Studying the Behavior of Asphalt Stabilized Gepseous Soil for Earth Embankment Model

Hussein Q. Kasim Abdulameer
M.Sc. Civil Engineering
college of Engineering-University of Baghdad
email:hussein83m@yahoo.com

Saad I. Sarsam
Professor
College of Engineering-University of Baghdad
email: Saadisasarsam3@yahoo.com

Mahmood D. Ahmed
instructor
College of Engineering-University of Baghdad
email:mahmoud_Baghdad@yahoo.com

ABSTRACT

The study presents the test results of stabilizing gypseous soil embankment obtained from Al- Faluja university Campus at Al-Ramady province. The laboratory investigation was divided into three phases, The physical and chemical properties, the optimum liquid asphalt (emulsion) requirements (which are manufactured in Iraq) were determined by using one dimensional unconfined compression strength test.in the first phase , The optimum fluid content was 11% (6% of emulsion with 5% water content).. At phase two, the effect of Aeration technique was investigated using both direct shear and permeability test. At phase three for the case of static load , the pure soil embankment model under dry test condition was investigated, The testing program included the determination of the unconfined compressive strength, direct shear strength, constant head permeability test, and one dimensional consolidation test for pure and asphalt stabilized gypseous soil. Testing was carried out in dry and absorbed conditions, the maximum pressure that can be supported before failure (ultimate sustained pressure) is 0.76 MPa with vertical settlement (0.21 mm) . However, For the pure soil embankment model under absorbed condition it was found that the maximum pressure before failure (ultimate sustained pressure) is 0.3 MPa with vertical settlement (12 mm), Which reflects the reduction in bearing capacity by (61%). Compression was made for absorbed stabilized soil and un-absorbed soil tested under hydraulic conductivity test for seven days, the results showed that a very low margin deffeneces in maximum pressure resistance and settlement were obtained (4.38 MPa , 0.11mm) and (4.11MPa , 0.12mm).

Key words: gypseous soil, Emulsion, hydraulic conductivity , soil stabilization.

دراسة تصرف التربة الجبسية المحسنة بالاسفلت لنموذج تعلية ترابية

حسين قاسم عبد الامير
ماجستير هندسة مدنية
كلية الهندسة-جامعة بغداد

سعد عيسى سرسم
أستاذ
كلية الهندسة- جامعة بغداد

محمود ذياب احمد
مدرس
كلية الهندسة- جامعة بغداد

الخلاصة

التربة الجبسية لهذا البحث احضرت من جامعة الفلوجة مدينة الرمادي, الفحوص المختبرية قسمت الى ثلاث اقسام: القسم الاول ايجاد الخواص الفيزياوية والكيمياوية, والنسبة المثلى لمستحلب الاسفلت المصنوع في العراق التي وجدت من فحص مقاومة الضغط الامحصور حيث كانت النسبة المثلى للسائل هي 11% (6% مستحلب الاسفلت + 5 % ماء) , وبرنامج

الفحوص العملية كانت ايجاد مقاومة الانضغاط, مقاومة القص المباشر, النفاذية و الانضمام بأتجاه واحد للتربة الجبسية في حالتها الجافة والرطبة. القسم الثاني استعملت تقنية التهوية من خلال فحص القص المباشر , اما القسم الثالث فقد تم تسليط حمل ساكن من خلال استعمال صندوق بأبعاد (35 * 35 * 30) سم بنفس الكثافة المحدولة المعدلة وايضاً خمس طبقات بمعدل (6) سم لكل طبقة , وتم فحص الانضغاط للتربة المحسنة و الغير محسنة بتسليط حمل ثابت بتأثير وعدم تأثير التوصيل الهايدروليكي وقد تم استعمال حساس رقمي لحساب الهطول العمودي. .

فقد وجد ان مقدار التوصيل الهايدروليكي للماء الى السطح خلال ثلاثة ايام للتربة الغير محسنة المغمورة فقد كان التشوه العمودي تحت ضغط اقصى مقداره (0.3) ميكا باسكال هو (12) ملم , و للتربة الغير محسنة والغير مغمورة تحت تأثير ضغط اقصى مقداره (0.76) ميكا باسكال هو (0.21)ملم, أي مقدار النقصان هم (61%). اما مقدار التوصيل الهايدروليكي للماء الى السطح خلال(7) ايام للتربة المحسنة المغمورة لم يتجاوز فتحات دخول الماء من الثلث السفلي فقد كان التشوه العمودي تحت ضغط اقصى مقداره (4.11) ميكا باسكال هو (0.12) ملم , و للتربة المحسنة والغير مغمورة تحت تأثير ضغط اقصى مقداره (4.38) ميكا باسكال هو (0.11)ملم, أي مقدار النقصان غير ملحوظ.

1. INTRODUCTION

The sandy soil with high gypsum content usually referred to as gypseous soil covers vast area in south, east, middle and west regions of Iraq, such soil possesses a type of cohesive forces when mixed with optimum amount of water and then compacted, but losses its strength when flooded with water again. Covering the soil particles with thin asphalt layer in a stabilization process will increase the cohesion, will limit the negative effect of water by blocking the voids, and will reduce the ability of water to traverse the soil layer through capillary action process.

The economic backfill material suitable for such embankments and roads could be the available local soil. When the soil is gypseous, it will be suitable for compaction use in the dry condition. There will always be a possibility for water to penetrate through the pavement cracks to the soil beneath. It may exhibit hazardous situation ,Then to prevent the soil from collapsing, the asphalt stabilization could provide a good remedy. for such case, theoretically, each particle of the gypseous soil will be surrounded by a thin film of asphalt which will act as a binding and a damp proofing agent. Stabilization of such soil with liquid asphalt will furnish waterproof layers with extra particles bond to serve for embankment construction. Two loading type subjected on embankment during the service life are the repeated load by vehicles and static loading due to its self weight.

2. BAGROUND

For the construction of any type of structure resting on problematic soils such as gypseous soils, there are many available methods to improve the behavior of soil. One of these methods is stabilization with asphalt which is used as addition to prevent water penetration that cause collapsibility potential and to improve the characteristics of the soil.

2.1 Gypseous Soils

In gypseous soils, collapse or compression occurs very quickly when the site is flooded with water during heavy rainfall, irrigation or breaking of sewerage and water pipes which may damage the engineering structures because the element of structure can not follow the sudden deformation occures by rearrangement of the inside forces or stresses , **Al-Mohammadi, 1987.**
high strength of dry gypseous soil can be obtained, but great losses in strength and sudden increase in compressibility occur when these soils are fully or partially saturated. The dissolution of the cementing gypsum causes high softening of the soil. The problem becomes more complicated when the ground water flows through the gypseous soil causing leaching and movement of gypsum. In addition to softening, a loss in soil solids takes place. This causes a continuous collapse in the gypseous soil, **AL-Mufty, 1997.**

2.2 Asphalt Emulsion

It is simply a suspension of small asphalt globules in water assisted by an emulsifying agent such as soap. The emulsifying agent assists by imparting an electrical charge to the surface of the asphalt cement globules. Emulisified asphalts are divided into three major groups, namely, anionic, cationic and nonionic, on the basis of the electrical charges of the asphalt particle in the emulsion. Emulisified asphalts are further classified into three main groups namely, rapid-setting (RS), medium-setting (MS) and slow-setting (SS), on the basis of how quickly the suspended asphalt particles revert back to the asphalt cement, a form in which it is actually nedded as a binder **Olutaiwo, et al., 2008,** so **Table 2** shown the property of emulsion.

3. CHEMICAL TEST

The following chemical tests are conducted:
1- Total soluble salts (T.S.S.) (%).
2- Total (CO_3) (%).
3- Total (SO_3) (%).
4- Gypsum content (%).
5- pH value.

