Behavior of Reinforced Gypseous Soil Embankment Model under Cyclic Loading

Prof. Saad Issa Sasam (saadisasarsam3@yahoo.com)

Asst. Prof. Dr. A`amal Abdulghani Alsaidi (dr_aamal@yahoo.com)

Asst. Teacher Omar Jabbar Mukhlef (almo7b_al3raqi@yahoo.com)

ABSTRACT

The construction of embankment for roadway interchange system at urban area is restricted due to the large geometry requirements, since the value of land required for such construction is high, and the area available is limited as compared to rural area. One of the optimum solutions to such problem is the earth reinforcement technique which requires a limited area for embankment construction. Gypseous soil from Al-Anbar governorate area was obtained and subjected to various physical and chemical analysis to determine it is properties. A laboratory model box of 50x50x25 cm was used as a representative embankment; soil has been compacted in five layers at maximum dry density (modified compaction) and an aluminum reinforcement strips were introduced between layers. The model was subjected to cyclic loading and the vertical and lateral deformations were detected at different stages of loading cycles using LVDT. The reinforced soil embankment under soaking condition exhibited vertical settlement at the top surface was (12.55 mm) while the lateral displacements at (1st, 3rd layer) were (2.18, 1.32) mm respectively at (47 load cycles).For reinforced gypseous soil, embankment without soaking cured for 24 hours, the Number of load cycles was found to be (165) loading cycles with vertical displacement (9.12 mm), that means an improvement of 59%. Accordingly, the lateral displacement in 1st and 3rd layers were (3.28, 2.59) mm respectively which observes improvement by (28% and 5%) respectively. The rates of improvement are taken with respect to the reinforced pure dry soil sample.

KEY WORDS: cyclic loading , gypseous soil , embankment reinforcement

تصرف التربة الجبسية المسلحة في التعلية الترابية تحت تأثير الاحمال الدورية

أ.سعد عيسى سرسم
أ.مساعد د.آمال عبد الغني السعيدي
مدرس مساعد. عمر جبار مخلف

الخلاصة:

ان انشاء التعليات الترابية في الطرق والمواصلات للمناطق الحضرية يكون مقيدا وذلك بسبب المتطلبات الهندسية للمساحة المحددة ذلك لان قيمة الاراضي تكون مكلفة للانشاء مقارنة بقيمة الاراضي في المناطق الريفية ، احد الحلول لمثل هذه المشاكل هي تقنية تسليح الاكتاف الترابية والتي لا تتطلق مساحة كبيرة للانشاء .التربة التي اجريت عليها الفحوص هي تربة جبسية من محافظة الانبار حيث اجريت عليها الفحوصات الفيزيائية والكيمائية لايجاد خصائص التربة.تم تصنيع موديل مختبري يمثل التعليات الترابية بابعاد 50 ×50 ×25 سم. تم رص خمس طبقات سمك كل طبقة 5 سم في الموديل المختبري بكثافة الحدل المعدل وتسليح كل طبقة من الطبقات بصفائح الالمنيوم ومن ثم تعريض الموديل المختبري الى

الحمل الدوري والذي تم تصنيعه محليا ليمثل حركة الاحمال الدورية على التعليات الترابية في الطرق والجسور حيث تم حساب النزول العمودي والازاحات الافقية من خلال جهاز الـ (LVDT) ، النزول العمودي الذي تم حسابة على الموديل المسلح بصفائح الالمنيوم والمعرض بالغمر كان (12.55)ملم بينما كانت الازاحات الافقية للطبقتين الاولى والثالثة هي (2.18 ، 1.32) ملم على التوالي عند 47 دورة تحميل. اما بالنسبة للموديل المختبري الجاف والمسلح بصفائح الالمنيوم حيث ترك في الهواء لمدة 24 ساعة ومن ثم تم تعريضه لفحص الحمل الدوري حيث كانت عدد دورات التحميل على الموديل 165 دورة تحميل سجل فيه نزول عمودي مقداره 9.12 ملم اما الازاحات الافقية كانت(3.28 و 2.59) ملم على التوالي .

الكلمات الرئيسيه : الحمل الدوري ، التربة الجبسية ، تسليح السداد الترابي

INTRODUCTION

The term gypseous soil is used to identify soils that contain gypsum. Gypseous soils are usually stiff specially when they are dry because of the cementation of soil particles by gypsum, but great losses in strength and sudden increase in compressibility occur when the soil is wet and the soil became collapsible or subjected to leaching because the cementing gypsum dissolves between soil particles. The construction of embankment for roadway interchange system at an urban area is restricted due to the large geometry requirements since the value of land required for such construction is high and the area available is limited as compared to rural area. One of the optimum solutions to such problem is the earth reinforcement technique which requires a limited area for embankment construction. On the other hand, the gypseous soil which covers vast area in west, middle, east and south west regions of Iraq exhibit acceptable strength properties when dry, but it is weak and collapsible when it comes in touch with moisture from rain or other sources. When such weak soil is adopted for earth reinforced embankment construction, it may exhibit hazardous situation. The loading type which an embankment will experience in the service life is the repeated load by Vehicles; it was felt that the behavior of such embankment under repeated (cyclic) loading must be investigated.

