

The Use Of Liquid Asphalt To Improve Gypseous Soils

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Abstract

This work aimed to study the effectiveness of liquid asphalt in the enhancement of gypseous soils properties. This enhancement is by reducing the effect of water on gypsum particles and increasing strength parameters.

The work included two types of treatments firstly is by mixing technique and the second type is by grouting technique.

The testing program included the determination of unconfined compressive strength, shear strength and collapsibility parameters of untreated and treated gypseous soil with different percent of liquid asphalt.

The test results showed that the maximum unconfined compressive strength and the shear strength of soil increased to an optimum value and then decreased with increasing liquid asphalt.

The study concluded that the mixing technique was better than the injection technique because the mixing technique will cover the particles with a film of asphalt while the injection fills the voids of soil with asphalt. Moreover the results show that the oblique injection gives more strength to the soil than normal injection.

Keywords: Gypseous soil, Liquid asphalt, Soil improvement, Grouting, Injection

استخدام الاسفلت السائل لتحسين التربة الجبسية

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الخلاصة

ان الهدف الرئيسي من هذه العمل هو دراسة تأثير الإسفلت السائل (cut-back RC-70) في تحسين خواص التربة الجبسية. حيث هذا التحسين يكمن في تقليل تأثير الماء على حبيبات الجبس المتواجدة في التربة والتي تعمل كمادة رابطة في التربة وكذلك في زيادة مقاومة التربة الجبسية.

في هذا العمل تم اجراء نوعين من المعالجة النوع الاول المعالجة بواسطة الخلط اليدوي والنوع الثاني المعالجة بواسطة الحقن.

تضمنت الدراسة اجراء فحص مقاومة الانضغاط غير المحصور وكذلك اجراء فحص القص المباشر لاجاد تماسك التربة وزاوية الاحتكاك الداخلي لها واخيرا " فحص الانهيارية. حيث أجريت جميع هذه الفحوصات للترب غير المعالجة والمعالجة بنسب مختلفة من الإسفلت في حالة الجفاف وحالة الغمر بالماء.

اوضحت النتائج ان مقاومة الانضغاط غير المحصور للتربة تزداد قيمتها (حوالي 33%) عند النسبة المثلى للمعالجة وهي (6%) ومن ثم تتناقص بزيادة محتوى الاسفلت. كذلك فان تماسك التربة يزداد بزيادة محتوى الاسفلت الى القيمة العظمى و من ثم تتناقص بزيادة محتوى الاسفلت. عند غمر التربة بالماء لوحظ تناقص قيم الانضغاط غير المحصور و كذلك تماسك التربة. كما بينت النتائج ان الحقن المائل تفضل من الحقن العمودي.

استنتج من هذه الدراسة انه طريقة الخلط اليدوي للسفلت مع التربة افضل من طريقة الحقن بسبب كونها طريقة مثالية حيث يتم تغطية حبيبات التربة بطبقة قليلة من الاسفلت في حين ان طريقة الحقن يتم فيها ملء فجوات التربة بالاسفلت.

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Introduction

The gypseous soils are defined that soils contain sufficient quantities of gypsum (calcium sulphate)[1]. These soils are usually stiff when dry especially because of the cementation of the soil particles by gypsum, but the problem becomes complicated when the water flows through the

gypseous soils causing leaching and then cause a continuous collapse in it.

Many problems have been reported on damages occurred to structures supported on gypseous soils such as cracks, tilting, and overturning of structures, these problems may be very dangerous, therefore improvement of the gypseous soils are very important.

Several studies have been pointed out the change in engineering properties as a result of water movement in the soils and leaching out of gypsum from it.

The effect of gypsum on consistency limits was studied by [2, 3], they found that addition of gypsum to the soil leads to decrease the liquid and plastic limits, and the plasticity index.

The results of long term field plate loading tests on gypseous soils show that the physical, chemical and mechanical properties of the soil changed due to gypsum leaching from the soil, and the settlement occurred [4], While [5] concluded that there exist two distinct stages of compression, Firstly a short term stage (primary consolidation) and secondly long term stage (secondary compression). Furthermore, the collapsibility of gypseous clay and sandy soils increased as the gypsum content increased [6]

The permeability of gypseous soil was high at the beginning of leaching and then reduces for some time randomly, until reaches steady state. The hydraulic conductivity decreases with increasing stress increment [7].

