress at each normal stress, while the untreated soil is not show clear peak, so the tests continued until the sample reached 20% strain.

II. For unsoaked and soaked in water it can be observed that the cohesion (C) increased as the Lime content increased to an optimum value and then decreased. The angle of internal friction (ø) was increased with addition of Lime.

3. The following conclusions can be drawn based on the results of this study:
The gypseous soils can be successfully treated with Lime for ***Improvement of Gypseous Soils below Foundations of buildings***. The treatment percentage is 1.5 percent for Al-Dour soil (65% gypsum).

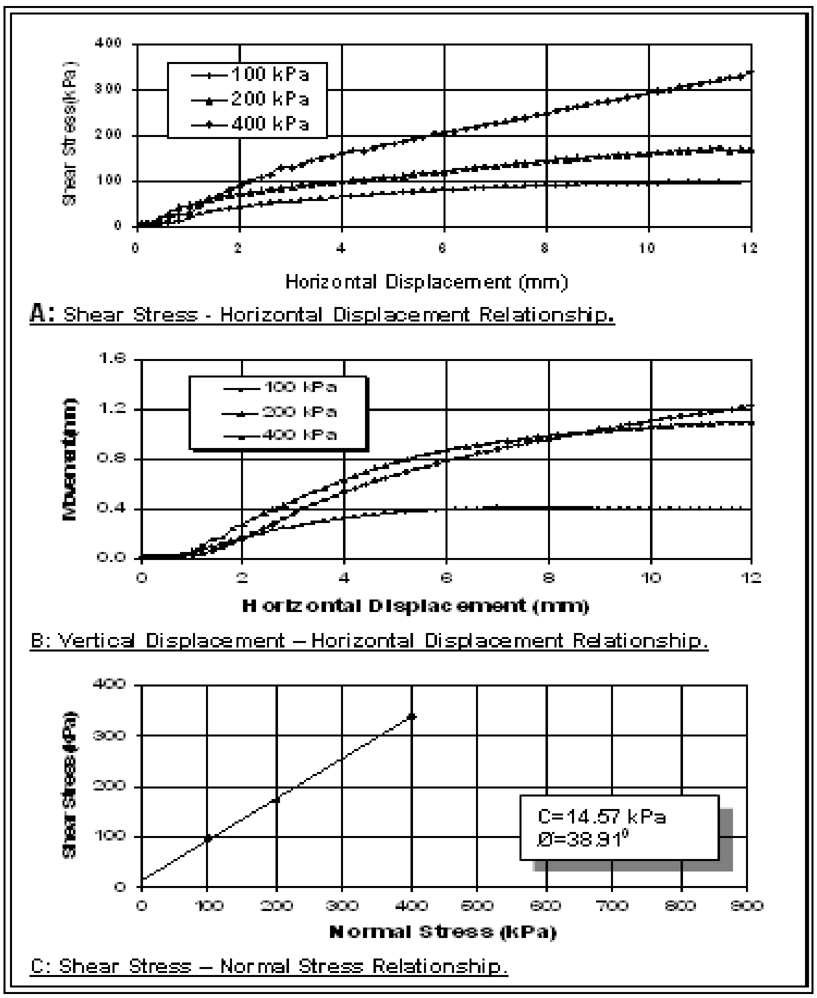

Figure (1) Direct Shear Results for Soil (untreated, without soaking)