4. PHYSICAL TEST

Classification tests performed on the soil include particle sizedistribution, specific gravity, Atterberg limits, relative density, and compaction characteristics. Physical tests were conducted as described in **Table 1**.

5. MATERIAL TEST

Asphalt Emulsion used in the testing program was locally manufactured by Al- Zahf Al- Kabeer company with low cost, The specifications as supplied by the manufactured are as given in **Table 2.**

5.1 Design of Gypseous Soil-Asphalt Mixture

To prepare the specimen, the pulverized and homogenous gypseous soil passing sieve No.4 was oven dried at a temperature of (45°). The optimum moisture content and the maximum dry density of the soil that were found through modified compaction test was 17.7 kN/m^3(95% of modified compaction test) and was selected as a field target in compaction process. Such an issue is mostly considered as an acceptable relative compaction in most engineering requirements, It agrees well with procedure of **Hamdy, 2010**, **Al-Mohammadi, 1987**, **Al-Mufty, 1997, Al-Safarani, 2007**, so, **Fig 1** shown the Stress-Strain relationship for the unconfined compression test for soil with 11% fluid content.

The test was conducted on soil samples mixed by splitting the optimum moisture content into water and emulsion content which will be referred as to optimum fluid content obtained from modified compaction which was (11%), .The water contents were in a range from 4% to 8% with (1%) increment, while the emulsion was in different percentages of 3% to 7% with (1%) increment. Specimens were allowed to cure for seven days at room temperature of (27± 3)ºC and the average value of the unconfined compressive strength for each duplicate specimens were calculated, and **Fig. 2** shown the Unconfined compression strength – emulsion content (%) relationship.

5.2 Absorption technique

Unconfined compression test specimens were prepared using the same method, size and density as was described in the unconfined compression test. Duplicate specimens having the same fluid content were prepared. Specimens were subjected to seven days curing at air dried condition. After an absorbed period of 7 days, The unconfined compressive strength of specimens was tested, same the results that obtained by **Ingles** and **Metcalf, 1972**. It is clear from **Table 4** that the effect of hydraulic conductivity on the unconfined compressive strength.

5.3 Direct shear test

Direct shear test was carried out on eleven groups of different specimens to determine the shear strength parameters, cohesion and angle of internal friction. The dry density was found to be 17.7 kN/m^3 as described in section(3.4, modified compaction). The optimum fluid content was determined from the unconfined compression strength test as (5% water + 6% emulsion) same the percentage that carried out by **Sarsam, 1979** and **Sarsam, 2008**. It is clear from **Fig. 3** to **Fig. 10**.

5.4 Aeration of asphalt soil

The Aeration technique was adopted before compaction by allowing the loose mix to be subjected to atmosphere condition at laboratory temperature of (30 ± 3)ºC for different times . The aeration periods were (30 ,60 , 90, 120, 240) minutes respectively with emulsion for direction shear test.

Eleven group of specimens were tested. The 1st and 2nd groups of specimens are not stabilized, It was pure soil. The specimens were tested in direct shear which was conducted in soaked and unsoaked conditions. The 3rd and 4th group of specimens are stabilized with optimum emulsion content and constructed without Aeration then the specimens were left for 7 days for curing. The period of soaking was (3-4)hrs. The 5th ,6th ,7th ,8th and 9th group of specimens were stabilized with optimum Emulsion content and subjected to Aeration for different time (30 ,60 , 90, 120, 240) minutes respectively and then the specimens were left for 7 days for curing. The 10th and 11th groups of specimens were stabilized with emulsion and subjected to Aeration condition as (120,140) minutes respectively and then tested under soaked condition. The effect of aeration on shear strength variable were examined. It is clear from **Fig. 9** and **Fig. 10**.

5.5 Static loading test

Four laboratory static loading tests were carried out on gypseous soil samples; the same procedure was applied for the four cyclic loads in the previous tests, but the new box was manufactured with dimension of (30cm x 30cm x 40cm) and had inlets in the bottom of box to allow the water touch the soil that put in the outer box under absorb condition. Same results are agreeing with **Al-Basri, 2012.**

The first test was on a non-stabilized gypseous soil embankment model cured for (24) hours in air.

The second test was carried out on a non-stabilized gypseous soil embankment model cured for (24) hours in air, then subjected to capillary rise with water through addition of water around the box that had inlets to allow the water touch the gyseous soil and then left for three days before applying the test.

The third test was carried out on stabilized gyseous soil with emulsion in dry condition; the mix was left for 2 hrs for aeration before the compact and then the model cured for (7) days before test. It is clear from **plate** 5 and **plate 6** are showing the set up of model.

The fourth test was for stabilized soil with under absorbed condition; the same procedure was applied for the third test by Aeration and curing, but the model was left with absorbed for 7 days. The model of dry pure soil of embankment model was considered as a reference to absorbed pure soil of embankment model as an improvement percentage, while the model of absorbed stabilized soil was considered as a reference for the pure stabilized embankment model with emulsion as an improvement percentage.

5.5.1 Static loading test for the pure gypseous soil embankment model with dry condition

The pure gypseous soil was selected for this test; it was compacted in the model box and cured for 24 hours and then tested. Measurements of vertical settlements versus the applied vertical pressure were carried out. It is clear from **Fig. 11** that the load-vertical deflection characteristics of the pure gypseous soil sample, It is clear from **plate 6** that shows the test.

5.5.2 Static loading test for the pure gypseous soil embankment model under absorbed condition

The 2nd static loading test was for the pure gypseous soil embankment mode with observed condition. Hence, the model was allowed to face capillary rise of water for (3) days. It is clear from **Fig. 12** that the load-vertical deflection characteristics of the pure gypseous soil sample, and It is clear from **plate** 7 that shows the test.

5.5.3 Static loading test for the dry stabilized gypseous soil embankment model

The third test was carried out on a stabilized soil embankment model using emulsion asphalt for stabilization (based on 11 % of stabilizing material by weight, which is 6% Emulsion and 5% water. the mix was left for 2 hrs for aeration before the compact of 5 layers and then the model was cured for (7) days before test. The stabilized soil embankment model resists the pressure and less vertical displacement , Applied pressure - vertical settlement for stabilized gypseous soil with dry condition the vertical displacement at (0.77 Mpa) was (0.0037 mm), So the rate of decreased in vertical displacement was (- 69%) with compared to pure gypseous soil. This result is shows the strength and cementation added by emulsion to the soil. It is clear from **Fig. 13** that the load-vertical deflection characteristics of the pure gypseous soil sample, And it is clear from **plate 8** that shows the test.

5.5.4 Static loading test for the stabilized gypseous soil embankment model under absorbed condition

The fourth test was carried out for stabilized soil. In this test the same procedure was applied for the third test but after curing for 7 days. The model was absorbed for 7 days. The box was put in a container and the water was poured and left for 7 days to absorb condition from the inlet in the side bottom around the box. The applied pressure - vertical settlement for pure gypseous soil with absorbed condition the vertical displacement was (0.3 Mpa) with (12 mm), so when compared with absorbed stabilized gypseous soil, the vertical displacement was (0.0021 mm). Stabilization with emulsion was successfully as used to prevent the hydraulic conductivity and make blocking between the voids and add more strength and cementation for the soil particles especially for gypseous soil with a percent of gypsum that causes a collapse when touched by water or in wet state under road, embankment or another construction. It is clear from **Fig. 14** that the load-vertical deflection characteristics of the pure gypseous soil sample.

