Evaluation of Reinforced Sub-Base Layer on Expansive Sub-Grade Soil

Dr. Mohammed Y. Fattah
Building and Construction Engineering Department, University of Technology/ Baghdad
Dr. Aqeel S. Aladili
Building and Construction Engineering Department, University of Technology/ Baghdad
Hussam F. Yousif
Building and Construction Engineering Department, University of Technology/ Baghdad
Email:hussamfy120@gmail.com

Received on:21/10/2015 & Accepted on:19/5/2016

ABSTRACT

Reinforced pavement layers have been gaining popularity in the field of civil engineering due to their highly versatile and flexible nature. With the advent of geosynthetics in civil engineering, reinforced earth technique has taken a new turn in its era. The practice of reinforced earth technique became easy and simple with geosynthetics. The research requirements are providing the materials and manufacturing of the loading machine (loading test apparatus). Materials include soil (bentonite), granular sub base, sand, and geogrid. The testing program consists of preparing of 6 models that represent layers beneath flexible pavement layers (subgrade and sub base layers). The model dimensions are 800*800*800 mm, subgrade layer is 400 mm thick and sub base layer 300 mm thick. The model tests include using geogrid reinforcement at the interface of the subgrade and sub base layer and in the center of sub base layer.

It was concluded that a geo-grid reinforced soil is stronger and stiffer and gives more strength than the equivalent soil without geo-grid reinforcement. Geo-grids provide improved aggregate interlock in stabilizing road infrastructure through sub base restraint and base reinforcement applications, Geo-grid reinforcement provided between the sub base course and subgrade soil carries the shear stress induced by vehicular loads and thus it reduces the load transferred to the subgrade and the volume changes induced by swelling of the subgrade soil. The load carrying capacity of the pavement system is significantly increased for geogrid reinforced sub base stretch compared to unreinforced sub base layer on expansive soil subgrade. Comparison of the results of the model without geogrid reinforcement with other models reveals that there is an increase in the bearing capacity of model that includes geogrid reinforcement at the interface of subgrade by about 40%; and 20% for the model that consists of geogrid reinforcement in the center of sub base layer.

Keyword: Expansive soil, geogrid reinforcement, static test, saturated

INTRODUCTION

https://doi.org/10.30684/etj.34.9A.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq

The subgrade of any foundation plays an important role in load bearing and support of traffic and pavement construction over expansive clays requires a suitable working platform to enable machinery to operate. Studies show that the use of safe bearing capacity for subgrade assessment does not suit CH (highly cohesive) soils. Subgrade treatment needs to be a mandatory consideration coupled with using the lowest California Bearing Ratio CBR readings to provide the maximum pavement thickness. The most effective method of subgrade treatment currently appears to be geosynthetics placed on the subgrade. Expansive soils are known to cause damage mostly to light structures, such as residential dwellings and road pavements. The losses due to extensive damage to highways running over expansive soil subgrades are estimated to be in billions of dollars all over the world (Jones and Holtz, 1973 and Steinberg, 1992).

Characteristic expansive or swelling soils are highly plastic clays and clay shale that often contain colloidal clay minerals such as the montmorillonite. Soils that exhibit greatest volume changes from dry to wet state usually possess a considerable percentage of montmorillonite. Since expansive soils have a tendency to change their volume to a large extent, they cause heavy distress to engineering constructions. The light weight structures are severely affected due to high swelling pressure exerted by these soils. Such type of large-scale distress, due to expansive shrinking nature of expansive soil, can be prevented by either obstructing the soil movement and reducing the swelling pressure of soil or making the structure sufficiently resistant to damage from soil movement, (Chen, 1975).

Azadeejan et al. (2008) studied the effect of geo-grids on compressive strength and elastic modulus of lime-cement (L-C) treated soil in order to find out the effect of geo-grid applications, on the geotechnical behavior of lime-cement treated soil used as base, sub-base or structural foundation materials. Study was performed on compressive treated soil sample with or without geo-grid layers and found that when there is an increment in modulus of elasticity and the cohesion, produced by pozzolanic reaction of lime and cement, side deformation of the cylinder decreases and therefore the tension produced in reinforcement and the confinement forces would decrease too. To have appropriate interaction, the mix design should comprise enough ductility and side deformation for which, L/C ratio should be greater and must be selected and total amount of applied cement must be lower than 5 percent. Unconfined compression test was adopted using cylindrical sample. It was observed that the deformation prior to the reinforcement of the geo-grid did not correlate with California Bearing Ratio.

Zornberg et al. (2008) shared their field experience on pavement over expansive soil in Milam country, Texas. Extensive network of longitudinal cracks was observed on the pavement section. Use of reinforcement was considered using a layer of geo-grid at the interface between the base and sub-grade along with lime treated sub-grade and asphalt seal coat on the top. Two geo-grid reinforcement sections were constructed in addition a controlled (unreinforced) section to evaluate the effect of geo-grid. While a falling weight deflectometer (FWD) testing was conducted to try to quantify the pavement performance, visual inspection of the pavement results showed that the control section was found to develop longitudinal cracks in with very short period as where the two geo-grid reinforced sections were found to perform well, without any evidence of longitudinal cracking.