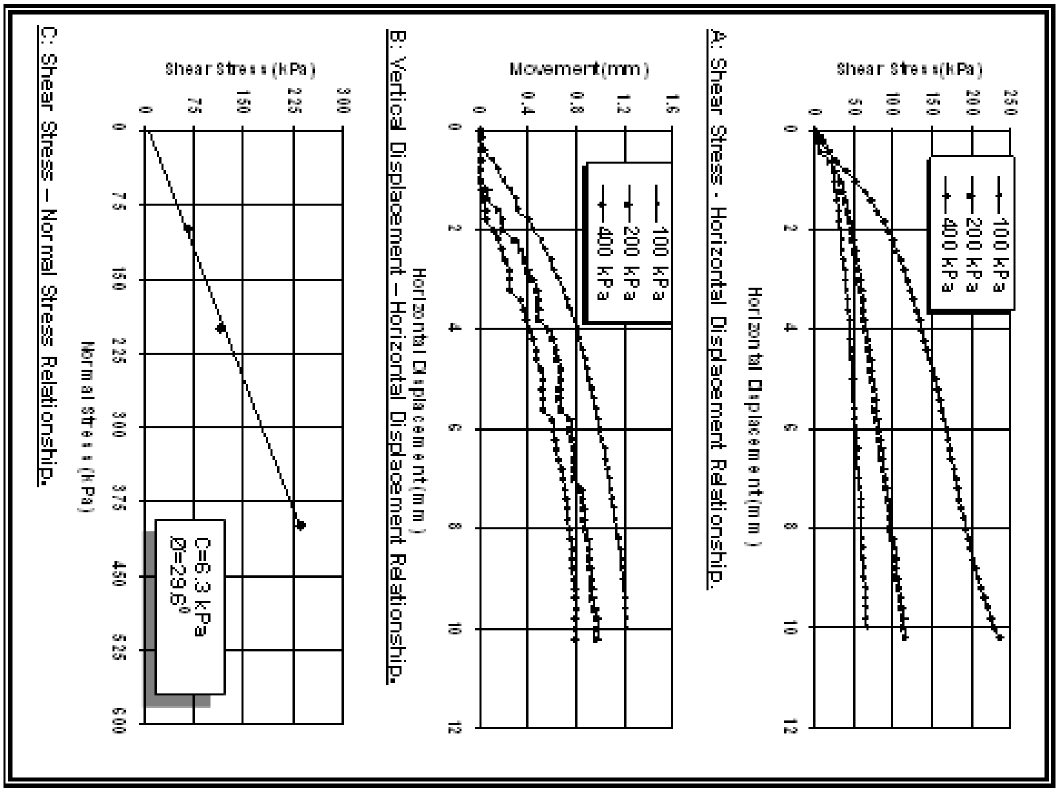

Figure (2) Direct Shear Results for Soil (untreated, with soaking)

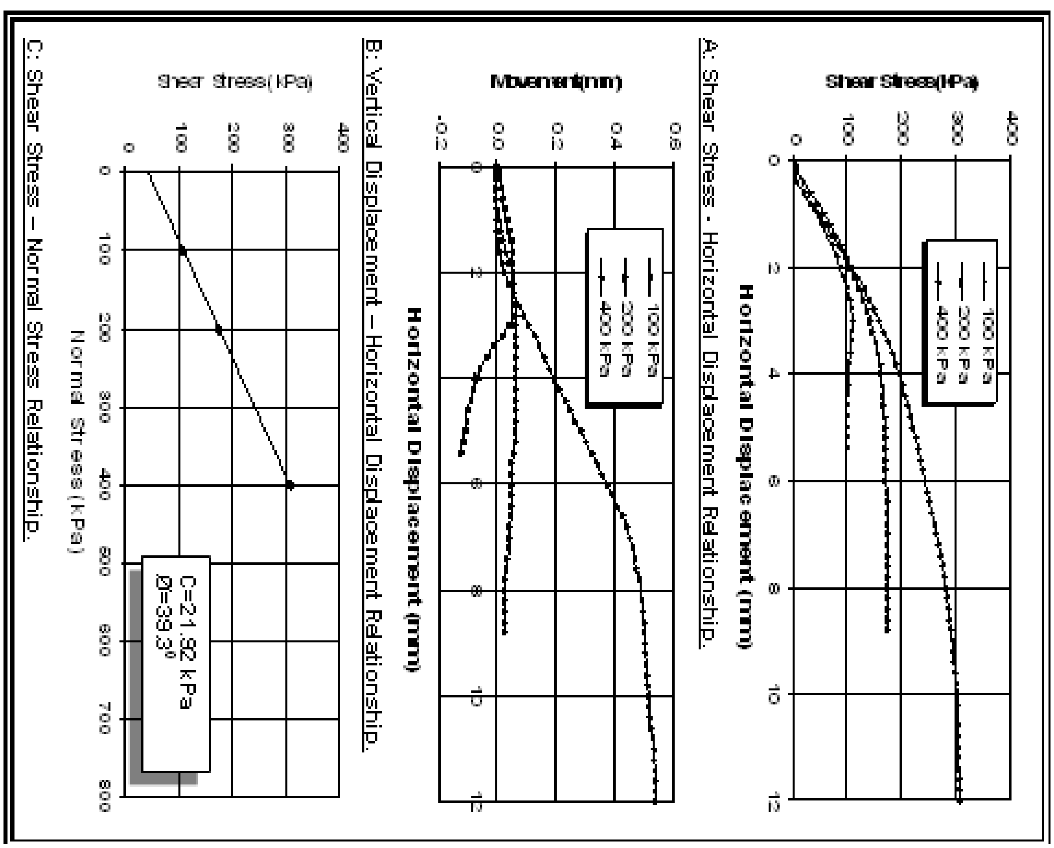

Figure (3) Direct Shear Results for Soil (treated with (0.5% L), without soaking)