6. CONCLUSION

1. The unconfined compressive strength of the soil-emulsion mixture under dry and absorption test conditions increases with increasing emulsion asphalt content up to the optimum emulsion asphalt content of 6% and then decreases.
2. For pure gypseous soil tested at dry condition, the cohesion (c) was found to be 41 kPa, when the soil was stabilized by emulsified asphalt without Aeration condition; the cohesion was increased to 140 kPa which means an improvement by 250 %.
3. When the soil was stabilized by emulsified asphalt and aerated for two hours and tested under dry condition, the cohesion (c) was found to be 168 kPa , so the cohesion was improved by 21.5% improving on stabilized soil without Aeration.
4. When gypseous soil was tested at absorption condition, the cohesion (c) was found to be 29 kPa, But when the soil was stabilized with emulsified asphalt without aeration and tested at absorbed condition, the cohesion was 53 kPa which means an improvement by 83 %.
5. When the soil was stabilized by emulsified asphalt and aerated for two hours at absorbed condition , the cohesion (c) was found 64 kPa , so the cohesion was improved by 21 % , with respect to non aerated condition.
6. For the case of static load of the pure soil embankment model under dry test condition, the maximum pressure that can be supported before failure (ultimate sustained pressure) wass 0.76 MPa with vertical settlement (0.21 mm) . However, For the pure soil embankment model under absorbed condition, it was found that the maximum pressure before failure (ultimate sustained pressure) was 0.3 MPa with vertical settlement (12 mm).which means an decrease in bearing capacity (61%).
7. The hydraulic conductivity of gypseous soil was changed by asphalt stabilization. When tested under dry condition, a maximum pressure resistance of 4.38 MPa with vertical settlement (0.11 mm) was shown. But when stabilized soil was subjected to absorption for seven days, a maximum pressure resistance of 4.11 MPa with vertical settlement (0.12 mm) was shown;i.e. there was no difference in claim.

REFERENCE

- Al-Basri, M.F., 2012, *Assessing Frictional Behavior of Earth Reinforcement Embedded in Asphalt Stabilized Gypseous Soil*, M.Sc. Thesis, Civil Engineering Department, University of Baghdad.
- Al-Mohammadi, N.M., Nashat, I.H. and Bake, G.Y., 1987, *Compresibility and Collapse of Gypsiferous Soils*, 6th Asian Conference on Soil Mechanics, Tokyo.
- Al- Mufty, A.A. 1997, *Effect of Gypsum Dissolution on the Mechanical Behaviour of Gypseous Soils*, M.Sc. Thesis, Civil Eng Dep., Baghdad University.
- Al-Safarani, M.G., 2007, *Improvement Ability of Gypseous Soil Characteristics Using Cutback Aasphalt and Lime*, M. Sc. Thesis, Civil Engineering Department, University of Al – Mustansiria.
- Hamdy, B.H., 2010, *Implementation of Gypseous Soil-Asphalt Stabilization Technique for Base Course Construction*, M.Sc. Thesis, Dep.of Civil Engineering, University of Baghdad.
- Head, K.H., 1982, *Manual of Soil Laboratory Testing*, Vol. 2, Prentch, Press, London.

- Ingles, O.G., and Metcalf, J. B., 1972, *Soil Stabilization Principles and Practice*, Butter Worth Limited, Australia.

- Olutaiwo, A. O., Adedimila, A. S., and Sidiq, U., *An Examination of the Use of Liquid Asphalt Binders in Road Works in Nigeria*, Journal of Engineering and Applied Sciences, Vol. 3, No. 1, 2008 p 134-142.

- Sarsam, S. I., 1979, *Soil-Cutback Mix for Base Course Construction in Some Parts of Iraq*, M. Sc. Thesis, Civil Engineering Department, University of Sulaimaniah.

- Sarsam, S. I. and Ibrahim, S.W., 2008, *Contribution of Liquid Asphalt in Shear Strength and Rebound Consolidation of Gypseous Soil,* Engineering and Technology, Vol. 26, No. 4.

Table 1 Properties of gypseous soil.

Test result	Physical property
Gs=2.48	Specific gravity according [B.S-13377:I976, test No. (6)]
 24 Non plastic Non plastic	Atterberg Limits: Liquid limit (%) according Plastic limit (%) according Plasticity Index (%)
17.17 kN/m^3 14%	Standard compaction properties according Max. standard dry density Optimum moisture content (%)
18.67 kN/m^3 11%	Modified compaction properties Max. modified dry density Optimum moisture content (%)
15.5 kN/m^3	Maximum dry density according to
11.7 kN/m^3	Minimum dry density according to ASTM
1.5	Coefficient of curvature
6.2	Coefficient of uniformity
SP-SM	Unified Classification System

Table 2 Properties of asphalt emulsion.

Test result	Property
+ve	Particles charge
45	Viscosity CSt
1.2	Cement mixing
19	Settling time (hr)
Good	Coating ability and water resistance
Fair	Coating dry & wet aggregate

- Al-zahf Al-Kabeer Co./Baghdad
-

Table 3. Chemical composition of the natural soil.

Percentage %	Chemical Composition
49	Gypsum content (CaSO4) (%)
46	Carbonate content (CaCo3) (%)
38	Total soluble salts (T.S.S.) (%)
22	Total (SO3) (%)
7.77	pH value

Table 4 Effect of hydraulic conductivity on the unconfined compressive strength.

Percent changing unconfined compressive strength (%)	Unconfined compressive strength (kPa) (under absorbed condition)	Unconfined compressive strength (kPa) with dry condition	Emulsion content (%)
-85.31	73	497	4
-87.59	80	645	5
-87.68	85	690	6

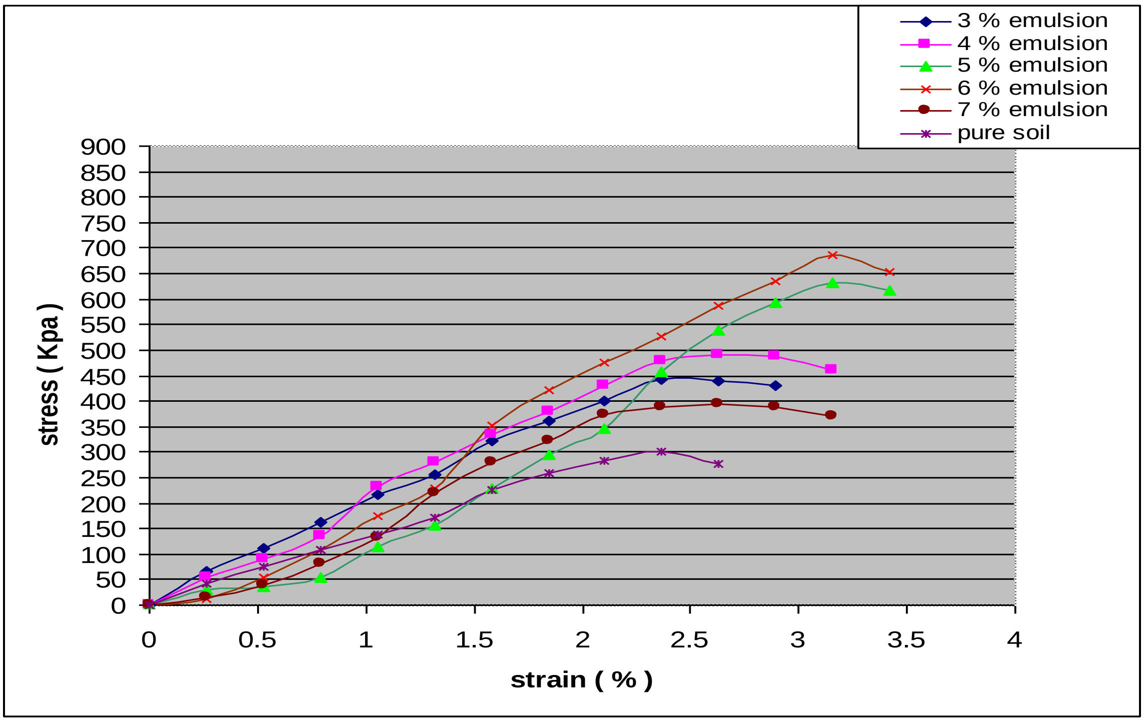

Figure 1. Stress-strain relationship for the unconfined compression test for soil with 11% fluid content.