Evaluation studies on flexible pavement system were carried out by Prasad and Kumar (2010) using different reinforcement materials in the gravel sub base courses laid on expansive soil subgrades. Six alternative test tracks (Geogrid reinforced sub base, Bitumen coated Chicken mesh reinforced sub base, Bitumen coated bamboo mesh reinforced sub base, Waste plastics reinforced sub base, Waste Tire Rubber reinforced sub base and Untreated sub base) were prepared on expansive soil subgrade with gravel sub base materials separately, as shown in Figure (2.4) and the details of which are presented in the following sections. Cyclic load tests were carried out in the field by placing a circular metal plate on model flexible pavements. It was observed that the maximum load carrying capacity associated with less value of rebound deflection is obtained for geogrid reinforced stretch followed by bitumen coated chicken mesh, bitumen coated bamboo mesh, waste plastics and waste tire rubber reinforced stretch in the flexible pavement system laid on expansive subgrades.

There is a problem under flexible pavement layers (sub-grade) which lies in the presence of swelling soils which exhibit volume changes that may cause damage to pavement layers. The research aims to study volumetric changes in expansive soils as a result of exposure to moisture, and distortions occurring in the sub base layer. Then it studies the possibility of using geogrid reinforcement to reduce volumetric changes, and swelling and its impact on the sub base layer. A laboratory model representing the flexible pavement layers is built, and subjected to different saturation conditions and different loads. Experiments are carried out to study the best depth to place the geogrid, in dry and saturation conditions.

Materials Used

1. Expansive soil

The bentonite was mixed by 70% weight, with 30% sand (70:30 bentonite to sand) and this mixing is represents the soil which used in this research to prepare the expansive subgrade soil in the model. The soil sample was used in the model and subjected to routine laboratory tests, the soil properties were determined by routine tests. Table 1 shows results of the physical properties of the expa soil.

The dry density of the soil is computed and plotted versus moisture. Instead of known in the optimum moisture content and maximum dry density of soil, the determination of optimum moisture content and maximum dry density of the soil by drawing the moisture-density relationship is shown in Figure 1. The optimum moisture content and maximum dry density are given in Table 1.

Table (1): The physical properties of the soil used

Physical tests	Index value	Specification
Specific gravity (Gs)	2.63	ASTM D 854-00
Liquid limit (L.L) %	89	ASTM D 4318-00
Plastic limit (P.L)%	31	ASTM D 4318-00
Plasticity index (P.I)	59	ASTM D 4318-00
Optimum moisture content %	18.5	ASTM D 698-12
Maximum dry unit weight KN/m^3	16.6	ASTM D 698-12
California Bering ratio (CBR)	3.1	ASTM D1883-99
Swell potential %	12	ASTM D 4546-03
Expansion index	120	ASTM 4829-03

Swell pressure (kPa)	125	ASTM D 4546-96
Organic matter (O.M.) (%)	0.305	B.S 1377

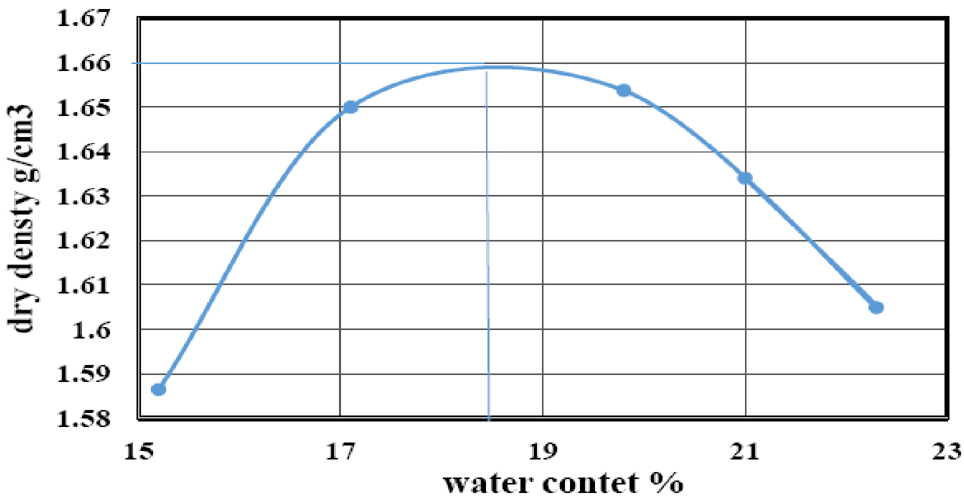

Figure (1): Moisture-density relationship for subgrade soil used.