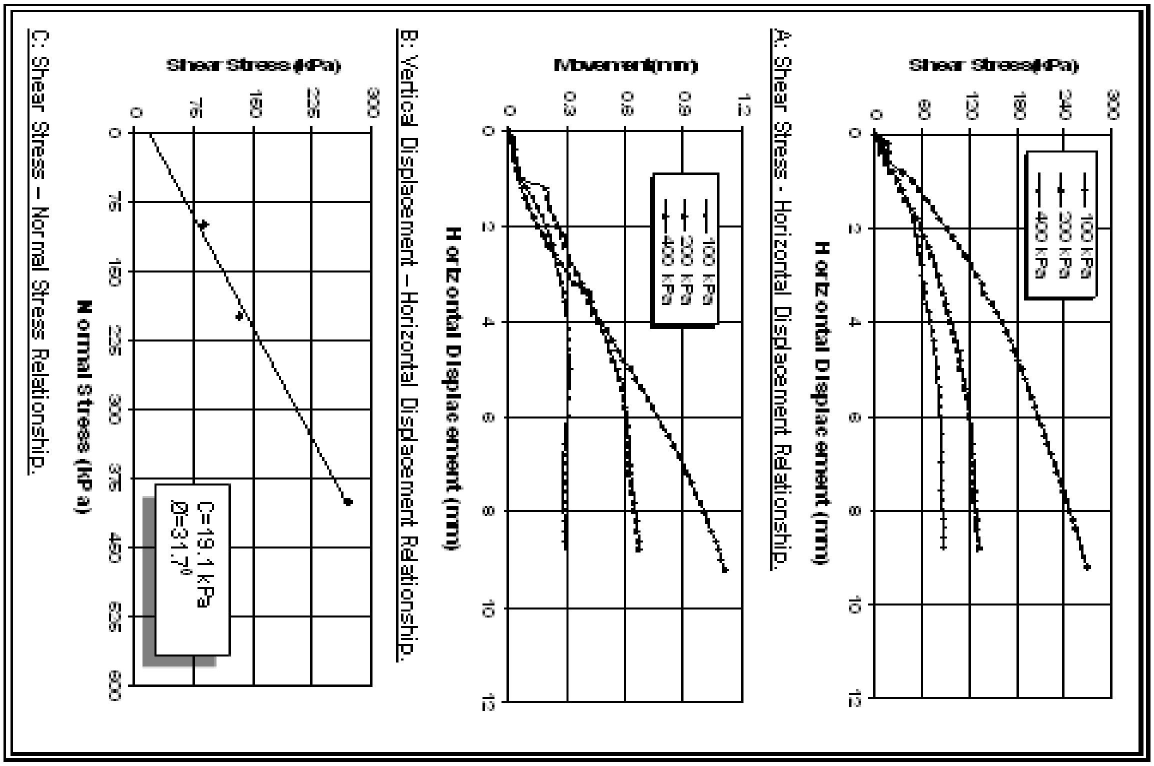

Figure (4) Direct Shear Results for Soil (treated with (0.5% L), with soaking)