BACKGROUND

The concept of soil reinforcement is not a new one, the Ziggurats of Ur; 190 Km south of Baghdad and Agar-goof; 5 Km north of Baghdad is believed to be some 5000 years old and is constructed of clay bricks reinforced with woven mate of reeds.

In the modern context, reinforced soil began to be used during the early 1970's where, firstly steel strips reinforcement and later, geotextiles reinforcement were used in the construction of reinforced soil walls for slope stabilization. **[1]**

The present concept of systematic analysis and design of reinforced earth was first developed by a French Engineer, Henri Vidal in 1966 and later on, numerous works have been done by Darbin in 1970, Schlosser and Long in 1974, and Schlosser and Vidal in1969 on the use of metallic strips as a reinforcing material. Reinforced earth retaining walls have been constructed around the world since Vidal started his work. The first reinforced earth retaining wall with metal strips as reinforcement was constructed in 1972 in USA in the San Gabriel Southern California.

The use of geotextiles in soil reinforcement started in 1971 in France after their beneficial effect was noticed in the construction of embankments over weak sub grades. The use of geogrids for soil reinforcement was developed around 1980. **[2]**

The behavior of soil under cyclic stresses is more complex than the static, so difficulties arise when a realistic simulation of field conditions is required to be studied. **Das , (1983)** , mentioned five different laboratory test techniques which are available to determine the response of soil to cyclic loading **[3]**:

- ➲ Resonant column test
- ➲ Cyclic simple shear test
- ➲ Cyclic torsional shear test
- ➲ Shake table test
- ➲ Cyclic triaxial compression test

The resonant column tests are used to measure dynamic soil properties at small strain magnitudes, while the other tests are used to determine the soil behavior under cyclic loading. Triaxial cyclic testing of soils started on a large scale in the late 1950, since then several triaxial setups and test procedures have been introduced **.[4]**

AL-Mosawe , (1998), showed that the volume change due to cyclic loading of saturated sand by water is greater than that for the dry and saturated by petroleum products (kerosene and gasoil) .This was attributed to the dissolution of the soluble salt contained between soil particles, Fig. (1).The deformation of oil contaminated sand under cyclic loading , was of the same trend to that of (dry and saturated) sand **[5].**

Many reinforced soil structures may be subjected to repeated or cyclic surcharge loading. The source of such loading comes from wave action, axle load wind loading, fluctuation of water table ...etc. little attention has been given to the long term effects of repeated loading on reinforced earth structures.

Al-Ashou, (1981) carried out a large scale model repeated loading tests on instrumented reinforcing steel strips in dry sand. His results indicated an initial stable state followed by a short failure stage, with accelerated movement, which led to rapid pull-out of the reinforcement. The effect of repeated loading is to cause a redistribution of load along the reinforcement and break down of the frictional resistance at the soil/reinforcement interface. It was found that the ultimate pull-out capacity of strip reinforcement may be reduced by (20-35)% after repeated loading**.[6]**

EXPERIMENTAL PROGRAM

The soil of this investigation was taken from Anbar University- Al-Ramadi city, Al-Anbar Governorate, west of Iraq, has been implemented for the testing program; Table (1) shows the physical and chemical properties of the soil.

APPARATUSES OF MODEL

The apparatuses of modle includs as fallow:

a. Steel Box with dimenssion 50×50×25 cm
b. Shaft for repeating load
c. LVDT stands for Linear Variable Differential Transformer. An LVDT is also referred to as a linear displacement transducer, or linear position transducer. This sensor device measures linear displacement (or linear position) very accurately. (calibrated as 1mm = 0.004 V)
d. Electronic dial gauge (accurcy (0.01 mm)
e. Aluminum strips :(Aluminum strips were groved and drilled). The Aluminum strips when were drilled and grooved give us higher risitance to the shear as **Al-Basri, (2012**) reported
f. Load (the load was portion of maximum bearing capacity of soil which was taken 10% from bearing capacity for puer soil under absorption condition)

g. Electric motor(electric power : two hores , 1400 r/m)
h. LVDT holder
i. Avometer
j. Tire print with (2) inch of diameter and it has 0.5 inch thickness
The details can be shown in the plate (1) below .

PREPARATION OF SOIL EMBANKMENT MODEL FOR CYCLIC LOADING

The test was adopted for soil embankment model with optimum moisture content. The dry density was (95% of modified compaction test). two soil embankments model were prepared for testing under cyclic loading .Embankments soil model for cyclic loading which absorbed pure soil and dry pye soil were carried out as follow :

In order to reach the required predeterminated dry density of (18.05) KN/m^3 which equal 95% of modified comaction test, the volume of soil used to compact five layers in metal box was (62,500) cubic centemeter , then by multyplying this volume by the used dry density (95% of modified compaction test) , the wiegth of the required soil was determinated and devided to five layers each layer of pure soil mix at its optimum moisture content. Soil was mixed throughly with water then save in nylon bags to insure homogeous of the mix. The static compaction was used for each layer.

Grooved and drilled aluminum strips were used as reinforcement of pure soil. The strips laid over each compacted layer, one end of strip was attached to the face strips box. The number of strips and their postions in the box were demonstrated in fig (2 and 3) .

CYCLIC LOADING TEST

The model of repeated load system consisted of a load with shaft , the load was repeatedly applied by electric motor. The repeated load mechansim and wave pattern are shown in fig(2).