Different methodology has been used to improve these soils, [8] studied the stability of lime in treatment of the gypseous soil, while [9] used cement as an improvement material. Bituminous materials are considered as main water proofing agent that could be used for gypseous soil, [10] used cut back bitumen, while [11] suggest a treatment with emulsion asphalt. The stabilization of gypseous soil by lime and emulsion asphalt was done by [12].

The main function of asphalt material is to reduce the effect of water on gypsum particles and to increase the strength parameters of the soil.

The main objective of this study is to investigate the improvement of the gypseous soils properties by using liquid asphalt. The study seeks the following aims:

- 1- The suitability of liquid asphalt as an improvement material using mixing technology.
- 2- The suitability of the treated soil as a foundation.
- 3- The effect of water on the treated soil with liquid asphalt.
- 4- The suitability of liquid asphalt as a grouting material to conserve the gypseous soil using normal and oblique injection techniques.

Mechanism Of Bituminous Treatment

The mechanism of treatment with bituminous material consists of adding cohesive strength and reducing water penetration by the physical presence of bitumen; there is no chemical interaction in this process, [13].

1- Water proofing action

The water proofing of bituminous material may be explained by combination of two theories: **The first theory** is a plug theory which means that the bituminous globules literally act as plugs or stoppers in soil void spaces or soil capillaries, there by, removing or eliminating the presence of the flow channels of water along which surface water might enter and makes it tight, [13]. **The second theory** is called membrane theory, which assumes that a thin bituminous film will act as a coating for individual soil particles or aggregation of them, thereby producing the same of water proofing the soil but in somewhat different manner from that visualized by plug theory, [9].

2- Cementation action

The effect of the cementing action of the bituminous materials may be related to the adhesion, which takes place between the binder and soil particles. This adhesion is the combined effect of the action of surface tension, adsorption, and other properties of the solid and liquid surface, [9].

Materials Used And Testing Program

The soil was brought from Tikrit city at depth of 1.0 to 3.0 meters from ground level. Physical tests consist of specific gravity; Atterberg limits, grain size distribution, and unit weight were conducted on this soil. The test results are shown in Table (1). Also several chemical tests were performed according to standards as shown in table (2).

The liquid asphalt used for treating the soil was cut-back RC-70 and was taken from Baiji refinery.

Table (1) Results of physical tests for soil used

Soil Property	Result Value	Astm Designated
Specific Gravity	2.59	D854-58 ⁽¹⁾
Liquid Limit	31	D423-66
Plastic Limit	NP	D424-59
Gravel (≥ 4.75)%	3.985	D424-59
Sand (4.75mm to .075mm)%	92.877	
Silt and Clay ($\leq .075$ mm)%	3.138	
Unified Soil Classifications	SP	D 2487
Maximum Dry Density (kN/m^3)	16.45	D1557-79 ⁽²⁾
Optimum Moisture Content (%)	13.5	

(1) Modified method by U.S. Army Engineer Waterways Experiment Station

(2) Modified Proctor compaction test

Table (2) Results and standards of chemical tests

TEST	STANDARD	VALUE
Gypsum Content, g.c %	US Department of Agriculture Handbook ^[14]	40-50
Total Soluble Salts (T.S.S)%	Earth manual ^[15]	45-56
Total Sulphate Content (SO ₃)%	B.S.1377:1975	16-30
Organic Matters Content	B.S. 1377:1975	0.12-0.14

The manufacturing process consists of mixing 65% asphalt cement (AC) penetration grad 85-100 with 35% gasoline or naphtha produced cut-back asphalt RC-70, Table (3) presents the full properties of cut-back RC-70.

In this study the gypseous soil was treated by two techniques, mixing the liquid asphalt with soil and grouting technique, the testing program included the determination of unconfined compressive strength, shear strength by using direct shear test and collapsibility tests. The three types of tests are conducted for undisturbed and disturbed (treated and untreated) samples.

Table (3) Details of Prosperities of Cut-Back Bituminous RC-70 (Baiji Refinery).