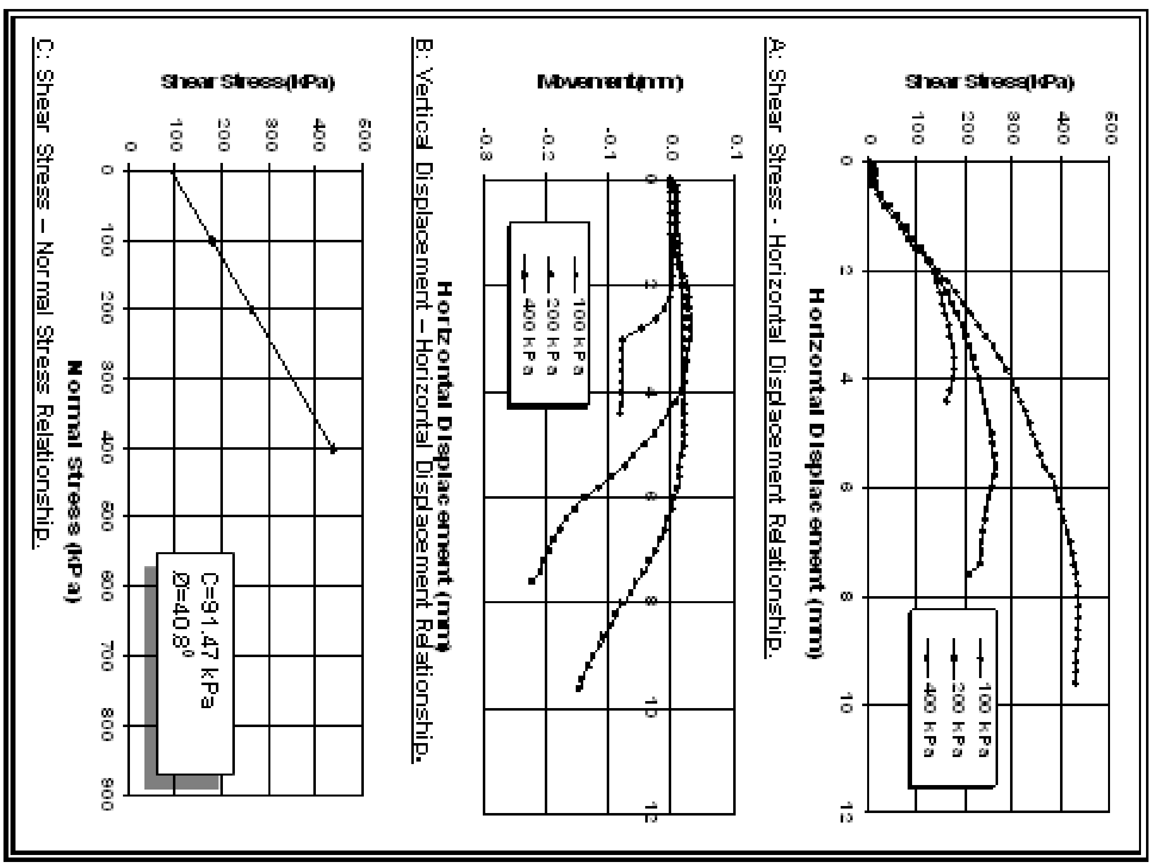

Figure (5) Direct Shear Results for Soil (treated with (1.5% L), without soaking)