The swelling test was carried out to measure swelling potential, expansion index and swelling pressure according to ASTM D4829-03. Table 2 shows the results of the swelling potential, expansion index and swelling pressure obtained from the swelling test which was carried out for each soil using two different initial water contents.

The swelling potential is calculated as:

Swelling potential% = $\Delta H / Hi \times 100$ … (1)

Where: ΔH = the change in sample height, D2 -D 1

Hi = the initial sample height,

D1 = the initial dial reading mm.

D2 = the final dial reading mm.

But the expansion index (EI) can be found according to ASTM 4829-03 as follows:

$EI = \Delta H / Hi \times 1000$ (2)

The results show that the swelling percent increases with increase the initial void ratio due to decrease in the initial water content which is the main factor for the capability of swelling because its capacity to absorb water deceases with increase in its degree of saturation as stated by Murthy (1989).

Table 2: The results of swelling test

Sample ID	Swelling potential %	Expansion index	Swelling pressure (kPa)
B1	16	160	200
B2	14	140	162.5
BS1	12	120	125
BS2	9.3	93	87.5

sub base granular material

The sub base is brought from Badra area, east of Wasit governorate; this type is used as a base layer in flexible pavement construction. The sub base sample was subjected to routine laboratory tests to determine its properties. The tests included, sieve analysis, dry unit weight, California bearing ratio with compaction to 95% of the maximum dry density, according to the specification of the State Organization of Roads and Bridges, Standard Specification for Roads and Bridges (SORB, 2003). The compaction curve of the sub base material is shown in Figure 2, Table 3 presents the physical properties of sub base material with the corresponding specification.

Geogrid reinforcement

One type of geogrid was used in this study. The geogrid was manufactured by Al-Latifia Factory for plastic mesh having engineering properties (imported from Saudi Arabia). The sheet of geogrid used from test to test but was replaced whenever any of the strands become visibly overstressed. Figure 3 shows the geogrid reinforcement used.

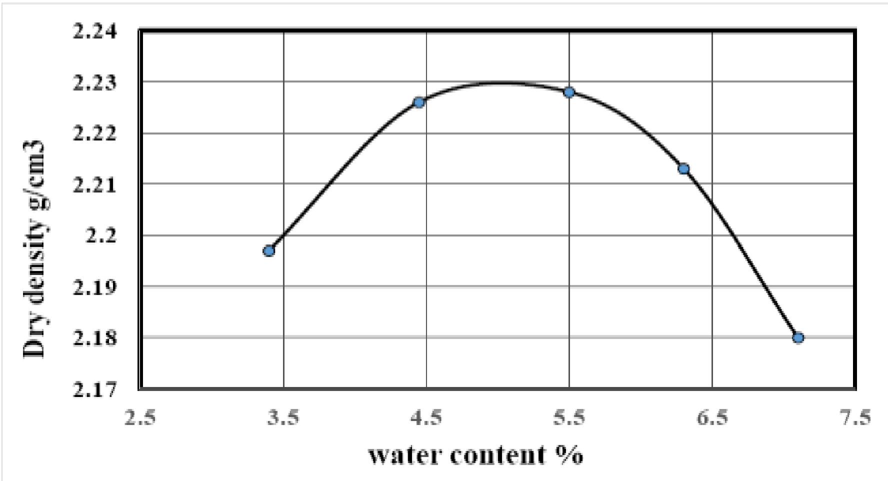

Figure (2): Moisture – density relationship for sub base (Modified).

Manufacturing of the Loading Machine (Loading Test Apparatus)

The loading frame shown in Figure 4 was designed to meet the requirements of this study, it is an electrical device, with capacity of 100 kN a diameter of 100 mm, this movement is controlled by AC drive that controls an electrical motor. The applied load generated is measured by a load cell shown in a digital reader and the movement is measured by a pair of dial gauges.

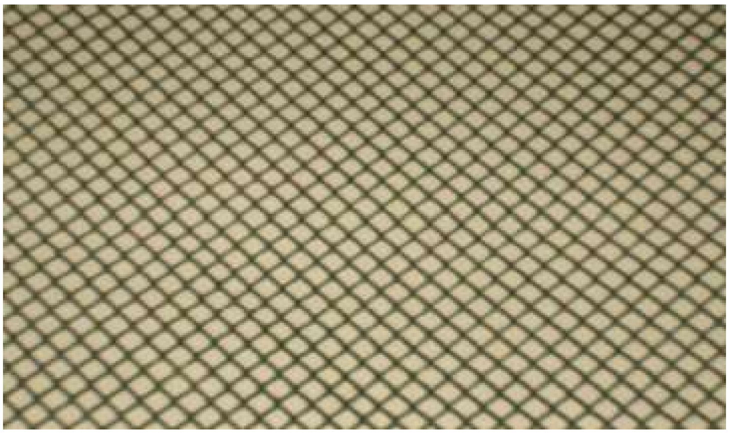

Figure (3): Geogrid used.