Properties	Value	Method
Kinematics Viscosity at 60°C; (mm ² /s)	70 to 140	AASHTO T 201
Penetration at 25 C° (100gm; 5sec; 0.1 mm)	80 to 120	AASHTO T 49
Residue from distillation to 360 °C; minimum, % volume by difference	55 %	AASHTO T 78
Water; Maximum, % by weight	0.2 %	AASHTO T 55
Ductility	100	AASHTO T 51
Solubility in carbon tetrachloride CCl ₄ (% by weight)	99.0 %	AASHTO T 44
Distillate; % by volume of total distillate to 360 °C	>10	AASHTO T 78
To 225°	>10	
To 315°	>10	

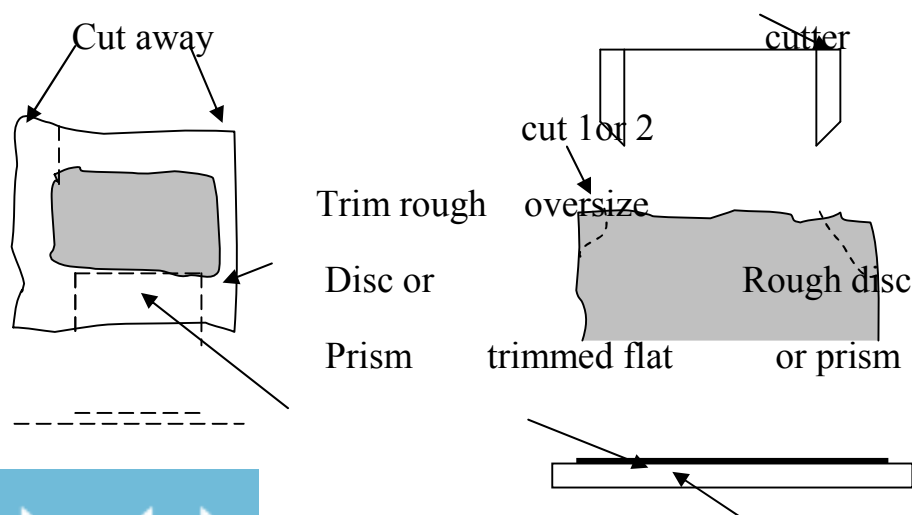
Sample preparation

Air dried pulverized and homogenous soil was used. The required amount of water was added at room temperature in a slow stream and thoroughly mixed by hand for 2.5 minutes or until the water dispersed throughout the mixture. Then the wet mixture was kept in an airtight container. Different percentages of the liquid asphalt, expressed as a percentage of total dry weight of soil was added to the wet mixture and mixed thoroughly by hand. The mixing process may require 5 minutes, so that the soil particles will be coated properly by a thin film of bituminous binders.

Fig. (1) present the procedure used for the preparation of specimens for the standard odometer test (70 mm dia.* 19 mm thick), Row cells (152 mm dia. * 51 mm thick) and (70 mm dia.* 20 thick), with shear box (60 mm* 60 mm* 20 mm). All the samples were trimmed by hand from undisturbed block samples of the gypseous soil.

Grouting

Grouting apparatus was designed and assembled for the purpose of this study and is shown in Fig. (2). In order to match the in-situ soil conditions and obtaining soil samples of considerable void ratio, the disturbed soil was compacted with a specified water content of (11%) and a dry unit weight of 12.75 kN/m^3 .