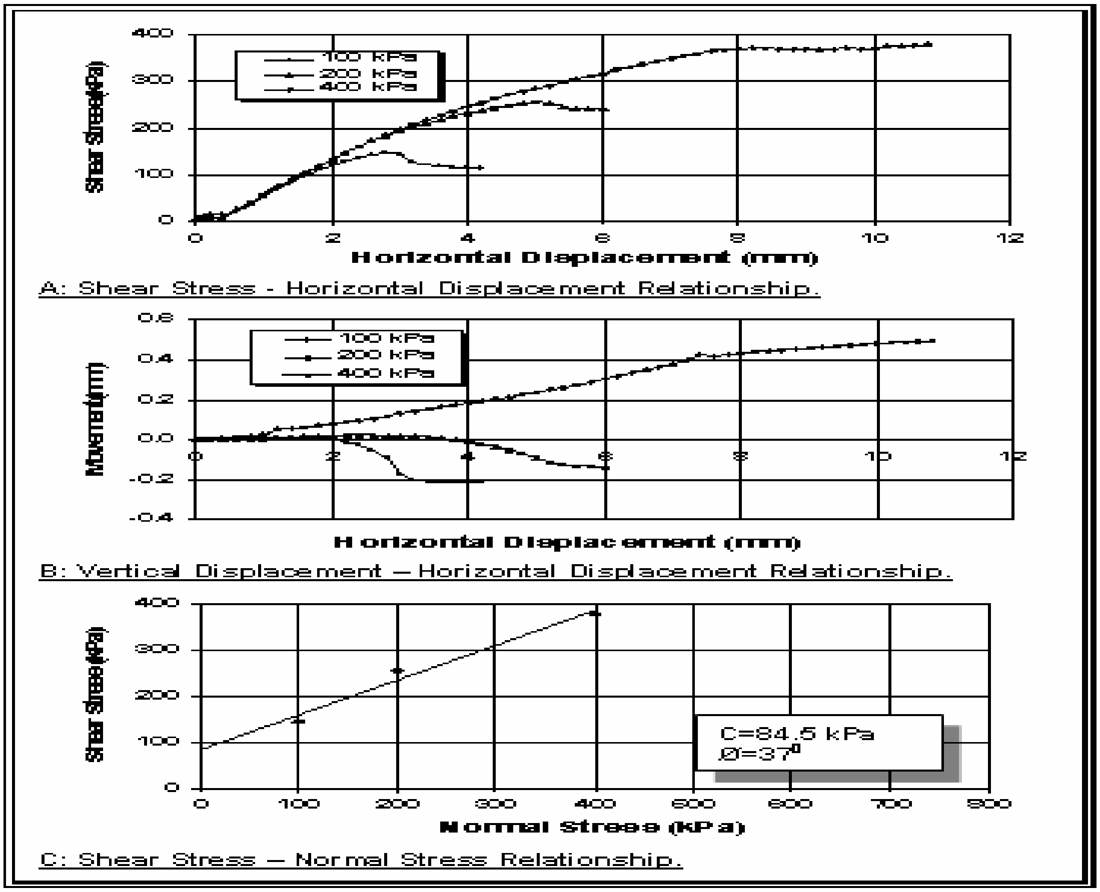

Figure (6) Direct Shear Results for Soil (treated with (1.5% L), with soaking)

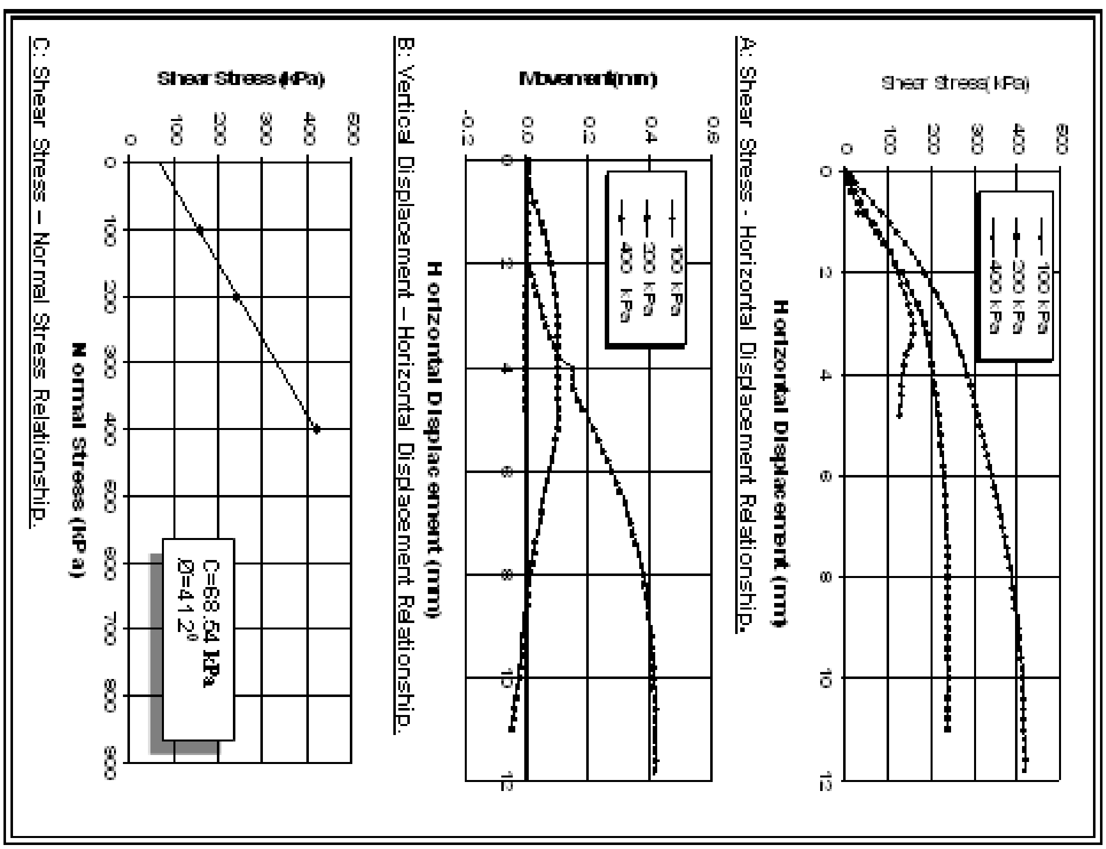

Figure (7) Direct Shear Results for Soil (treated with (2.5% L), without soaking)

