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Deformation Analysis of Road Embankment Foundation Soil Improved with Fiber Glass

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ABSTRACT

The main objective of this research is to evaluate the improvement of embankment soil foundation soil using the fiber glass treatment. To accomplish the main objective, laboratory tests, includes direct shear test and unconfined compression test are made to evaluate the potential of acting the fiber glass as cementing agent in terms of strength parameters (cohesion and angle of internal friction). The ANSYS program of version (12.1) was employed for analyzing embankment foundation system. The results showed that increasing the percent of fiber glass from (1 to 3%) reduce the vertical and horizontal displacement about (75%) at 3%, and reduced the horizontal and vertical strain about (75%, 85%) respectively at the same fiber glass content (3%). This means, that the general role of adding the fiber glass works as a tender to soil mixture not as fiber reinforcement. So it can be concluded that the fiber glass act as cementing agent as shown in the obtained experimental results for strength parameters (cohesion and angle of internal friction) from the direct shear and the unconfined compression test that carried out in this works.

Keywords: Road Embankment; Fiber glass, Finite element; Deformation; Unconfined compression strength; ANSYS.

تحليل التشوه للتربة الاساس للتعليات الترابية المحسنة بالياف الزجاج

الخلاصة

الهدف الرئيسي من هذا البحث هو تقييم تحسين تربة اساس التعلية باستخدام الياف الفايبر كلاس. ولاتمام الهدف الرئيسي تم اجراء فحوصات مختبرية تضمنت فحص القص المباشر وفحص الانضغاط غير المحصور لحساب نسبة فعالية الياف الفايبر كلاس كعامل رابط بدلالة معاملات المقاومة (التماسك وزاوية الاحتكاك الداخلي). برنامج ANSYS ذا version (12.1) تم استخدامه لتحليل نظام اساس التعلية. النتائج المستحصلة اظهرت ان زيادة نسبة الياف الفايبر كلاس من 1 الى 3 % يقلل الهطول

العمودي والافقي حوالي (75%) في النسبة 3 % . ويقلل الانفعال الافقي والعمودي بحوالي (75%
,85%) على التوالي عند نفس نسبة الياف الكلاس (3%) . هذا يعني ان القاعدة العامة لاضافة الياف
الكلاس تعمل كمادة محسنة لخليط التربة وليس كمادة تسليح. بالتالي نستنتج انه الياف الكلاس تعمل
كمادة رابطة كما هو موضح بالنتائج المختبرية لمعاملات المقاومة, التماسك وزاوية الاحتكاك الداخلي
من فحص القص المباشر وفحص الانضغاط غير المحصور.

INTRODUCTION

Several investigators (e.g., Bell et al., 1977, Andraws et al., 1980, Rowe et al., ***1984)*** have used finite element techniques for the analysis of geotextile - soil systems. They are not all suitable for the analysis of reinforced embankments on soft or compressible or plastic failure with the soil. Kamal et al., (2005***)*** conducted a parametric study of reinforced and unreinforced embankment using finite element (Sage Crisp) program. Construction sequence and consolidation during construction were modeled using Cam Clay model; it was found that, the mode of embankment failure occurred in the form of circular shape with base heave occurring near the toe of the embankment. Cudny and Neher (2003) studied the behavior of a test reinforced road embankment constructed on soft soil deposits at Haarajaki. The numerical calculations are completed with finite element method program capable to perform coupled static/ consolidation analysis of soils. Yetimoglu et al., (2005) performed a laboratory California Bearing Ratio (CBR) tests to investigate the load-penetration behavior of sand fills reinforced with randomly distributed discrete fibers overlying soft clay. The effect of fiber reinforcement content on bearing capacity, stiffness and ductility of the fiber-reinforced sand fill-soft clay system was determined. The test results indicated that adding fiber inclusions in sand fill resulted in an appreciable increase in the peak piston load. The reinforcement benefit increased with an increase in fiber content. Ramesh et al., (2010) described the compaction and strength behavior of black cotton soil (BC soil) reinforced with coir fibers. BC soil reinforced with coir fiber shows only marginal increase in the strength of soil, inhibiting its use for ground improvement. In order to further increase the strength of the soil-coir fiber combination, optimum percentage of 4% of lime is added. The effect of aspect ratio, percentage fiber on the behavior of the composite soil specimen with curing is isolated and studied. They are found that strength properties of optimum combination of BC soil-lime specimens reinforced with coir fibers is appreciably better than untreated BC soil or BC soil alone with coir fiber. Lime treatment in BC soil improves strength but it imparts brittleness in soil specimen. BC soil treated with 4% lime and reinforced with coir fiber shows ductility behavior before and after failure. An optimum fiber content of 1% (by weight) with aspect ratio of 20 for fiber was recommended for strengthening BC soil.