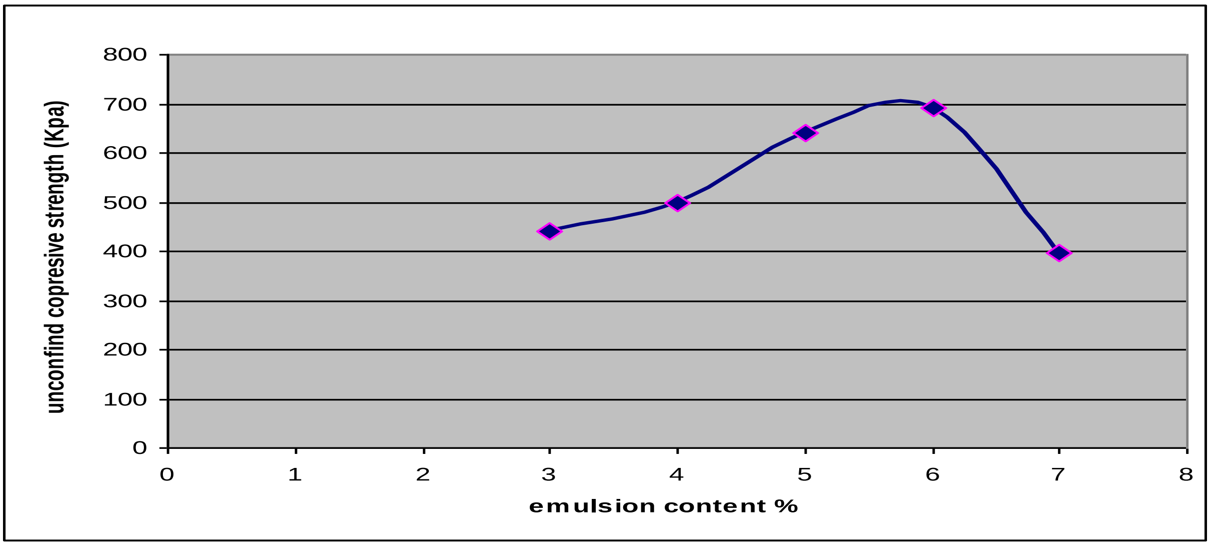

Figure 2. Unconfined compression strength – emulsion content (%) relationship.

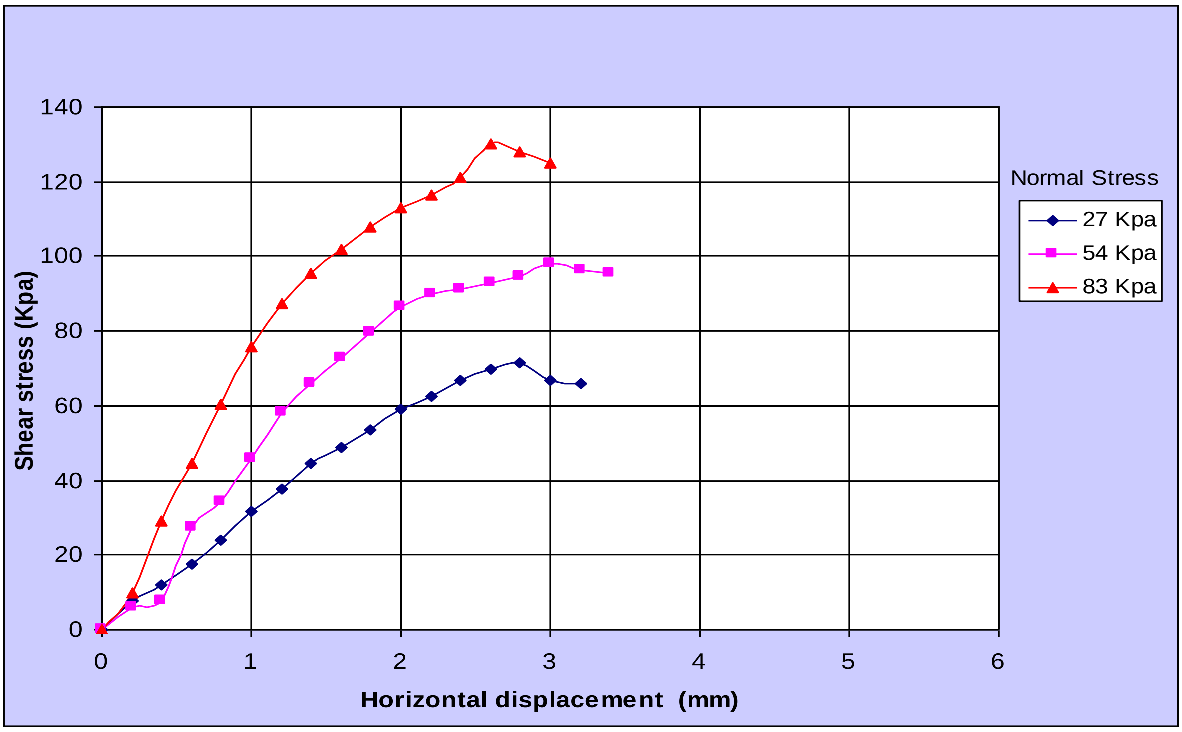

Figure 3. Shear stress- horizontal displacement relationship for non-stabilized gypseous soil (dry condition).

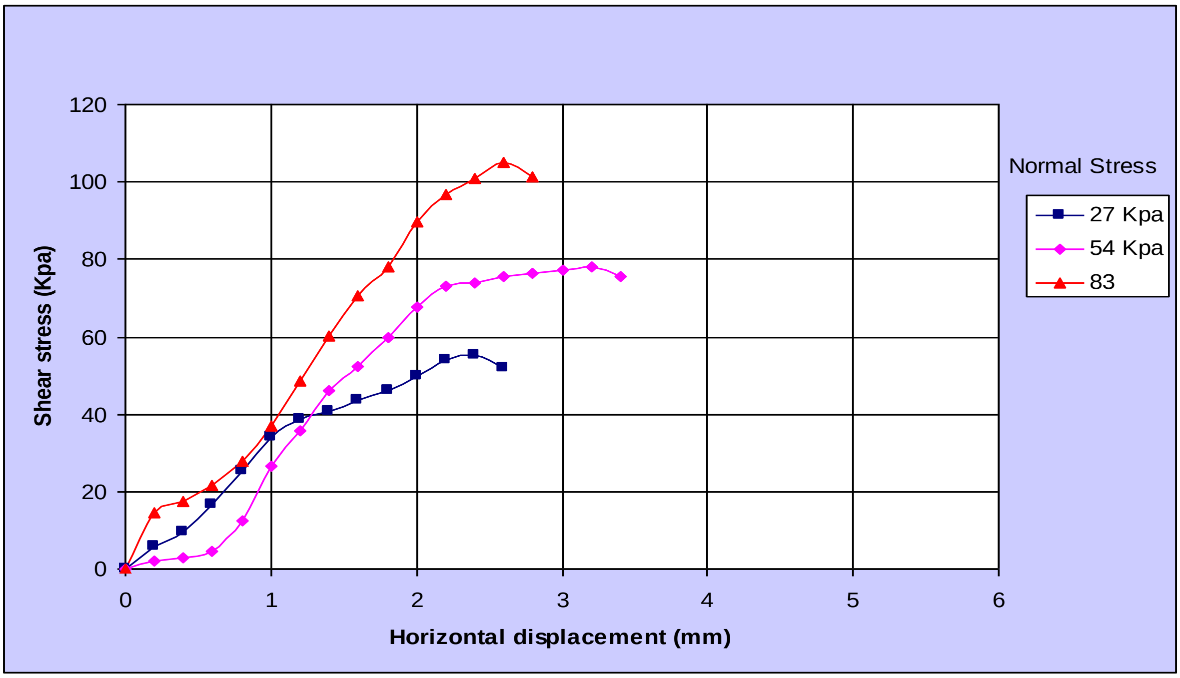

Figure 4. Shear stress- horizontal displacement relationship for non - stabilized gypseous soil (soaked condition) period time (3-4) hrs.