The repeated loading was generally taken as a percentage of the ultimate static bearing capacity of the pure soil in soaking condition (critical condition)

Thus in complete loading cycle , the footing settlement was recorded at the end of loading cycle by LVDT which it was attached with ovemeter to read the settlement as voltage (calibrated as 0.004 V = 1mm) So the digital camera used in this test for computing the loading cycles with settlement.

The load was applied in cycles and the vertical and horizontal deformation were observed through electronic dial gauges. Two locations has been detected to be critical. For horizontal deformation the level (1) and level (2) as shown in plate(4)

FAILURE CRITERIA IN SOIL EMBANKMENT MODEL

In UK, **Lister (1972)**, it is recommended to use deflection criteria that should ensure that the rutting is not exceeding (12.5 mm) in depth. The classification of pavement condition as used in T.R.R.L method, **Molenar,(1982)** is as table (2) below

Rut depth of (0.5) inch was used as a failure criterion for thickness design in Kentucky**, Jain, (1980)**. The value of (0.5) inch used as failure in the soil embankment model were based on the depth of rutting made in the top soil due to cyclic loading.

PREPARATION OF EMBANKMENT MODEL AND TESTING

Two soil embankment models have been constructed as per the procedure. First box was constructed using absorbed pure soil, The soil embankment model contains soil compacted in five layers each layer (5cm) , the box was also subjected to the compaction and reinforcement. The box model was subjected to the partial immersion in water for three days to allow the water to rise through the capilary action then subjected to the cyclic loading test as shown in plate (5). this procedure may represent the behavior of embankment in the fieled when rain water accumulates at the base surrounding for few days at the location.

The second soil embankment model which was for dry pure soil. It was left 24 hrs to allow for the chemical reaction between the water content and the Gypsum exsisting in the soil to take place. After curing the box was supjected to cyclic loading in model without soaking as shown in plate (6).

RESULTS AND DISCUSSION

The first test was on a pure gypseous soil embankment model and reinforced with Aluminum strips which were grooved and drilled and subjected to capillary rise of water through addition of water to model till water rise to third layer then left for three days, then, that found the level of water reduce to fifth layer due to water absorption in soil. The second test was carried out on a dry pure soil embankment model cured for (24) hours in air and reinforced with Aluminum strips which were grooved and drilled. Data are as described in the table (3) and figures (4.15- 4-22) below

The model of absorbed pure soil reinforced with strips was considered as a reference to dry pure soil reinforced model as an improvement percentage, while the dry pure soil embankment model with reinforcing strips was considered as a reference for the stabilized embankment model with cutback MC-250 and emulsion as an improvement percentage.

TEST OF CYCLIC LOADING ON PURE SOIL EMBANKMENT MODEL WITH REINFORCING STRIPS SUBJECTED TO ABSORPTION CONDITION:

The first test of cyclic loading was carried out on a soil embankment model. No stabilization is performed in this test but the model was allowed to face capillary rise of water for (3) days.

The relationship of Log. No. of loading cycles – vertical displacement results at the top soil are given in table (2) while the corresponding characteristic curve representing the Log. of loading cycles – vertical displacement behavior is given in figure (3).The lateral deformations of the 1^{st} and 3^{rd} soil layers with log no of loading cycles are presented in figure (4).

The first soil embankment model which was pure reinforced soil and subjected to capillary rise was tested under cyclic loading till the soil embankment model was failed in rutting depth as mention above. it was found that the No. of cycles of cyclic loading (47 cycles) as shown in table (2) with vertical displacement (12.55 mm) and lateral displacement for 1^{st} and 3^{rd} layers were (2.18 mm) and (1.32 mm) respectively as shown in fig.(3) and (4).

As noted that the lateral displacement in first layer (1^{st} layer) was more than the third layer (3^{rd}), because the cohesion and interlacement were reduced due to dissolved the gypsum in the water. In plate (7) and (8) shows the failure in sample due to cyclic loading, it was shown the tire print was penetrated the top soil sample.

TEST OF CYCLIC LOADING ON DRY PURE SOIL EMBANKMENT MODEL WITH REINFORCING STRIPS:

The second test of cyclic loading was carried out on a dry pure soil embankment model compacted in five layers with reinforcing strips (grooved and drilled Aluminum). The soil embankment model was curing in air for (24) hours. Table (2) shows the No. of loading cycles and vertical displacement results at the top soil while the corresponding characteristic curve representing the Log. of loading cycles – vertical displacement behavior is given in figure (5).The lateral deformations of the 1st and 3rd soil layers with log no of loading cycles are presented in figure (6).

For the second dry pure soil embankment model with reinforcing strips was tested in cyclic loading test. The No. of loading cycles of cyclic loading was (165 cycles) as shown in Table (2) with vertical displacement (9.216 mm) and the lateral displacements of (1st layer) and (3rd layer) were (3.28 mm) and (2.59 mm) respectively. But, when the No. of cycles for this model at (47 cycles), the vertical displacement was (3.77 mm) and lateral displacement for (1st layer) and (3rd layer) were (1.56 mm) and (1.26 mm) respectively as shown in fig.(5) and (6) above. As observed from the above results , the number of cycles has increased with respect to the absorbed pure soil. And reducing in vertical displacement by (- 59.06%) and lateral displacement in (1st layer) by (-28.4%) and (3rd layer) by (-4.5%) have been noticed. this reduction in vertical and lateral displacements due to cementation of gypsum content which increases the friction between the soil particles and strips reinforcing. Plates (9) shown that the test of cyclic loading on the dry pure soil embankment model.