FINITE ELEMENT ANALYSIS

There are many practical problems either extremely difficult or impossible to solve exactly by the conventional analytical methods. This may be due to the complexity of the composite nature of the materials, difficulties associated with the representation of the load and boundary conditions or some constitutive stress-strain relations.

The finite element method is a numerical technique in which the continuous system with an infinite number of degrees of freedom is represented by an assemblage of discrete members, which has a finite number of degrees of freedom. The assemblage is composed of connected elements of finite size. Adjacent finite elements are joined with each other by a number of nodes specified along their boundaries. The development in the finite element method depends on the proper element properties and on the availability of an efficient means of solving the resulting system of linear or nonlinear simultaneous equations. For reinforced embankment, the nonlinear finite element analysis yields a wide range of useful information about displacements, strains, distribution of normal and shear stresses in embankment foundation system.

ANSYS (ANalysis SYStem) is a comprehensive general-purpose finite element computer program that contains over 100,000 lines of code and more than (180) different elements, has been used in this study to simulate road embankment foundation system with geotextiles reinforcement. One of the main advantages of ANSYS is the integration of the three phases of finite element analysis: pre-processing, solution and post-processing.

Pre-processing routines in ANSYS define the model, boundary conditions, and loadings. Displays may be created interactively on a graphics terminal as the data are input to assist the model verification. Post-processing routines may be used to retrieve analysis results in a variety of ways. Plots of the structure's deformed shape and stress or strain contours can be obtained in the post- processing stage.

Modeling Of Reinforced Embankments

In the present study, the ANSYS program of version (12.1) was employed for analyzing embankment foundation system. A plane 42, 2-D structural solid has been adopted in this research. The element can be used as a plane element (plane strain or plane stress) or as an axisymmetric element. The element is defined by four nodes having two degrees of freedom at each node, translations and the nodal x and y directions. The element has plasticity, and large strain capability. The embankment foundation soil modeled as an elasto-plastic material (plane strain condition) based on Darger –Parger model with isotropic material. Therefore a stiffness elastic modulus (E), Poisson's ratio (v), cohesion (c), angle of internal friction and angle of diltency are used to represent their behavior. The load case studied is a rectangular domain representation with uniform distribution (static loading case) within the rectangular to simulate the traffic loading (20kN/m^2).

The cross section of road embankment used in this study of 18m crest width and 1:2 side slops are shown in Figure (1). The depth of the soft foundation soil is 20m finite element discretization of the problem.