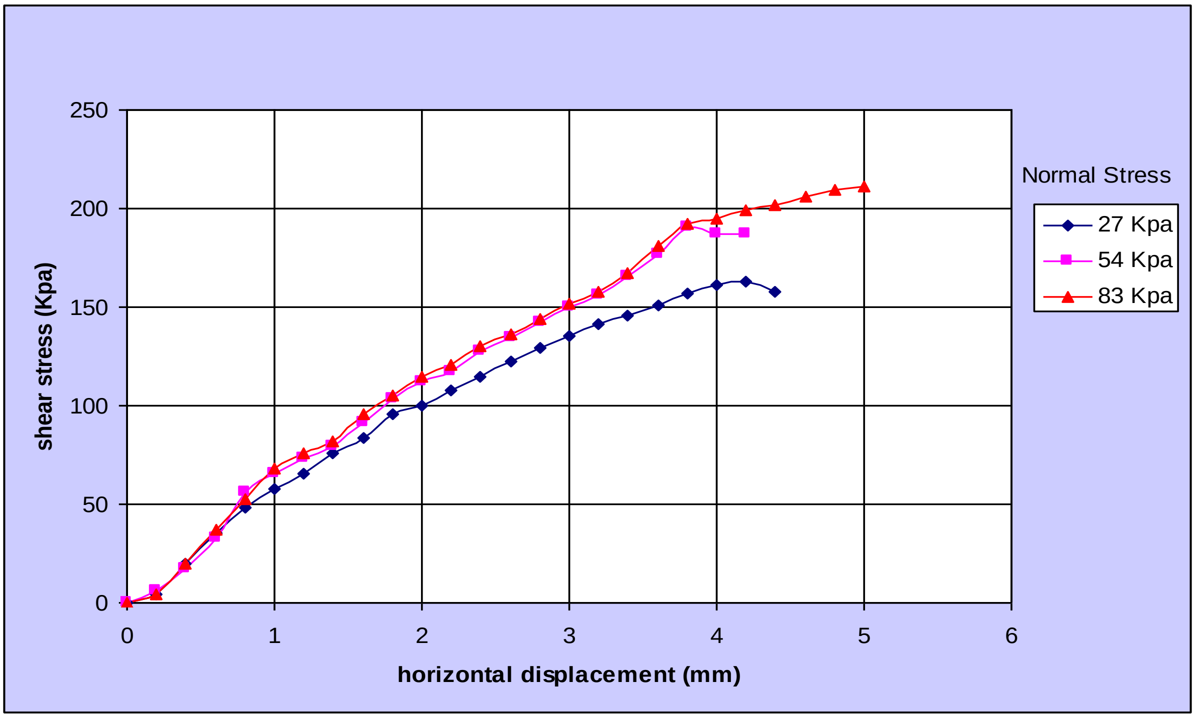

Figure 5. Shear stress- horizontal displacement relationship for stabilized gypseous soil with emulsion(dry condition). “0 aeration”

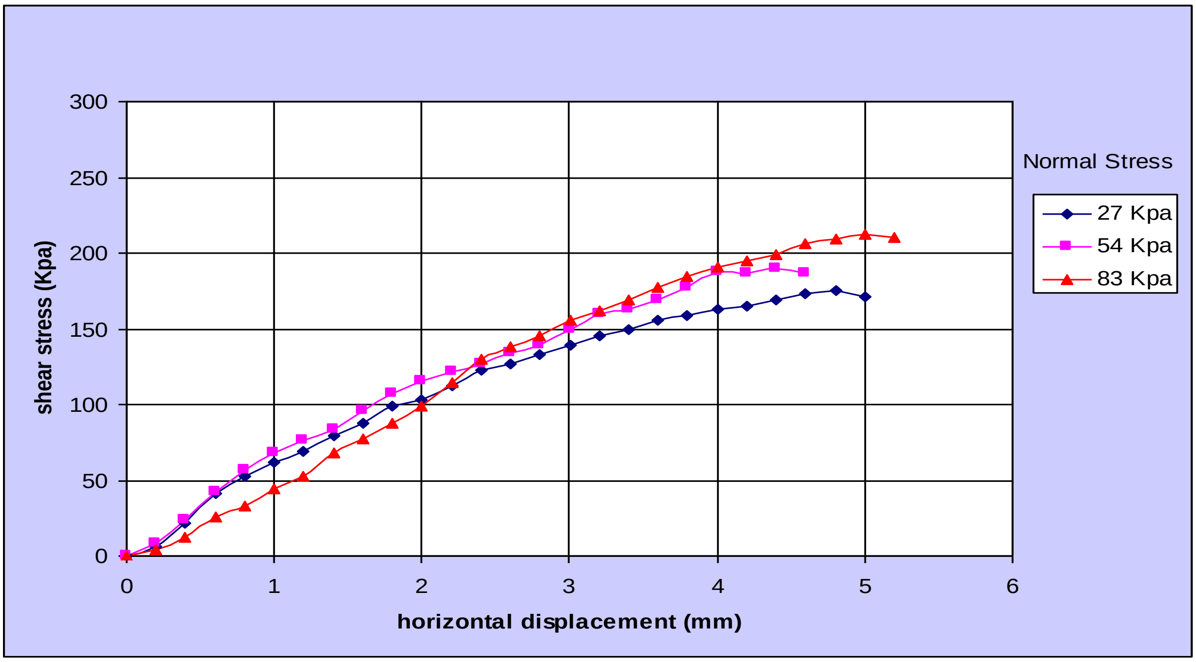

Figure 6. Shear stress- horizontal displacement relationship for stabilized gypseous soil with emulsion(dry condition). “½ hr aeration”