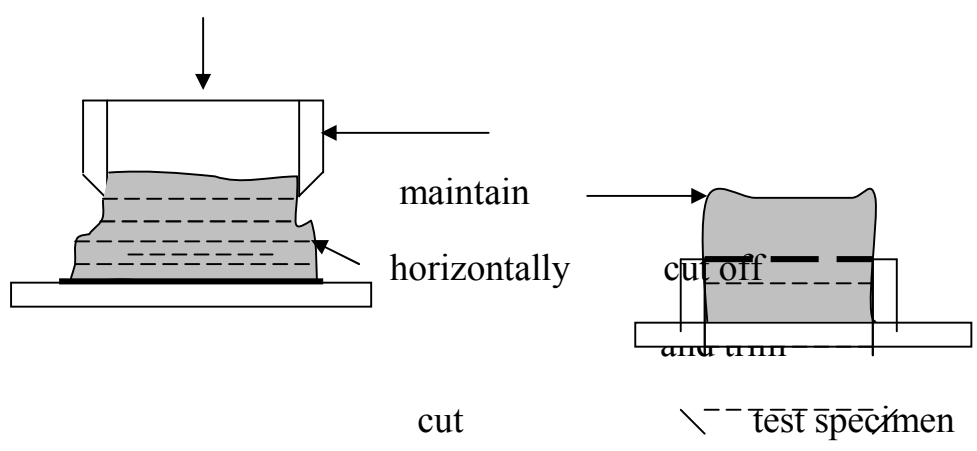


required specimen
 block sample
 plate
 glass

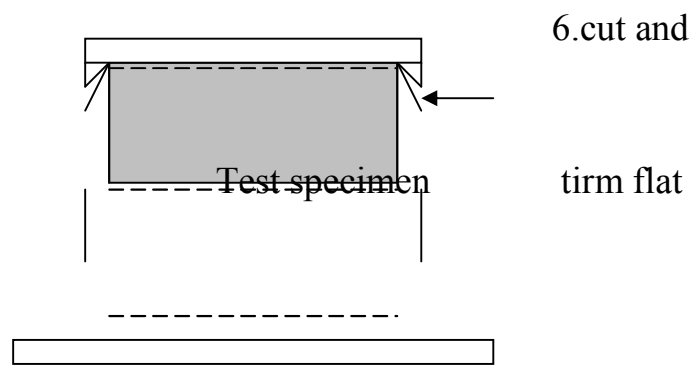
(Plan)

(a) (b)

push down
 vertically



(c) (d)

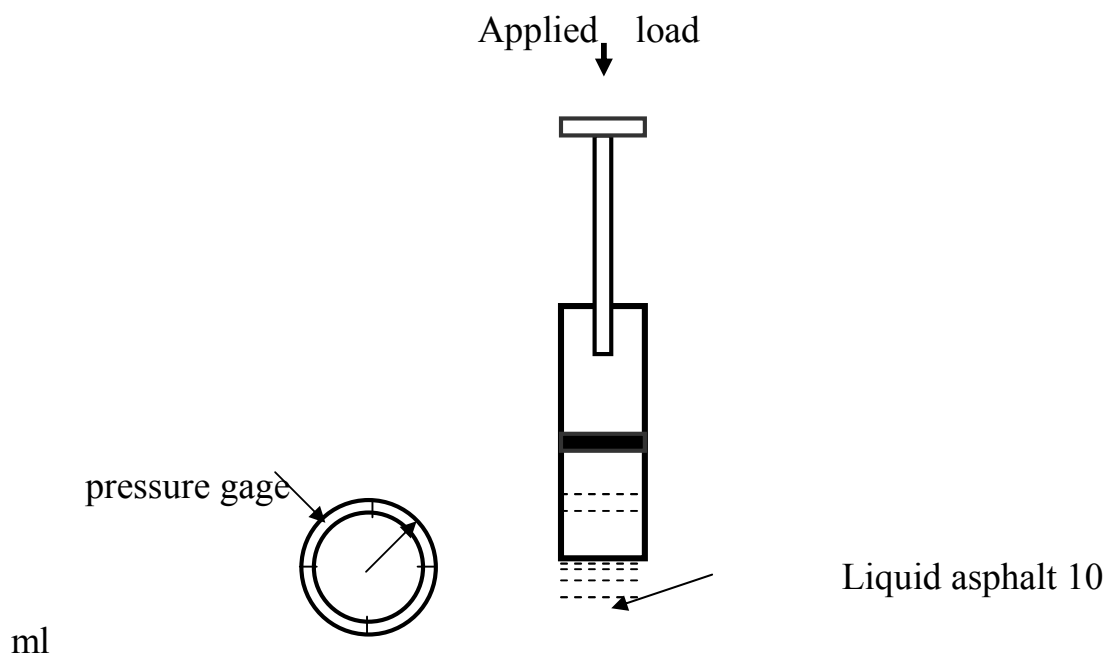


(e)

Fig. (1) Sample preparation

This approach will result in a void ratio of about (0.9) which is approximately equal to the field void ratio. After completion of compaction, it was required to perform a hole in the samples by forcing an open ended tube inside the samples with diameter 0.5 cm holes.

After the preparation of the boring, the grouting was performed. The operation of grouting was repeated with three spacing 3, 6 and 9 cm as shown in the Figure (3.a, b & c) in both cases normal and oblique injection. For both cases the grouting pressure was 3.5 kPa. In the oblique injection the angle of the holes was 60° with horizontal. After the grouting operation is completed, the sample was prepared for direct shear and collapsibility tests.