CONCLUSION

1. The reinforced soil embankment under absorption condition exhibit vertical settlement at the top surface was (12.55 mm) while the lateral displacements at (1st, 3rd layer) were (2.18, 1.32) mm respectively at (47 load cycles).

2. For reinforced gypseous soil, embankment without soaking cured for 24 hours, the No of load cycles was found to be (165) with vertical displacement (9.12 mm), that means an improvement of 59.06%. Accordingly, the lateral displacement in 1st and 3rd layers were (3.28, 259) mm respectively which observes improvement by (28.4% and 4.5%) respectively.

REFERENCES

Das. B., (1995) "Principles of Foundation Engineering".

Reddy, D.V.,(2003) " Long- term Behavior of Geosythetic reinforced Mechanically Stabilized Wall system", Department of Civil Engineering Florida Atlantic University, Boca Raton, FL33431, January, 2003.

Das , B. M. , (1983) , "Fundamentals Of Soil Dynamics" ,Elsevier , New York .

Khosla , V. K. and Singh , R. D. , (1983), "Apparatus for Cyclic Stress Path Testing" , Geotechnical Testing Journal ASTM , Vol. 6 , No. 4 , PP. 165-172 .

Al-Mosawe , M. J., (1998), "The Effect of Cyclic Loading on The Behaviour of Sand saturated with Petroleum Products" Al-Muhandis , No. 134 . PP. 35 - 52 .

Al-Ashou, M.O., (1981); "The behaviour of reinforced earth under repeated loading" Ph.D Thesis, Sheiffield university, England.

Lister N.W. and Addis R.R. , (1972) " Field Obsevation of Rutting their Practical

Molenar A.A, (1982) " Visual condition surveys, A tool in the planning of maintenance". proceding , seminar on maintenance and drainage aspects of road pavements - Barigalore July India.

Al-Basri, M.A.F (2012);"Assessing Frictional Behavior of Earth Reinforcement Embedded in Asphalt Stabilized Gypseous Soil". M. Sc. Thesis, Civil Engineering Department, University of Baghdad.
Implication", T.R.R. No 640, (P 28-38)

Table (1). Physical and chemical

Soil classification	**P C_U= 0.2 C_C= 6**
Liquid Limit (L.L %)	**23 %**
Plastic Limit (P.L %)	**Non Plastic Soil**
Plasticity Index (IP)	**Non Plastic Soil**
Maximum Dry density using standard test	**17.25 kN\m3**
Optimum Moisture Content, standard compaction test	**14.5%**
Maximum Dry density using modified test	**19.00 kN\m3**
Optimum Moisture Content, modified compaction test	**10.5%**
Specific Gravity (Gs)	**2.49**
TSS %	**44.0 %**
Gypsum content	**40.0%**
CO3 %	**0.27%**
PH	**8.1**

properties of gypseous soil

Table (2) shows the rut depth

Rut depth	Less than 10 mm	10-20 mm	Greater than 20 mm
Condition	Sound	Critical	Failed

Table (3) Results of deflection and number of loading cycles for cyclic loading test

Embankment Model Type	Total No. of loading cycles	Total Vertical displacement In (mm)	Total Horizontal displacement in (mm)	
			1st layer	3rd layer
Pure soil subjected to water absorption	47	12.55	2.18	1.32
Pure soil without soaking	165	9.216	3.28	2.59

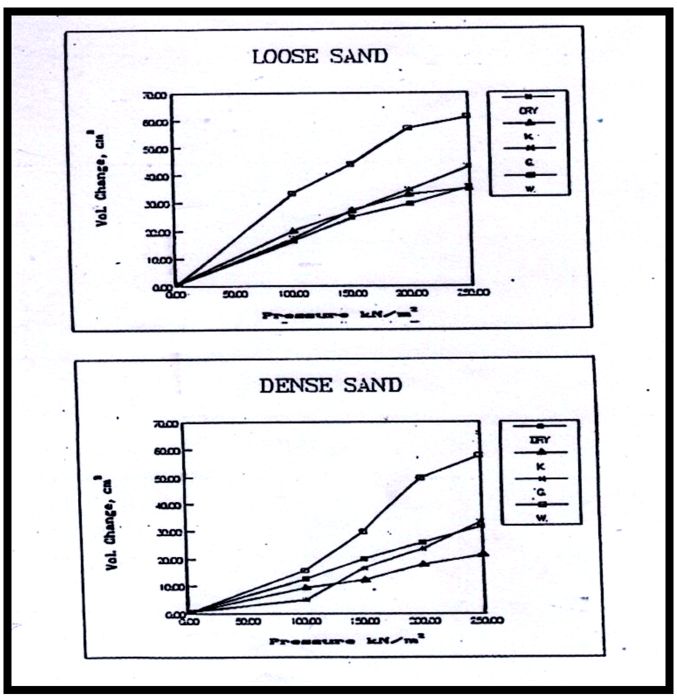


Fig. (1) Volume change due to cyclic loading (after 20 cycles) for dry and saturated by different liquids ,sand (after Bourdea,(1990).