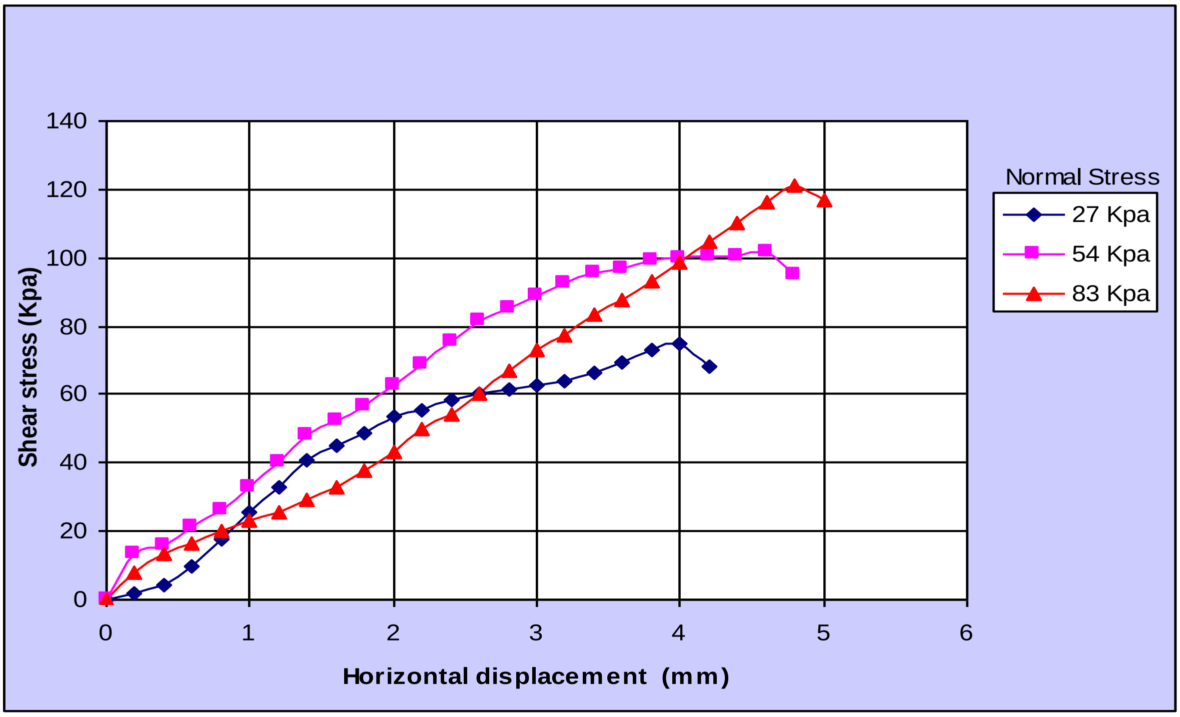

Figure 7. Shear stress- horizontal displacement relationship for stabilized gypseous soil with emulsion(soaked condition). " 0 aeration"

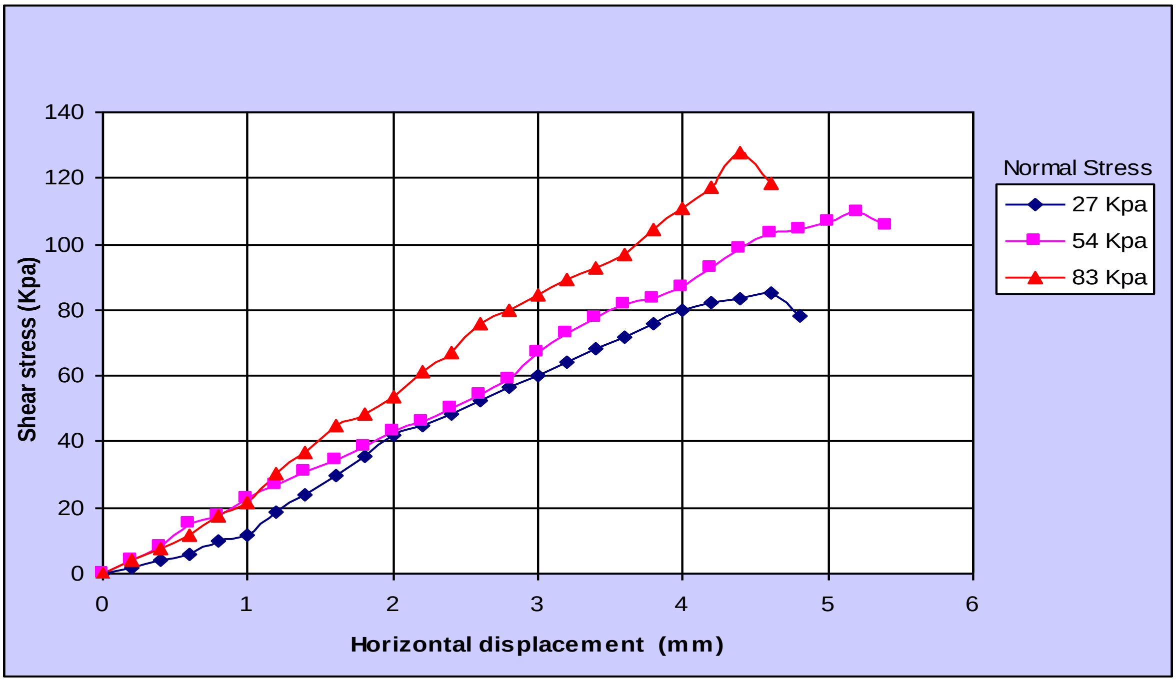

Figure 8. Shear stress- horizontal displacement relationship for stabilized gypseous soil with emulsion(soaked condition). " 2 hrs aeration"

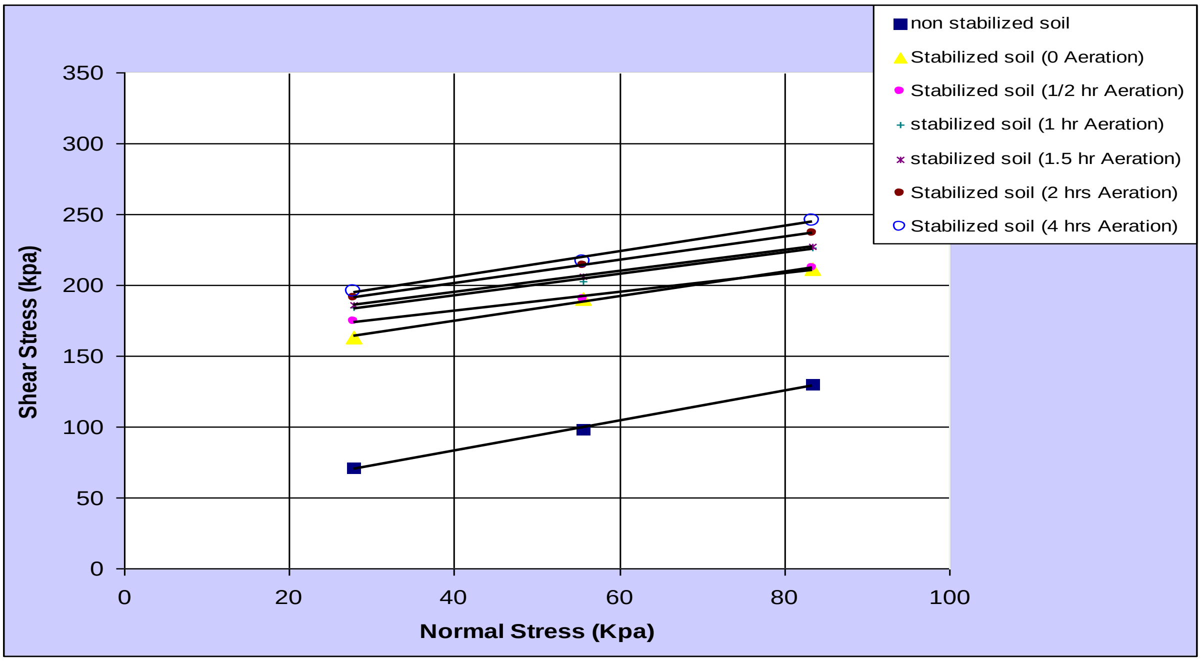

Figure 9. Direct shear test results for stabilized and non-stabilized.