Table (3): Physical properties of the sub base granular material used with the specification of SORB (2003)

Gradient test			Type requirements		
Sieve No.	**Sieve opening mm**	**Passing%**	**A**	**B**	**C**
3	75	-	100	-	-
2	50	100	95-100	100	-
1	25	81	-	75-90	100
3/8	9.5	71	30-60	40-75	50-85
No. 4	4.75	51	25-55	21-47	35-65
No. 8	2.36	42	16-42	21-47	26-52
No. 50	0.3	26	7-18	14-28	14-28
No. 200	0.075	13.7	2-8	5-15	5-15
Dry unit weight, g/cm^3		2.231	-	-	-
Optimum moisture content %		5.2	-	-	-
CBR		40	35 Min	30 Min	20 Min
L.L. %		15	25 Max		
P.I. %		4	6 Max		
Corrosion mechanical %		7	45 Max		
SO3 %		0.342	5 Max		
Total soluble salts (1:50)%		1.535	10 Max		
Gypsum (CaSO_4H_2 O)		0.736	10.75 Max		
Organic %		0.056	2 Max		

Method of work

This robust represents a testing machine which can be used for various tests under load and on displacement control, the four column frame is fitted with an upper beam which can set at various heights depending on the adjusted arm connected to jack, it is driven by an AC drive controls 3 hp (hour power) motor which controls the arm movement. The device allows for the tests to be carried out by applying static monotonic loads at a constant rate of 1 mm / min with a possibility of changing, the speed of the descent of load is 0-3 mm / min.

A mechanical device was used to apply move than 100 kN force, it employs a screw thread for giving a liner movement for loading arm at low or medium speeds, it is connected directly to an electric motor creating a compact line around shaft driver. Standard 3 phase motor was used, as shown in Figure 5.

Figure (4): Loading machine.

Figure (5): Load jack.

Model Preparation

Subgrade soil preparation

The subgrade layer was prepared by mixing 14 kg of betonie and 6 kg of sand (70% bentonite by weight and 30 % of sand) by mixer and adding water to conform to the optimum moisture content. The mixed materials have been stored for 5 days in closed sack bags for the purpose of getting uniformity of moisture, Figure 6.

Figure (6): Preparation of subgrade soil.

sub base layer preparation

The sub base layer preparation was made by weighing 25 kg of sub base, which was then placed in a mixer, the water was added by optimum moisture content (5.2%) as shown in Figure 7, the required quantity was prepared and put in the model above the soil layers, compaction was made in two layers, the thickness of a single layer is 150 mm, and the thickness of the overall class is 300 mm.

Figure (7): Preparation of sub base material.

Model test preparation (work method)

There are three types of models, without geogrid, with geogrid at the interface between the subgrade layer and sub base layer, and with geogrid at the center of the sub base layer. The model preparation was done by compaction of subgrade in four layers each layer (10 cm) thick; the compaction was maintained at 95% of the maximum dry density as shown in Figure 8. Each layer was compacted alone, then the second layer was added and rework the same was done for the rest of the layers, the total thickness of subgrade is 40 cm. There are two major methods of test, without geogrid and with geogrid, the first method without geogrid, after completing compaction of subgrade layer, the two-sub base layers were compacted above the subgrade layer, each layer is of thickness of 150 mm and the total thickness is 300 mm. The second method with geogrid, there are two techniques, the first technique is by placing the geogrid at the interface between the subgrade and sub base, and in the second geogrid, is placed at the center of the sub base layer.

Figure (8): Compaction process.

Testing Procedure

The load applied to the model continued at constant speed of 1 mm/min and the load was read every minute. This test was carried out on six models, which include test models on layers of pavement without geogrid, with geogrid at the interface of subgrade layer and sub base layer, and with geogrid at the center of sub base layer.

Results and Discussion

The results obtained from 6 model tests, the static tests consists of nein models, divided into three types according to the tests, dry test and saturation test. For each stage, three models are prepared without geogrid reinforcement, with geogrid reinforcement at the interface of the subgrade and sub base layers and with geogrid reinforcement in the center of sub base layer.

From the behavior of the load-settlement relation of the model tests in the present work, it is found that the tangent proposal it is the suitable method and adopted in this research to specify the ultimate bearing capacity for all models. The load is applied in increments at constant speed of 1 mm/ min, the time of each test was 20 minutes.

Results of dry soil tests

Figures 9 to 11 show the load- settlement curves obtained from the three models, unreinforced subbase, reinforced with geogrid layer at the interface with subgrade and reinforced subbase with a geogrid layer in the middle of subbase, respectively. When comparing the results of the tests of the three models at 10 mm displacement, it is found that the highest bearing load is about 10.70 kN in the model that consists of geogrid reinforcement at the interface of subgrade layer and subbase layers, while the lowest bearing load is about 9.15 kN in the model without reinforcement, while in the model that contains of geogrid reinforcement in the center of subbase layer, the bearing load is about 7.60 kN.