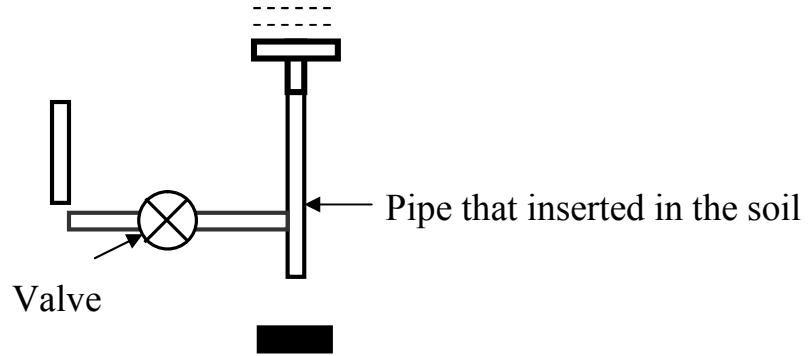


Figure (2) Schematic diagram of the grouting apparatus.

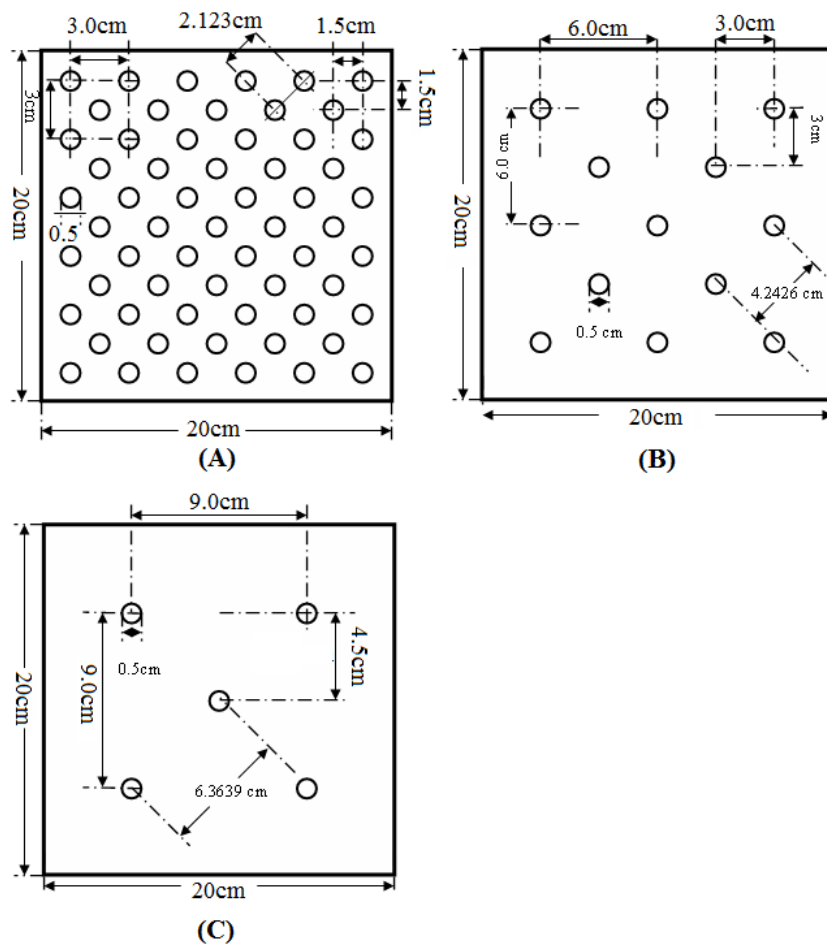


Figure (3) Distribution of grouting pipes

(A) 3.0 cm spacing

(B) 6.0 cm spacing

Results And Discussions

Specific gravity and dry density

The following equation was adopted to determine the specific gravity of treated soil [11]:

$$G_{s(\text{treated soil})} = [G_{s,s} + \text{b.c.} * G_{s,e}] / [1 + \text{b.c}]$$

..(1)

Where

$G_{s,s}$ = specific gravity of untreated soil

$G_{s,e}$ = specific gravity of cut-back asphalt = 1.06

b.c. = binder content

According to the above equation the effect of binder on the specific gravity was shown in Fig. (4). The specific gravity of the treated soil with different binder content decreases as the binder content increases. This

may be attributed to the low specific gravity of cut-back asphalt compared with that of the natural soil. This reduction in specific gravity leads to decrease the maximum dry density as the binder content increases as shown in Fig. (5).