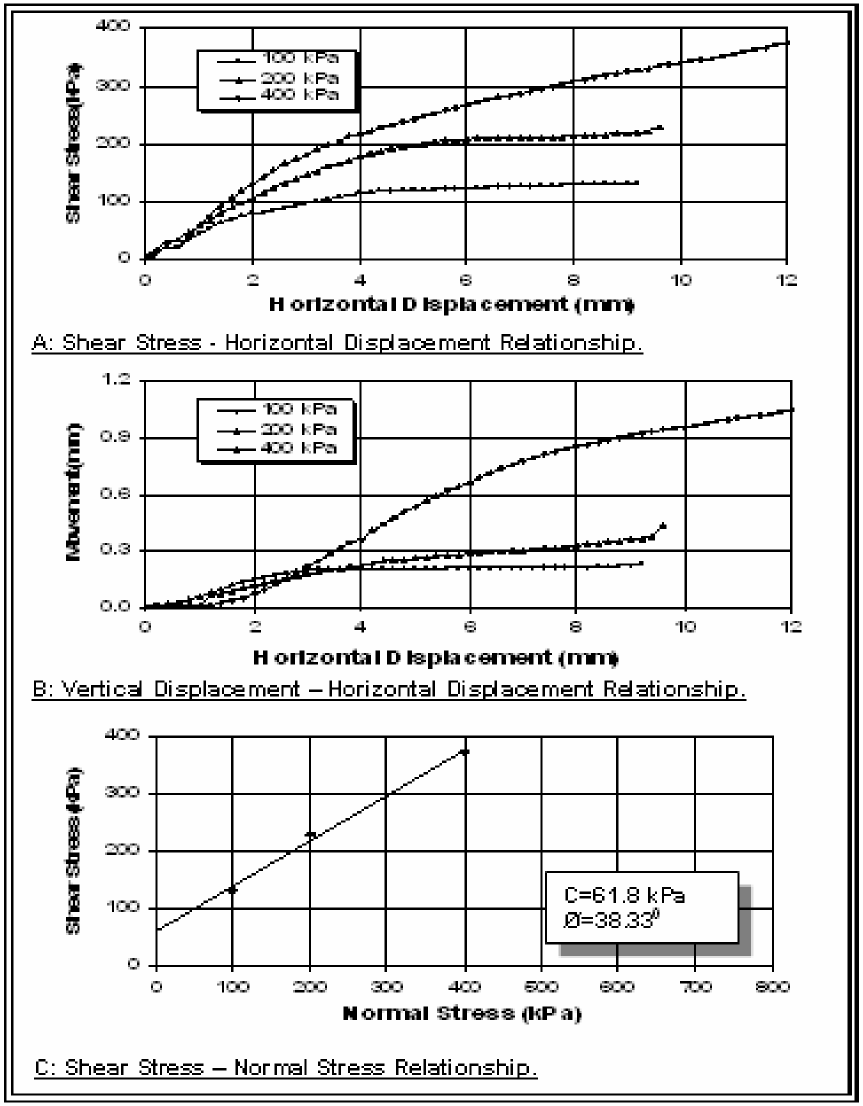

Figure (8) Direct Shear Results for Soil (treated with (2.5% L), with soaking)