Comparison of the results of the model without geogrid reinforcement with other models, reveals that there is an increase in the bearing capacity of model that includes geogrid reinforcement at the interface of subgrade by about 40% and 20% for the model that contains of geogrid reinforcement in the center of subbase layer. As well as, when comparing the result at the end of tests, the same results arrangement is found, the failure load is 16.90 kN for geogrid reinforced model at interface between subgrade layer and subbase layer, 12.37 kN for reinforcement in the center of subbase layer, and 9.61 kN without reinforcement. The increase in the bearing load is 75% of model that contains of geogrid reinforcement at the interface of subgrade and 29% for the model that contains of geogrid reinforcement in the center of subbase layers, as shown in Figure 10.

This improvement in the bearing capacity returns to several factors, the first factor, transferring part of the shear stresses induced in the subsurface to the geogrid, which is able to accept tensile forces and distribute them over a large area, the second factor, the geogrid reinforcement can decrease the shear stresses transferred to the subgrade and provide vertical confinement to the subgrade outside the loaded area where heave happens, thus decreasing the shear strain near the top of subgrade and limit subgrade rutting and upheaval. The third factor improves vertical stress distribution resulting from tensile stress.

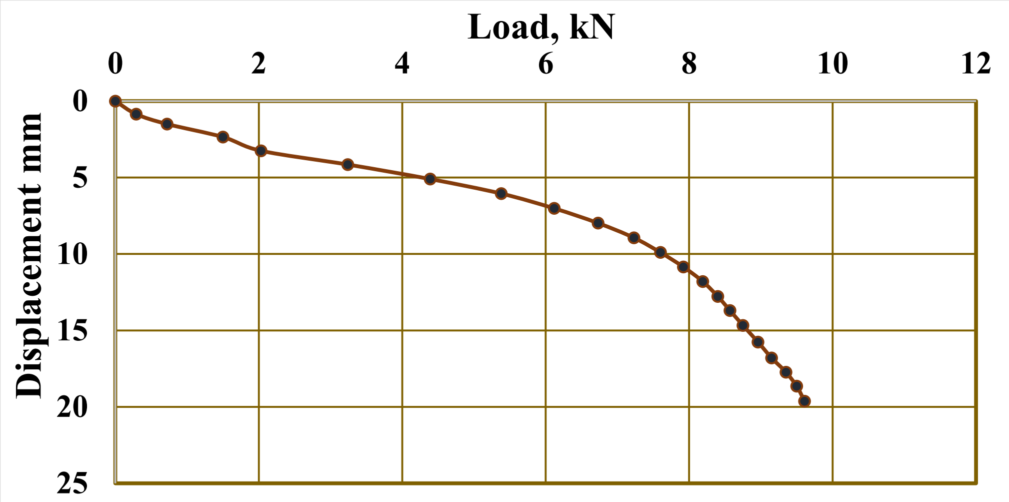

Figure (9): Load-displacement relationship for an unreinforced model of pavement layers subjected to static loading, (dry test).

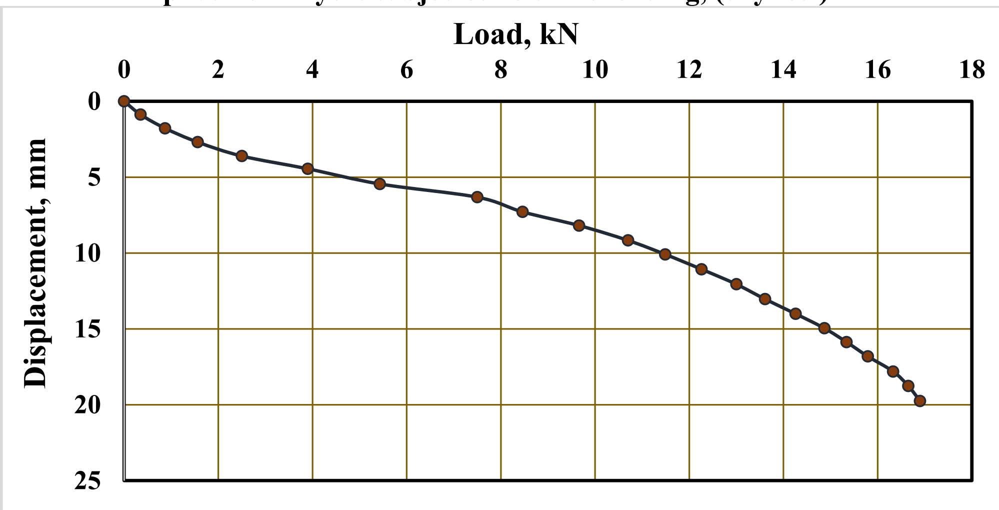

Figure (10): Load-displacement relationship for a model of geogrid reinforced subbase at interface with subgrade layer subjected to static loading, (dry test).