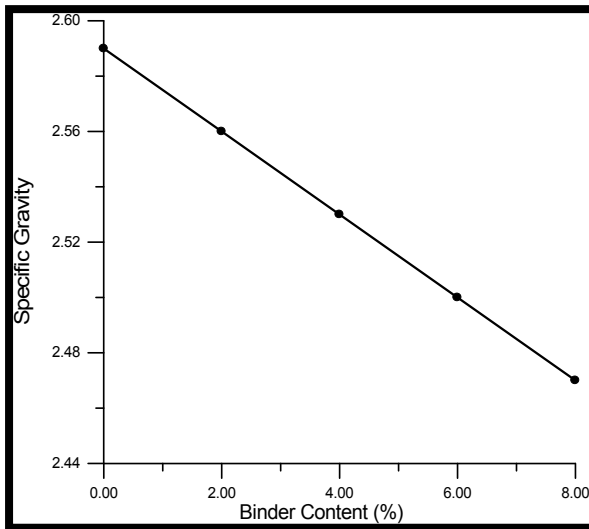


Fig. (4) The effect of binder content

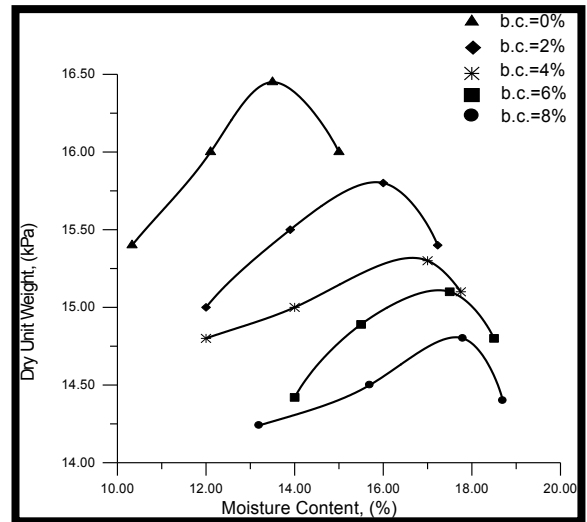


Fig. (5) Moisture content — Dry

Shear strength

The results of unconfined compression test were drawn and shown in Fig.(6), the relationship for unsoaked samples revealed an increment of unconfined compressive strength as the binder percentage increases, until it reach an optimum value at binder percentage of 6%. In spite of the reduction in strength for soaked samples, the compressive strength increases with addition of binder, the phenomena is due to the gain in cohesion which provided by continuous film of binder coating the soil particles. The statistical analysis was performed to support these results and show the effect of binder content on the maximum unconfined compressive strength, as shown in Fig. (6) ,for both soaked and unsoaked samples, indicates that significant differences exist between unconfined compressive strength of samples prepared with 0% binder content and those prepared with other binder contents.

Table (4) shows the relationship between the normal stress and shear stress for undisturbed and disturbed (treated and untreated) samples and for both cases soaked and unsoaked conditions. For unsoaked samples, it can be observed that the cohesion (c) increased as the binder content increased to an optimum value then it decreases. While the angle of internal friction was founded to be nearly constant. This behaviour may be attributed to the added cohesion introduced by binder.

For soaked samples, it can be notes that there is a high reduction in cohesion component (c) compared to unsoaked case, while it shows a little reduction in the friction component (ϕ).This reduction may be attributed to the destruction of the antiparticle of cementation bond in the particle system.

Also the table shows that the cohesion component (c) increased as the binder content increased. This phenomenon may be explained by the waterproofing action of asphalt.

Table (4) Results of direct shear tests

Type of Test	Without Soaked	Soaked in Water
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Soil Property	c kPa	ϕ deg.	c kPa	ϕ deg.	
Undisturbed Sample	35.0	38.0	3.0	36.0	
Sample With Binder Content	0%	45.0	43.6	9.0	42.5
	2%	55.0	43.0	35.5	42.0
	4%	67.0	45.0	54.0	44.0
	6%	78.0	44.5	75.0	43.0
	8%	70.0	45.0	67.0	39.0