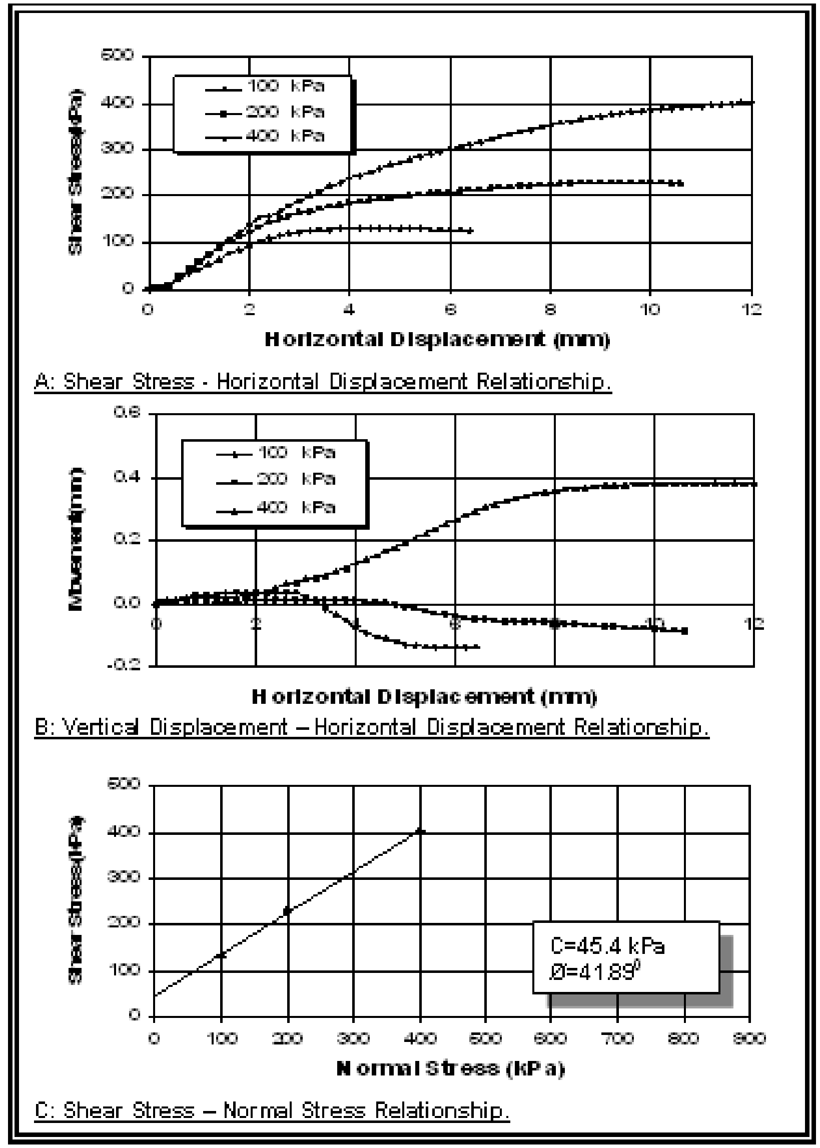

Figure (9) Direct Shear Results for Soil (treated with (5% L), without soaking)

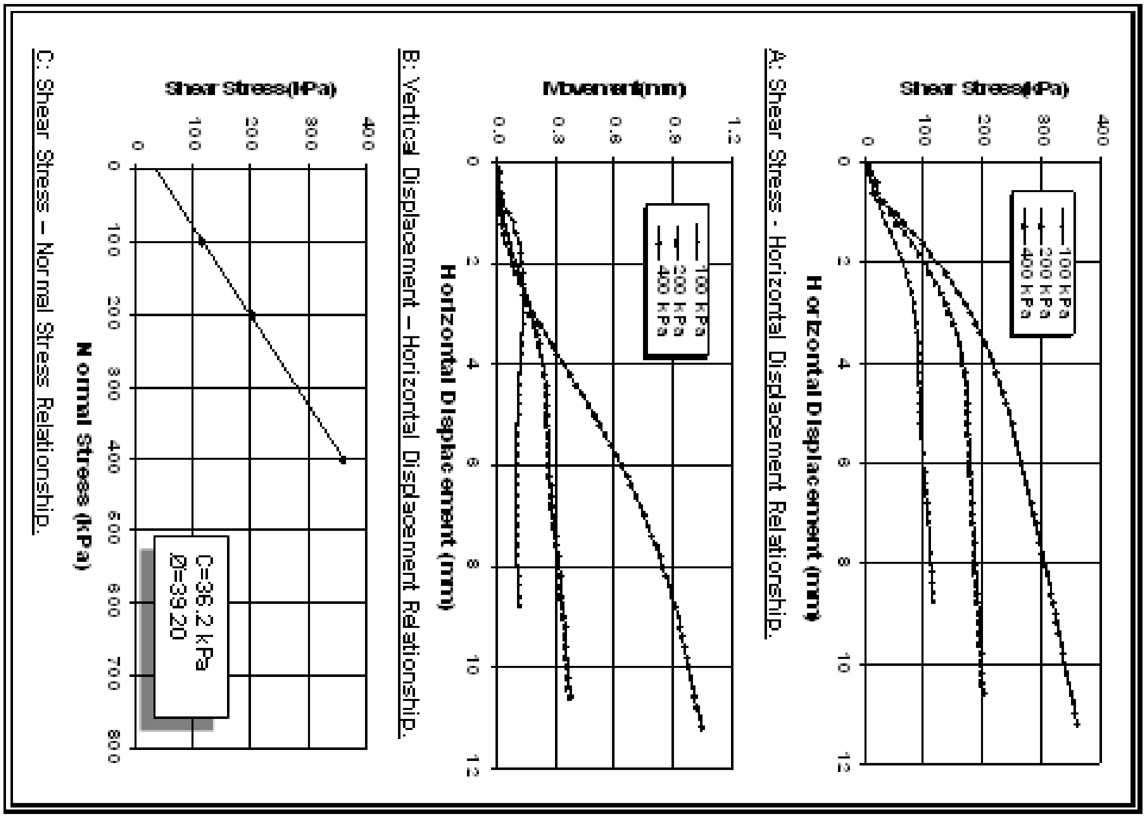

Figure (10) Direct Shear Results for Soil (treated with (5% L), with soaking)