1. LVDT holder
2. Box for soaking
3. Steel arm
4. Steel frame
5. LVDT
6. Pulley small D
7. Pulley large D
8. Electric motor
9. Load
10. Ovemeter
11. Soil specimen

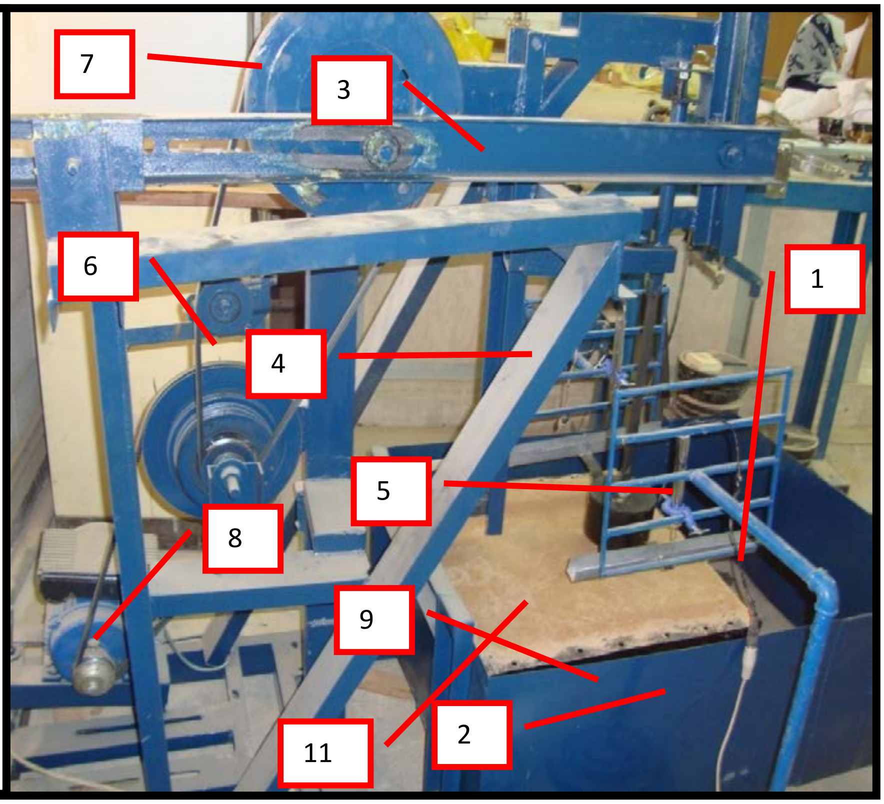


Plate (1) General view for set up of Model

Plate (2) Soil Embankment model preparation (pure soil)

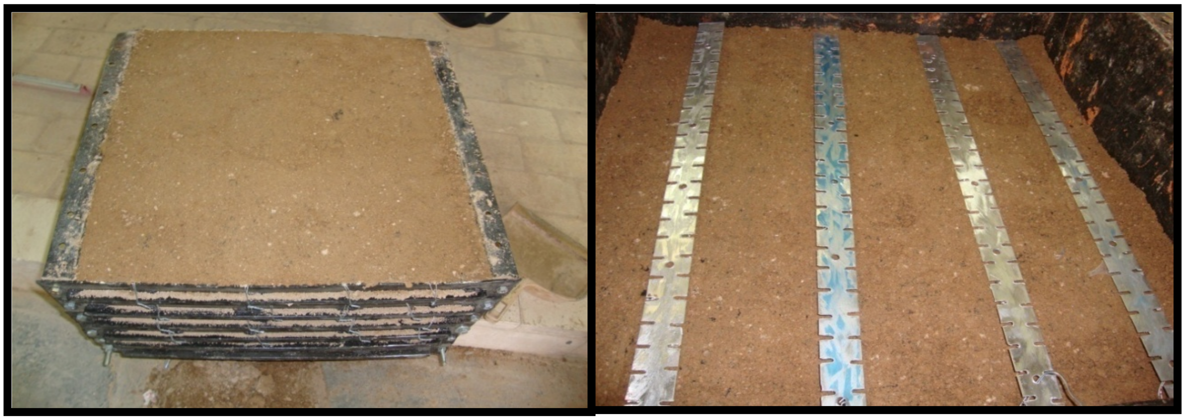
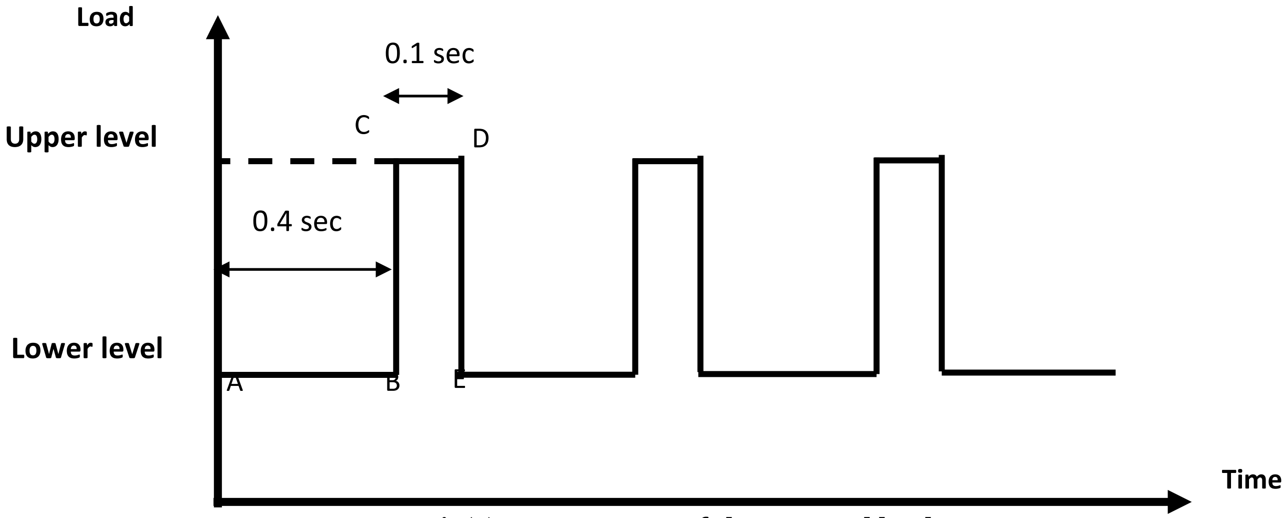