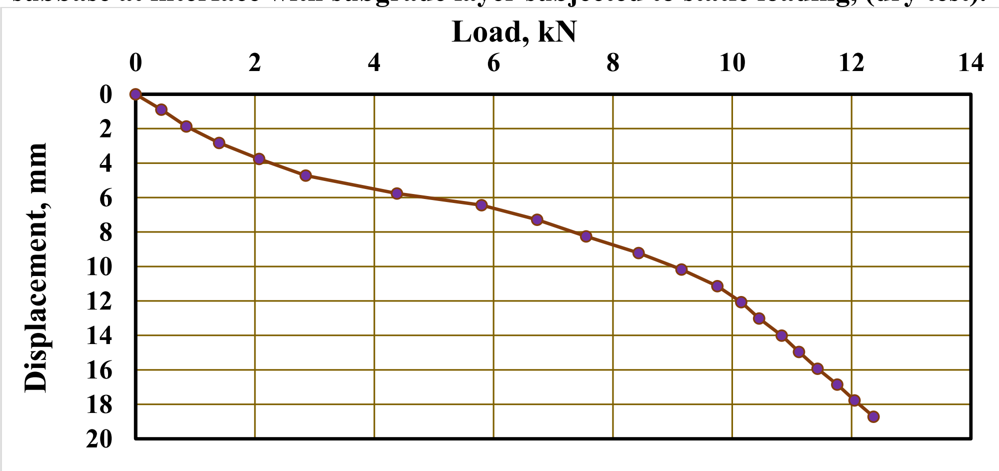

Figure (11): Load-displacement relationship for a model of geogrid reinforced in the center subbase layer subjected to static loading, (dry test).

It can be seen that heaving of the expansive soil considerably decreases the load carrying capacity of the pavement system. The improvement in the load carrying capacity could be attributed to the improved load dispersion through stabilized subbase on to the subgrade. This in turn results in lesser intensity of stresses getting transferred on to subgrade, thus leading to lesser subgrade distress. Geogrid functions in two ways: reinforcement and separation which are the techniques of improving poor soil with geo-grid, to increase the stiffness and load carrying capacity of the soil through frictional interaction between the soil and geo-grid material. A geogrid reinforced soil is stronger and stiffer and gives more strength than the equivalent soil without geo-grid reinforcement. Geo-grids provide improved aggregate interlock in stabilizing road infrastructure through subbase restraint reinforcement applications. Geogrid reinforcement provided between the base course and sub-grade soil carries the shear stress induced by vehicular loads.

Generally, geogrid reinforces the subbase or subgrade materials by providing lateral restraint (minimizing spread), tensile membrane support and increase in bearing capacity.

Results for saturation tests

In this group, three models were prepared in the same former way, after completing compaction of each model, the model was submerged in water, and the models were left submerged in water for five days and with installation of dial gages to read swelling for each model. The decrease in the water as a result of absorption and evaporation was offset by adding water continuously. After five days, the model was tested by applying loads for 20 minutes. The relationship between load and displacement is then drawn. Figures 12 to 14 present the load-settlement relationships for unreinforced subbase layer, reinforced at interface, and reinforced at the center of the subbase layer models.

The figures reveal that there is an increase in the bearing capacity of model that includes geogrid reinforcement at the interface of subgrade by about 32% and 15% for the model that contains of geogrid reinforcement in the center of subbase layer. The highest load was at displacement of 6.5 mm for three curves and the load started to decline after this point. The decline in bearing capacity is due to the complete saturation of the subbase layer and partial saturation of the subgrade layer. If the model results are compared with the formal group that was tested without saturation, it can be noticed that the bearing capacity continues to increase although slightly after failure point that is noticed at about 10 mm displacement. The point of failure load estimated by the tangent method, is found in the model that includes of geogrid reinforcement at interface of subgrade and subbase layers about 3.37 kN, followed by the model that contains of geogrid reinforcement in the center of subbase layer 2.94 kN at almost the same failure point, and followed by the model without geogrid reinforcement 2.55 kN.

As shown in Figures 12 to 14, when the results of model without geogrid reinforcement are compared with other models, it can be observed that there is increase in the bearing capacity of model that contains geogrid reinforcement at the interface of subgrade by about 33% and 17% for the model that includes geogrid reinforcement in the center of subbase layer.