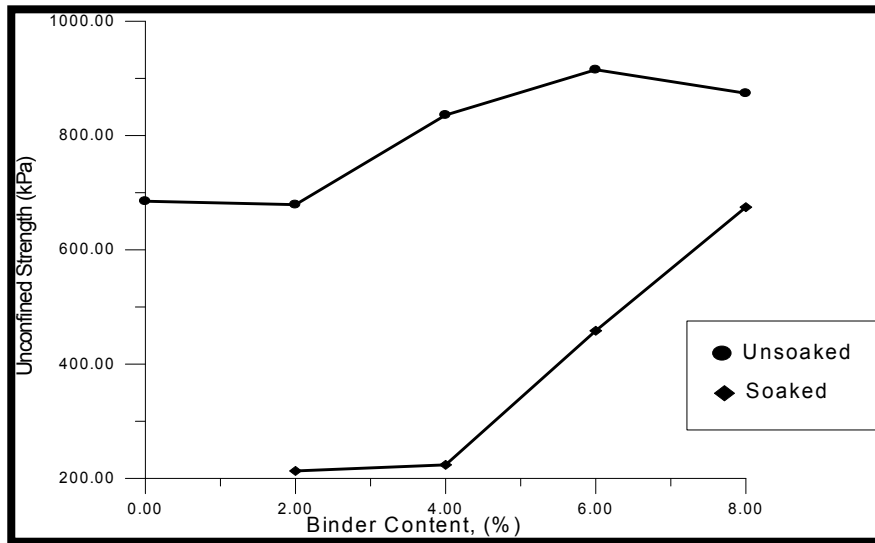


Fig. (6) Effect of binder content on the max. unconfined compressive strength.

Collapsibility and compression index

In Table (5), the collapse potential decreases as the binder content increases to an optimum value, and then it remains constant (at binder content more than 6%). While, the initial void ratio decreases as the

binder content increases until it reaches minimum value at binder content 6%.

The compression index (c_c) remains constant with binder content increment for unsubmerged. After the soil submerged in water the compression index decreases as the binder content increases as shown in Fig. (7).

Grouting method

In this procedure the spacing between holes may be control the maximum shear strength. The maximum value occurred at 6cm spacing, where at 3cm spacing the amount of liquid injected affect the interlocking between soil particles, while at 9cm spacing the asphalt will not cover all the area, therefore give strength less than that obtained at 6cm spacing, Figs. (8 & 9). Analysis of variance was performed for the validity of these results. As shown in Table (6), the results at 6 cm spacing produce the largest F-statistic value, which is significant at 1% significance level.

The results of oblique injection are better than that of normal injection; this is probably due to better distribution of binder in soil. In Table (6) the results show that the cohesion of the soil increases to an optimum value then decreases, while the angle of internal friction increases as the spacing between holes increased. Again the results of oblique injection also better than the normal injection method.

The standard deviation of the biases or differences between the normal and oblique injection data of shear strength parameters for each spacing was used to evaluate the variability of the results. For spacing 3 cm, the variability of the normal injection result was slightly less than the oblique injection. At other spacing, the statistical comparison of the results showed a significant variability and difference between the two types of injection.

Table (5) Results of collapse potential and initial void ratio

Soil Property	Initial Void	Collapse
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		Ratio (e_o)	Potential (C_p)
Undisturbed Sample		0.9837	17.74%
Disturbed Sample With	0% Treated	0.7823	8.223%
	2% Treated	0.7444	1.683%
	4% Treated	0.6514	1.120%
	6% Treated	0.538	0.700%
	8% Treated	0.630	0.736%