Plate (3) Soil Embankment model preparation (pure soil)



Fig(2) Wave partten of the repeated load

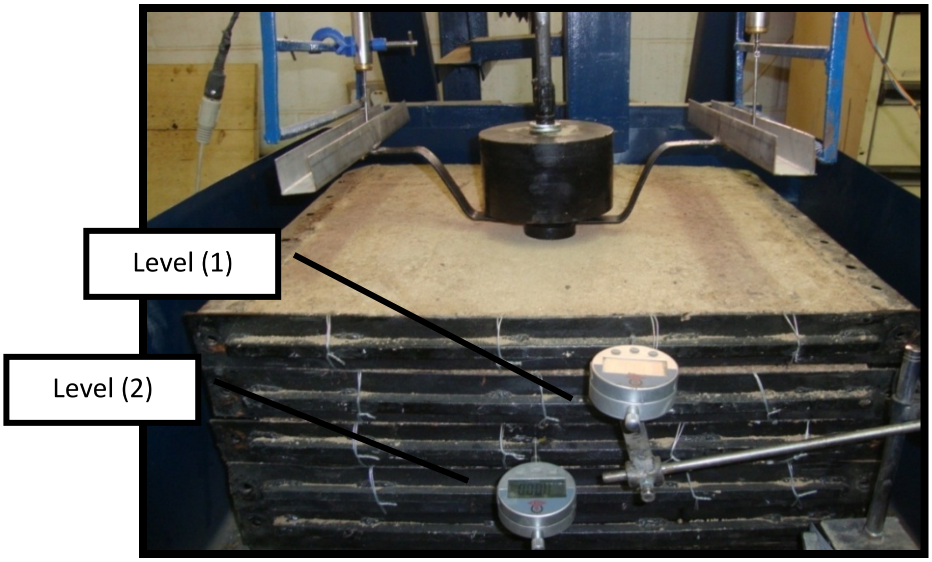


Plate (4) The loactions of electronic dial gauges

Plate (5) Soil Embankment model of pure soil subjected to absorption water in cyclic load model