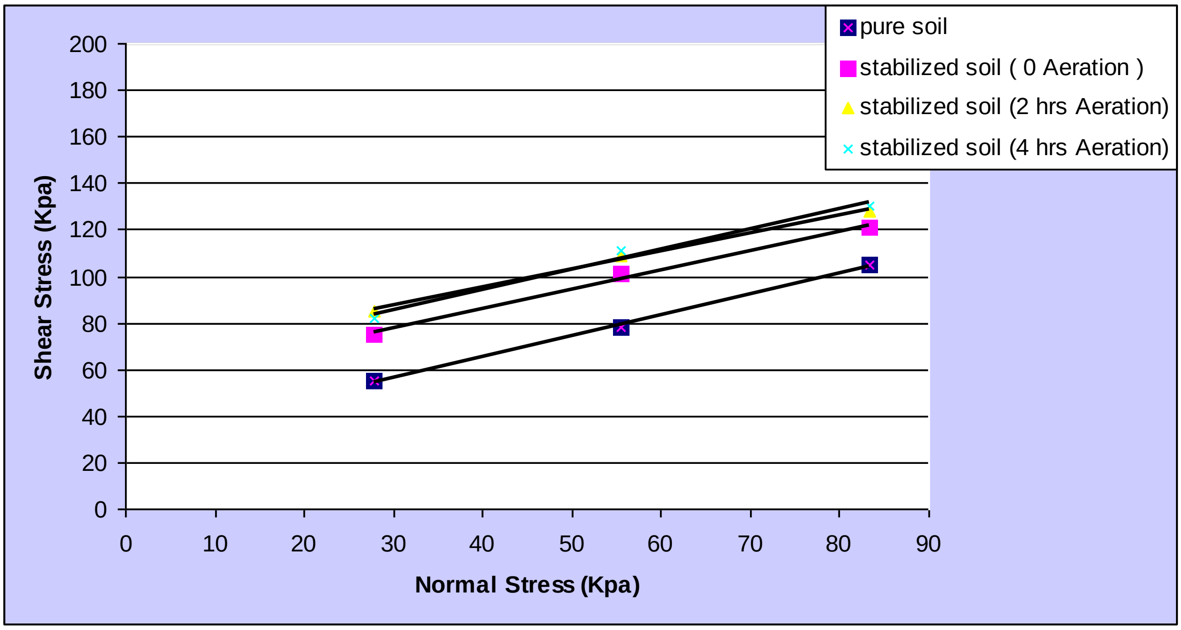

Figure 10. Direct shear test results for stabilized and non-stabilized gypseous soil under soaked condition with aeration technique.

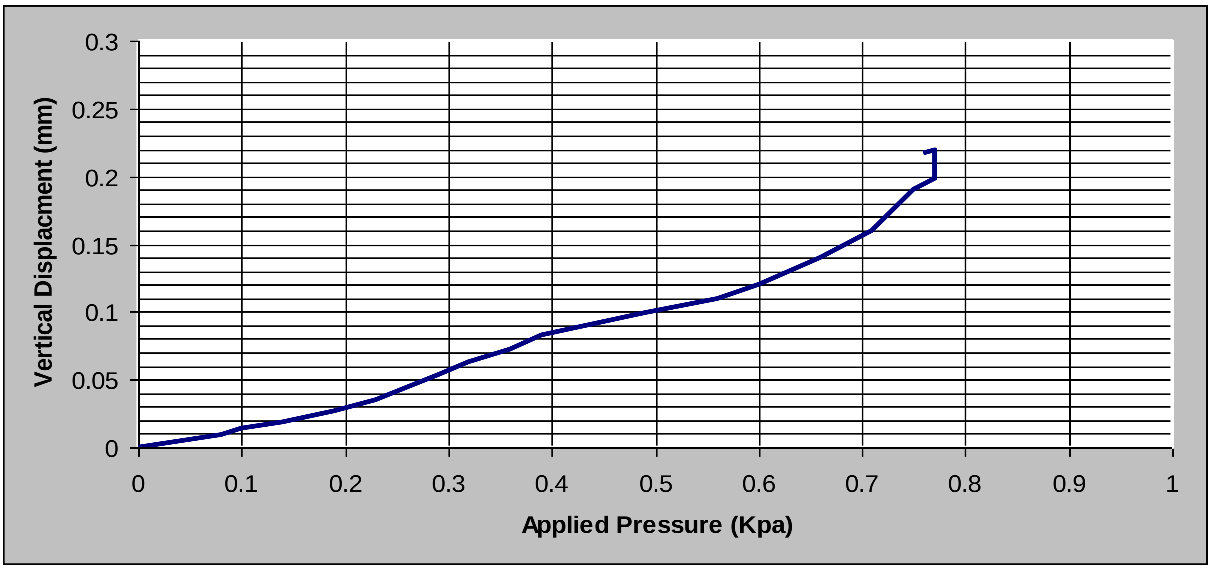

Figure 11. Applied pressure - vertical settlement for pure gypseous soil at dry condition.

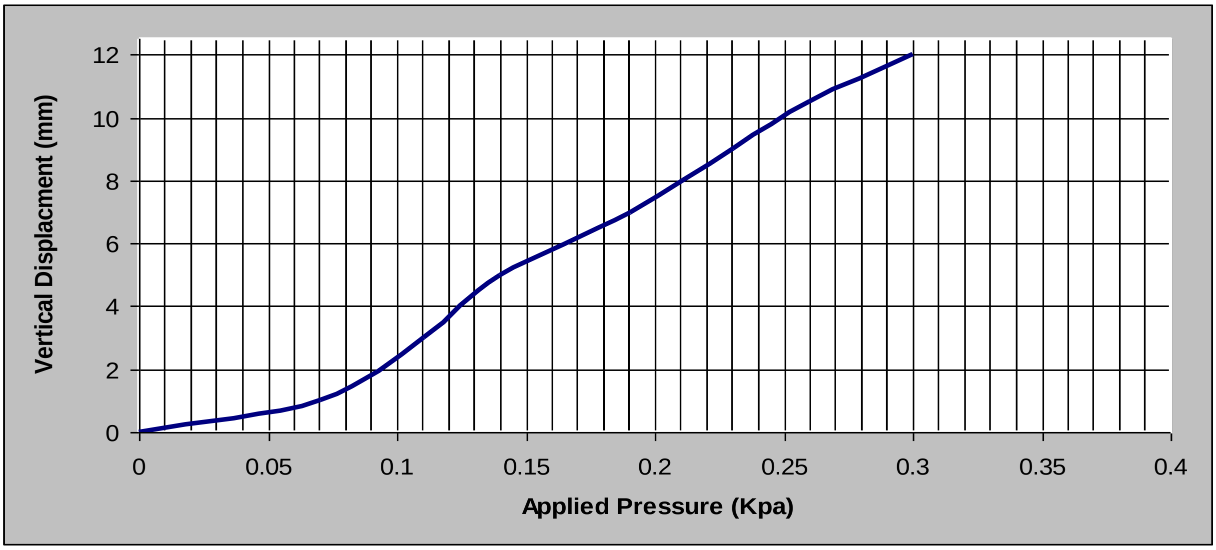

Figure 12. Applied pressure - vertical settlement for pure gypseous soil at hydraulic conductivity.