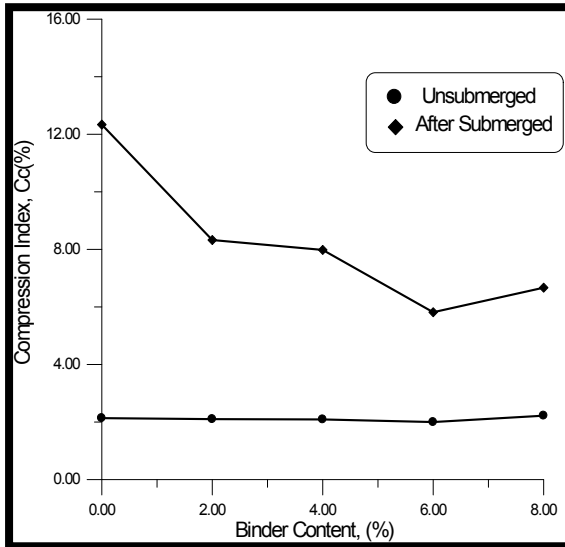


Fig. (7) The effect of binder content on compression index C_c

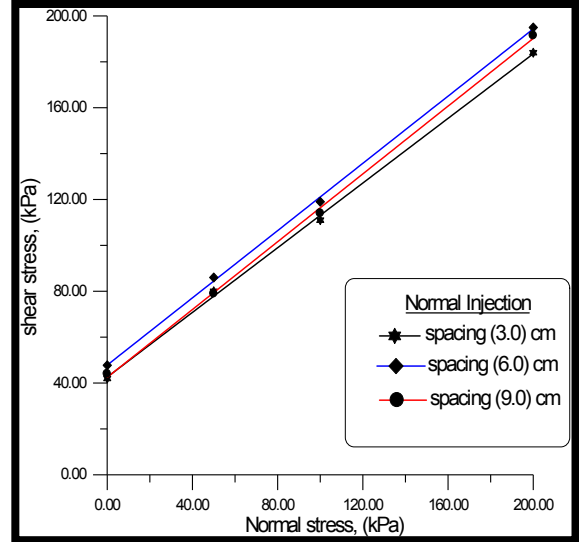


Fig. (8) Direct shear test for samples with normal injection at different spacing.

Table (6). Results of Cohesion and Angle of Friction for Oblique and Normal Injection.

Test	Normal Injection ®		Oblique Injection ©		Biases ®-©	
	c (kPa)	ϕ (degree)	c (kPa)	ϕ (degree)	Standard	F-statistic
Parameter						

))	Deviatio n	value		
Spacin g (cm)	3	42	35	43	34	0.033	3.462
	6	47	36	54	35.5	0.853	174.33**
	9	43	37	48	36	0.655	29.661*

* Significant at the 5 percent significance level.

** Significant at the 1 percent significance level.

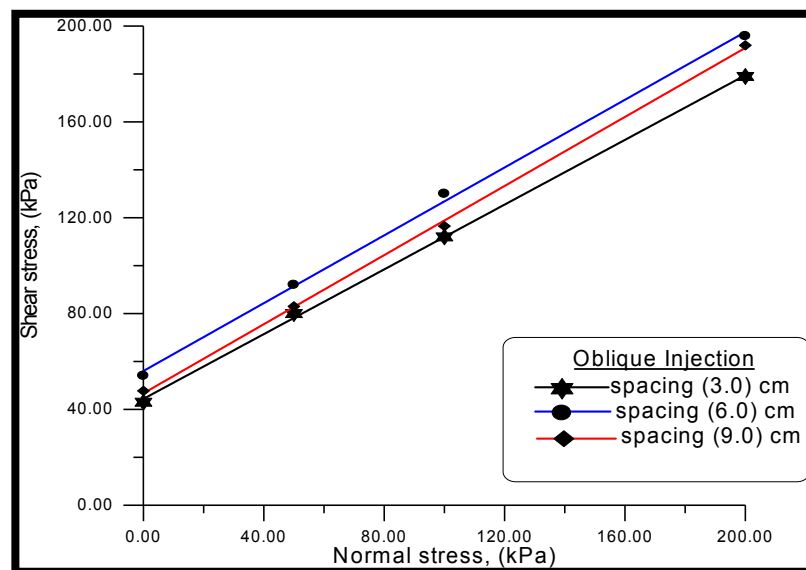


Fig. (9) Direct shear tests for samples with oblique injection of different spacing.

Conclusions

Based on the results presented in this study, with the conditions and limitations of the study, the following conclusions can be made:

1. As the binder content increases, the maximum dry density decreases with about (9%) and the optimum moisture content increases with about (28%) at binder content (6%).
2. Unconfined compressive strength, for the treated soil without soaking increase up as the binder content increase then it decreases. Also strain failure of treated soil is more than that of untreated samples.
3. For the direct shear tests, cohesion for unsoaked samples increases as the binder content increases to about (70%) then it decreases while the angle of internal friction is unaffected. But cohesion for soaked samples is relatively low as compared to the unsoaked. An increment of (90%) were found in cohesion and a slightly reduction in the angle of internal friction as the binder content increases to (6%).
4. As the binder content increased, a reduction in the values of the collapse potential, the initial void ratio and compression index were found.
5. From strength tests it was found that the optimum binder content is about 6%.
6. According to the limitations of this work, the mixing technique represents the preferable method than the grouting method.
7. The oblique injection gave a better results compared with the normal injection with an optimum spacing of 6 cm.
8. According to the statistical analysis examination of the biases evaluated and supported the accuracy of the study results.

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