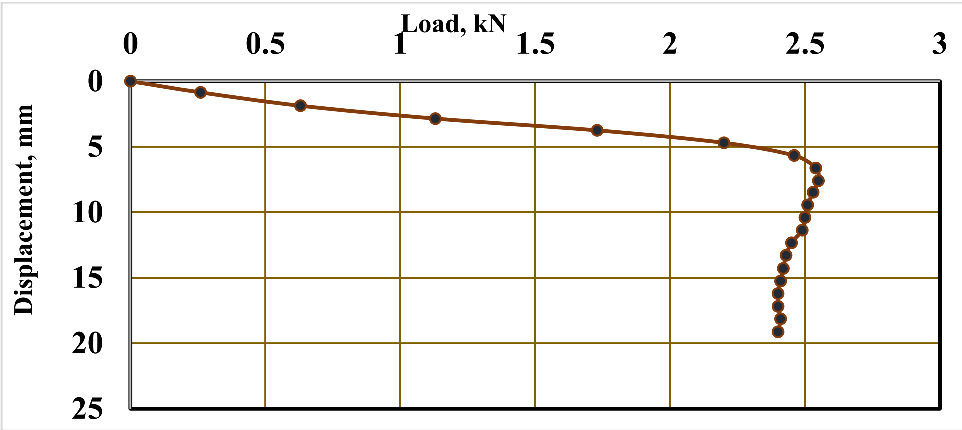

Figure (12): Load-displacement relationship for an unreinforced model of pavement layers subjected to static loading, (saturation test).

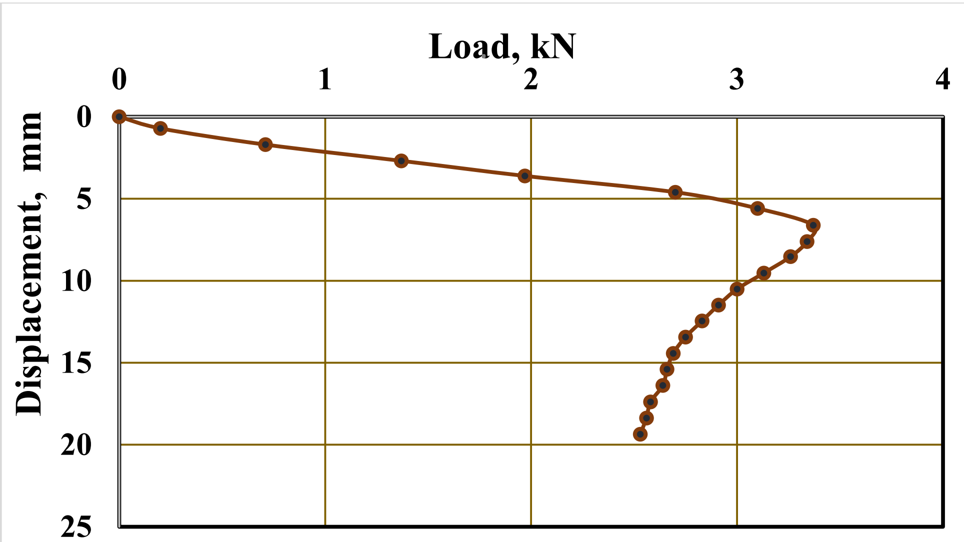

Figure (13): Load-displacement relationship for a model of geogrid reinforced subbase at interface with subgrade layer subjected to static loading, (saturation test).

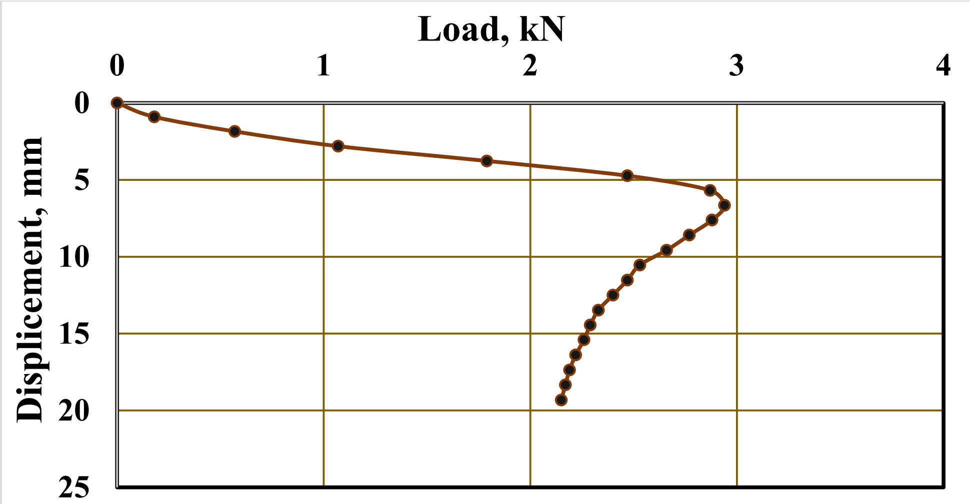

Figure (14): Load-displacement relationship for a model of geogrid reinforced in the center subbase layer subjected to static loading, (saturation test)

Shear stress developed between the base course aggregate and the geosynthetic provides an increase in lateral confining stress within the base. Granular materials generally exhibit an increase in elastic modulus with increased confining stress. The second base (or subbase) reinforcement component results from an increase in stiffness of the base (or subbase) course aggregate, when adequate interaction develops between the base (or subbase) and the geosynthetic. The increased stiffness of this layer results in lower vertical strains in the base. An increase in modulus of the base would also be expected to result in lower dynamic, recoverable vertical deformations of the roadway surface, implying that fatigue of the asphalt concrete layer would be reduced (Berg et al., 2000).