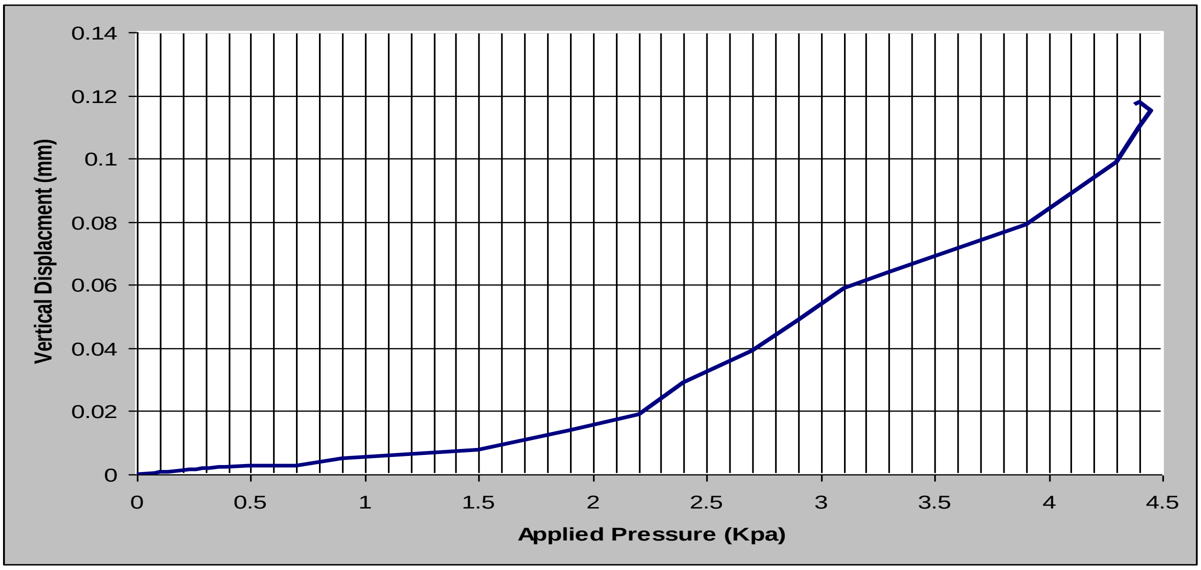

Figure 13. Applied pressure - vertical settlement for stabilized gypseous soil at dry condition.

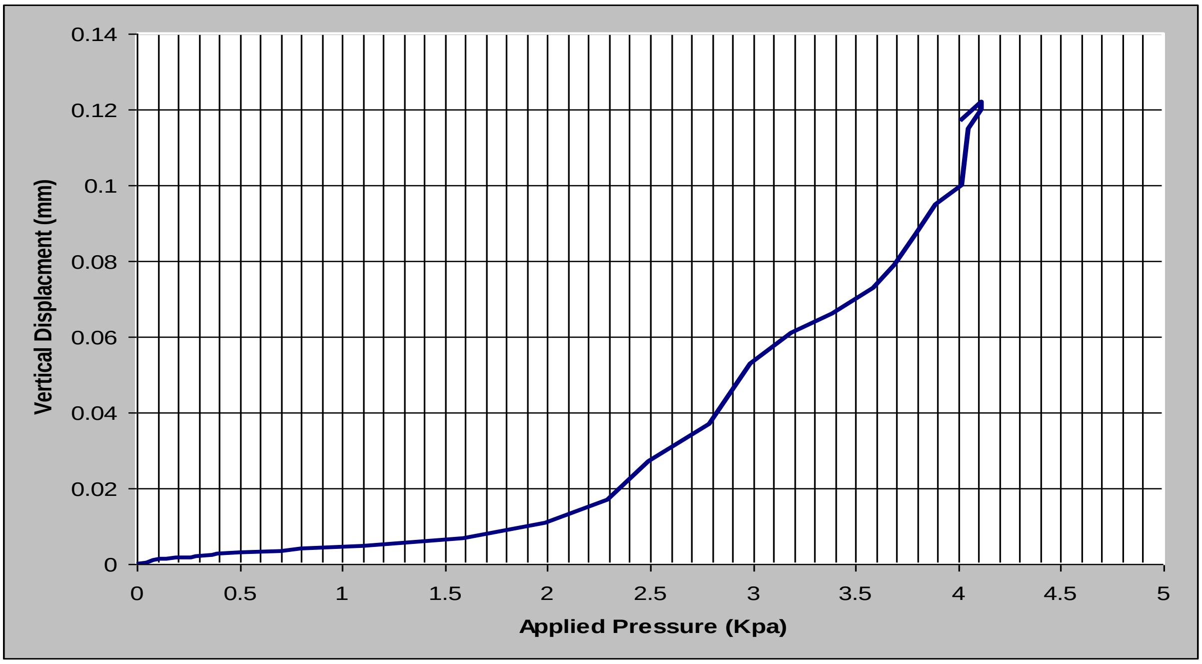

Figure 14. Applied pressure - vertical settlement for stabilized gypseous soil at absorbed condition.

Plate 1. Curing for specimens of soil stabilized with emulsion.

Plate 2. absorption technique for unconfined compression test.

Plate 3. Aeration technique in process.

Plate 4. Curing for specimens of soil stabilized.

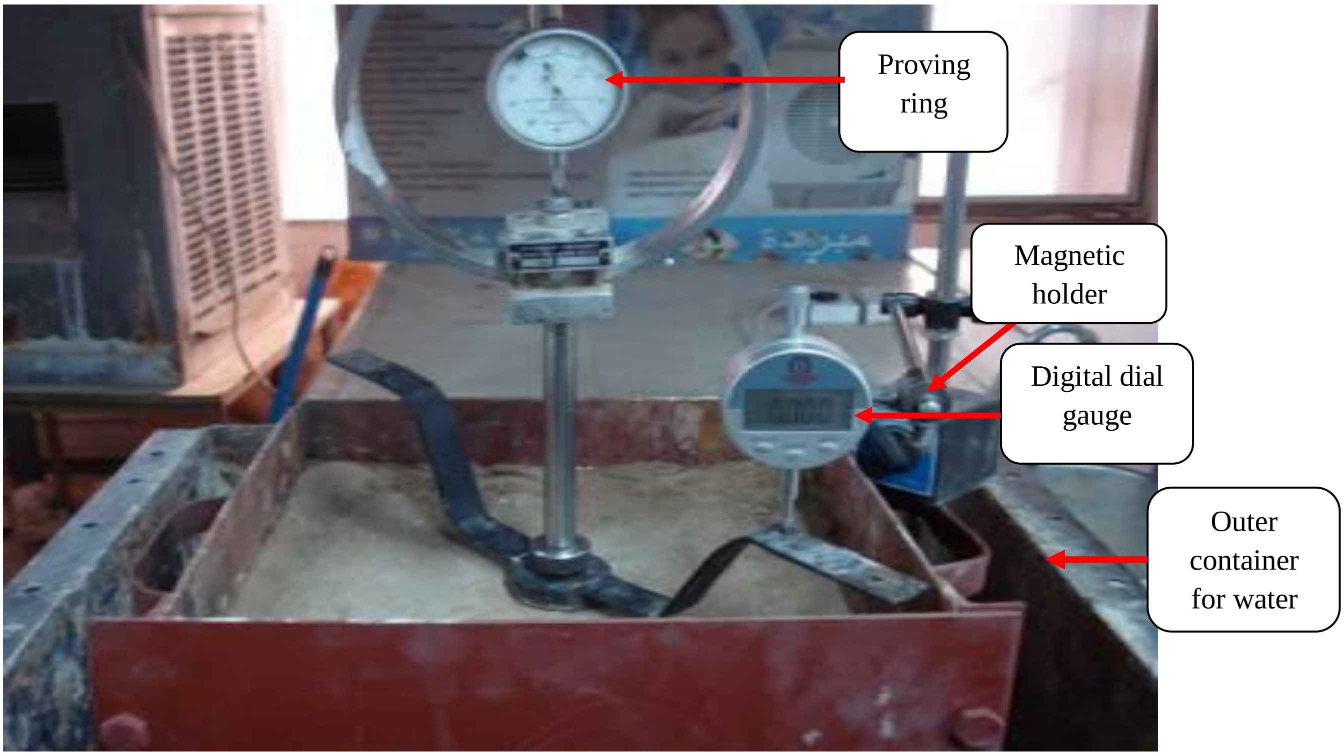

Plate 6. Set up of embankment model.

Plate 7. Punching failure after static loading test for the pure gypseous soil under absorbed condition.

Plate 8. Vertical deformation of tire print for stabilized embankment model.

Plate 9. Effect of hydraulic conductivity of asphalt stabilized soil on capillary rise of water after static loading application.