Plate (6) Soil embankment model of pure soil in cyclic load model

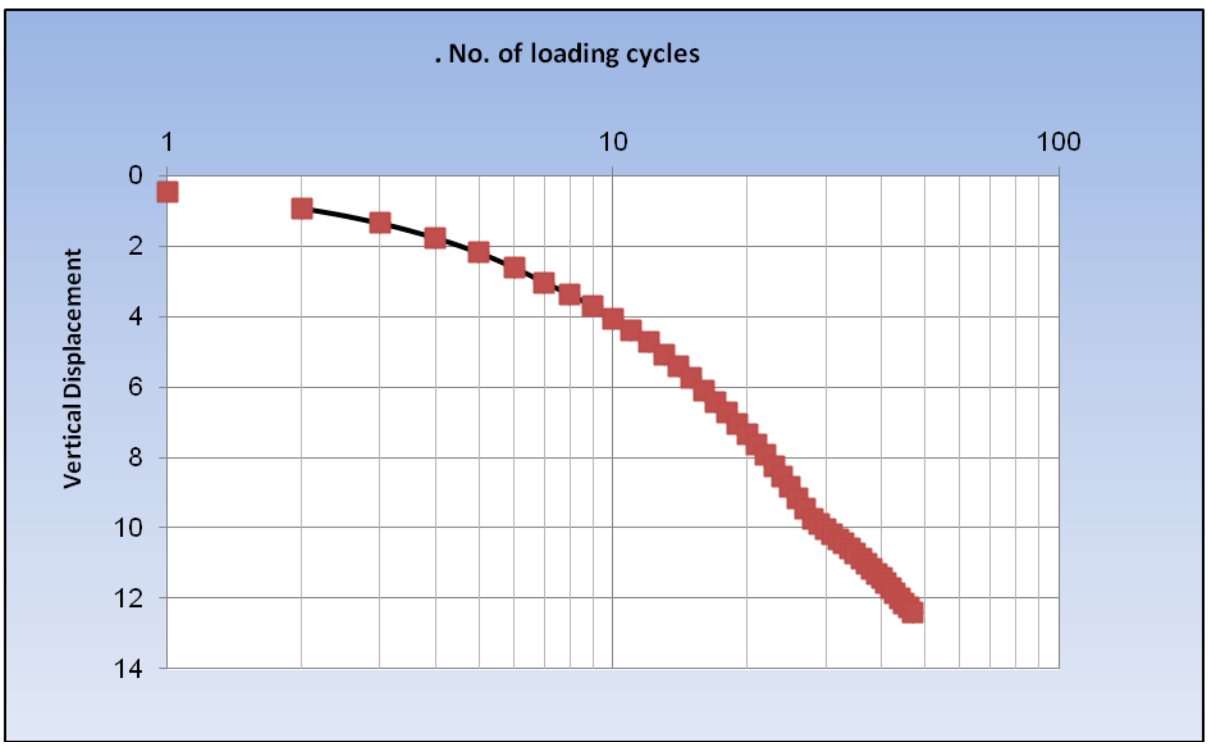


Fig.(3) Relationship between No. of loading cycles and vertical displacement for absorbed pure of gypseous soil embankment model

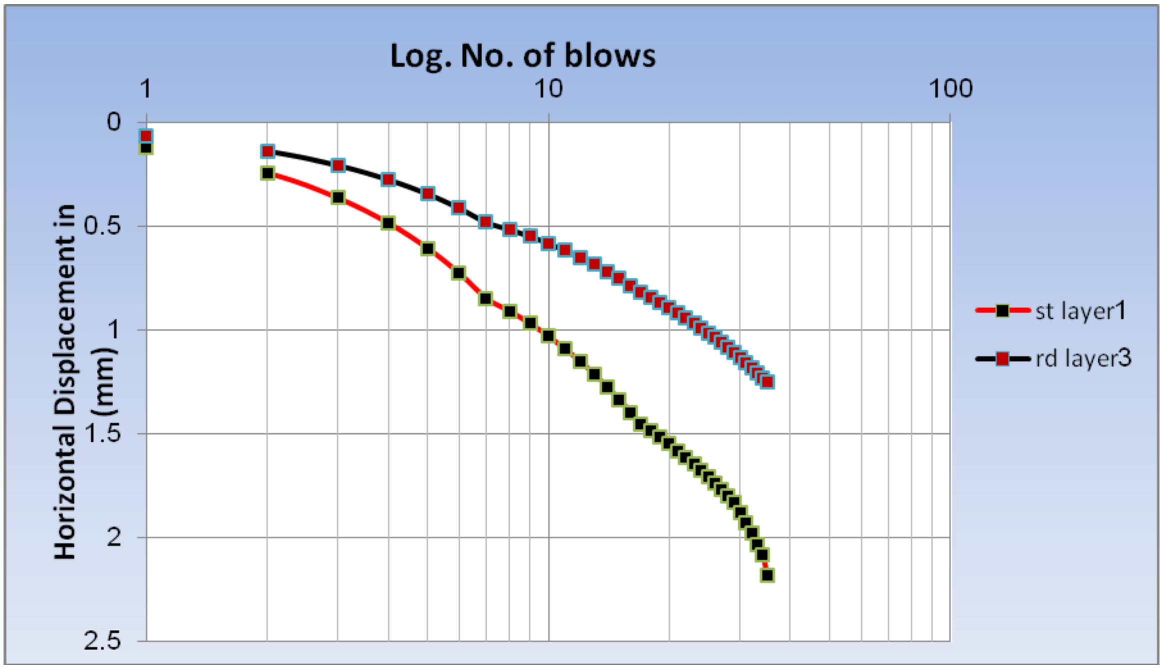


Fig.(4) Relationship between No. of loading cycles and horizontal displacement for absorbed pure of gypseous soil embankment model (1st&3rd) layers

Plate(7) The failure in pure soil embankment model subjected to the capillary rise due to cyclic loading.

Plate(8) The lateral displacement in pure soil embankment model subjected to capillary rise due to cyclic loading.