Conclusions:

A series of model experiments was conducted to determine how incorporating geogrid reinforcement into a granular subbase layer placed over swelling subgrade affects the behavior of pavement layers. The following conclusions are drawn from this study:

1. A geogrid reinforced subbase material is stronger and stiffer and gives more strength than the equivalent subbase material without geo-grid reinforcement. Geo-grids provide improved aggregate interlock in stabilizing road infrastructure through subbase restraint and base reinforcement applications.
2. Geo-grid reinforcement provided between the subbase course and subgrade soil carries the shear stress induced by vehicular loads and thus it reduces the load transferred to the subgrade and the volume changes induced by swelling of the subgrade soil.
3. The load carrying capacity of the pavement system significantly increases for geogrid reinforced subbase stretch compared to unreinforced subbase layer on expansive subgrade soil. This is reflected in the values of failure load which is greater in reinforced subbase layer model than in unreinforced model.

Comparison of the results of the model without geogrid reinforcement with other models, reveals that there is an increase in the bearing capacity of model that includes geogrid reinforcement at the interface of subgrade by about 40% and 20% for the model that contains of geogrid reinforcement in the center of subbase layers.

4. The point of failure load estimated by the tangent method, is found in the model that contains of geogrid reinforcement at the interface of the subgrade and subbase layers 3.37 kN, followed by the model that consists of geogrid reinforcement in the center of subbase layer 2.94 kN at almost the same failure point, followed by the model without geogrid reinforcement 2.55 kN.

REFERENCES:

[1].ASTM D 698-12, "Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (600KN-m/m3)", Reprinted from the Annual Book of ASTM Standards. Copyright ASTM, Vol.4, No.8.

[2].ASTM D 854-00, "Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer", Reprinted from the Annual Book of ASTM Standards. Copyright ASTM, Vol.4, No.8.

[3].ASTM D 4318-00, "Standard Test Methods for Liquid Limit, Plastic Limit and Plasticity Index of Soils", Reprinted from the Annual Book of ASTM Standards. Copyright ASTM, Vol.4, No.8.

[4].ASTM D 4829-03, "Standard Test Method for Expansion Index of Soils", Reprinted from the Annual Book of ASTM Standards. Copyright ASTM, Vol.4, No.8.

[5].ASTM D 1883-99, "Standard Test Method California Bearing Ratio of Laboratory-Compacted Soils, Reprinted from the Annual Book of ASTM Standards. Copyright ASTM, Vol.4, No.8.

[6].ASTM D 4546 – 03 " Standard Test Methods for One-Dimensional Swell or Settlement Potential of Cohesive Soils, Reprinted from the Annual Book of ASTM Standards. Copyright ASTM, Vol.4, No.8.

[7].ASTM D4829-03 "Standard Test Method for Expansion Index of Solis" Reprinted from the Annual Book of ASTM Standards. Copyright ASTM, Vol.4, No.8.

[8].Azadeejan, O., Mammad, J.Y. and Pourebrahim, GH.P. (2008), "Laboratory Study on Effects of Geogrid layers on Mechanical Properties of Lime/Cement Treated Granular Soils", Electronic Journal of Geotechnical Engineering, EJGE Vol. (2011), Bund. D.

[9].B.S 1377:1990 "Methods of Test for Soils for Civil Engineering Purposes", British Standards Institution.

[10].Chen, R.H., (1975) “Foundations on Expansive Soil,” 2nd edition. Elsevier Scientific Publishing Company, New York.

[11].Iraqi General Specification for Roads and Bridges, (2003)."Standard Specification for Roads and Bridges." The state Corporation for Road and Bridges, Revised Edition.

[12].Jones, D.E. and Holtz, W.G., (1973), “Expansive Soils- the Hidden Disaster”, Civil Engineering, Vol. 43, No. 8, pp. 49-51.

[13].Prasad, D.S.V. and Kumar, M. A., (2010), "Behavior of Reinforced Sub- bases on Expansive Soil Sub-grade", Global Journal of Research in Engineering, Vol. 10, No. 1, pp. 1-8.

[14].Steinberg, M.L., (1992), “Geogrids as a Rehabilitation Remedy for Asphaltic Concrete Pavements”, TRR-1409, pp. 54-62.

[15].Zornberg, J.G., Prozzi, J.A., Gupta, R., Luo, R., McCartney, J.S., Ferreira, J.Z., and Nogueira, C. (2008). "Validating Mechanisms in Geosynthetic Reinforced Pavements", Center for Transportation Research (CTR), Report No. 0-4829-1, Austin, Texas, February 2008.