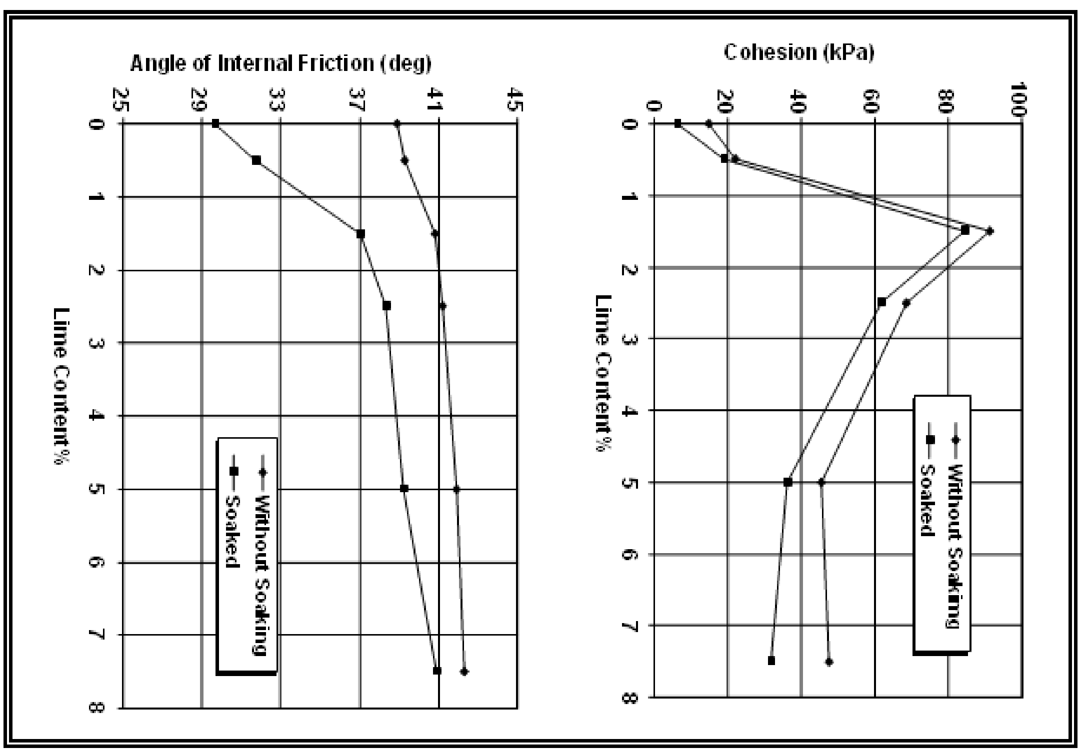

Figure (11) Effect of Lime Content on Cohesion and Angle of Internal Friction for Soil

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خصائص مقاومة القص للتربة الجبسية والنورة

طالب كامل قاسم الشكيري

كلية الزراعة - جامعة المثنى

الخلاصة

الترب الجبسية غزيرة في العراق وتشكل اكثرمن٣٣% من مساحة القطر.ولقد لوحظ حصول عدد من المشاكل الهندسية للمنشأت المقامة على هذه التربة وخاصة عند تعرضها للماء الذي يسبب انهيار التربة نتيجة لغسل الاملاح منها.تبحث هذه الدراسة في خصائص مقاومة القص للتربة الجبسية والنورة . حيث تم اختيار تربة جبسية من منطقة الدور (محتوى الجبس 66 %).وقد تم إضافة نسب مختلفة من النورة إلى هذه التربة (0.5, 1.5, 2.5 and 5%),وقد وجد إن هذه التربة لها قابلية كبيرة في التفاعل مع النورة وان أفضل نسبة للمعالجة هي 1.5 . فحوصات القص(فحص القص المباشر) جرت لدراسة خصائص مقاومة القص للتربة الجبسية والنورة و لإيجاد نسبة النورة الملائمة لتحسين خصائص مقاومة القص للتربة الجبسية لمقاومة تأثير غمر التربة بالماء. وللاقتراب أكثر من حالة التربة في الحقل،أستخدم كل من الكثافة و المحتوى المائي الحقليين للتربة. تركت جميع النماذج بدرجة حرارة 37 مئوية ولمدة سبعة أيام قبل أنجاز هذه الفحوصات.نتائج فحوصات مقاومة القص، بينت أن إضافة النورة للتربة الجبسية يزيد من مقاومتها للقص حتى نسبة المعالجة وبعدها تقل المقاومة.