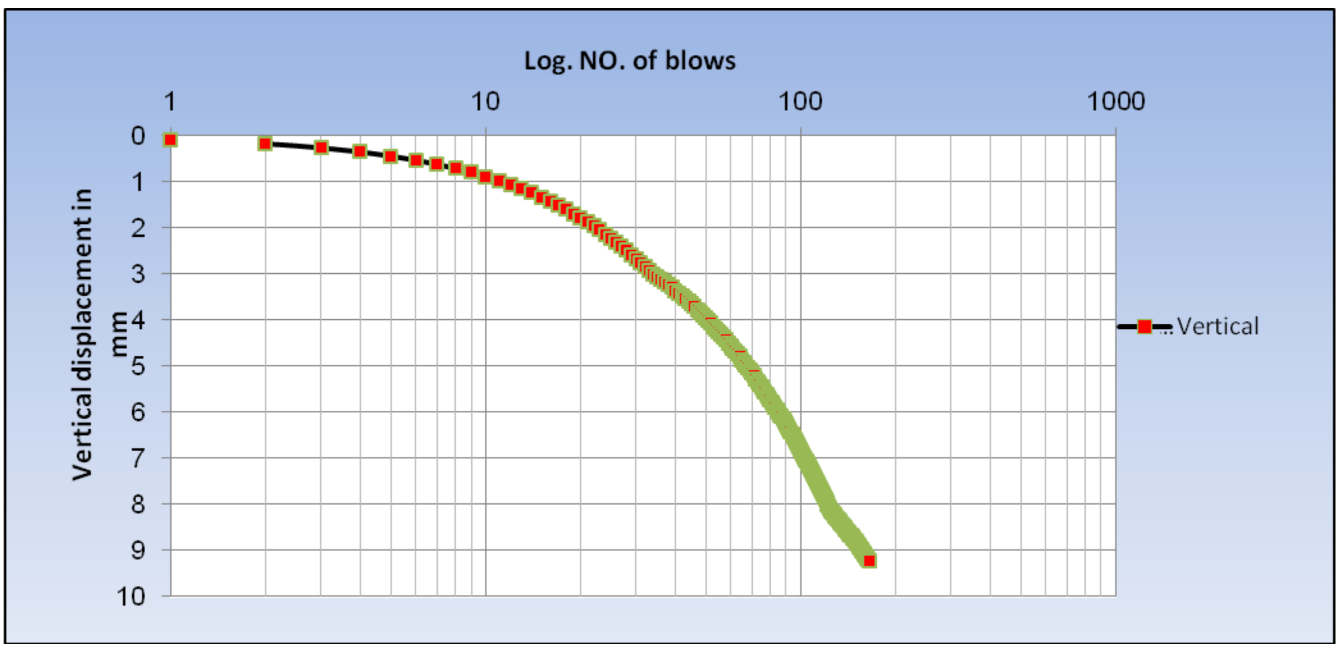


Fig.(5) relationship between Log. No. of loading cycles and vertical displacement for dry pure soil embankment model

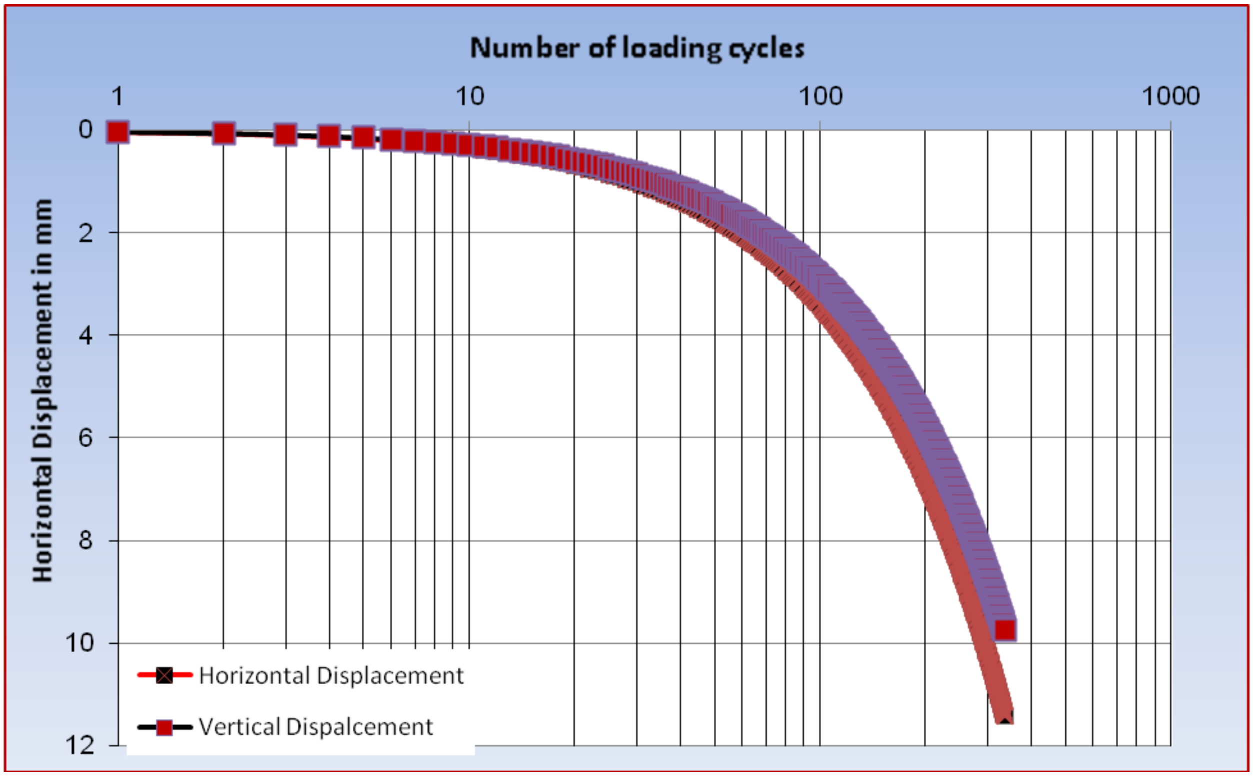


Fig.(6) Relationship between No. of loading cycles and horizontal displacement of dry pure soil embankment model (1^{st}&3^{rd}) layers

Plate (9) The cyclic loading test on dry pure soil embankment model shows the cracks in top soil.