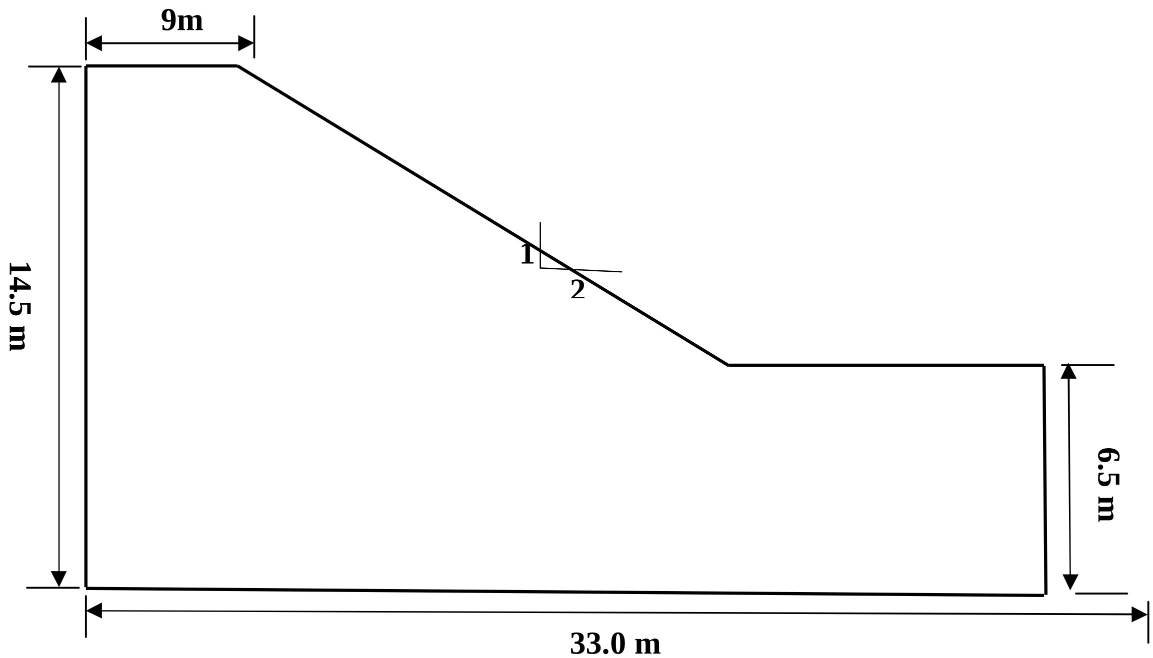

Figure (1): Cross section of road embankment.

Due to symmetry along the center line, only half of the geometry was simulate. The element can be used as a plane element (plane strain or plane stress) element. The element is defined by four nodes having two degrees of freedom at each node, translations and the nodal x and y directions. The element has plasticity, and large strain capability. Figure (2) shows the finite element mesh.

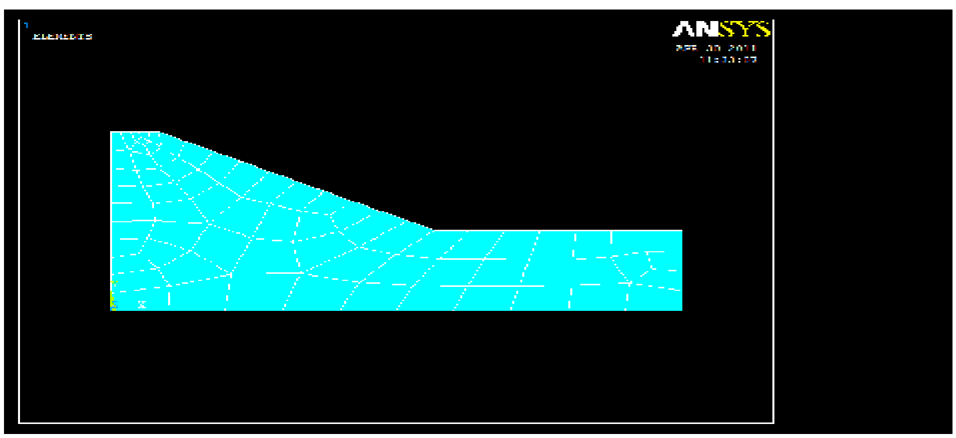

Figure (2): Finite element mesh.

EXPERMENTAL WORK

White kaolin clay is used to modeling the soft embankment foundation soil, which is supplied by the *General Company of Geological Survey and Mining*. The kaolin is originally obtained from Al-Dewiekhla near Akashat district in the west of Iraq.

Standard tests were performed to determine the properties of the Kaolin, and the results are shown in Table (1). The chemical composition results are shown in Table (2).

Table (1): Properties of soil.

Gs	**LL** %	**PL** %	**Optimum Moisture Content** %	**Maximum Unit Weight**, kN/m^3	**Cohesion (c)**, kN/m^2	**Angle of Internal Friction(Φ)**, degree	**Classification (USCS)***
2.58	60.0	28.0	21.28	15.7	34.0	12.0	CH*

* USCS: Unified Soil Classification System.

Table (2): Chemical compositions of kaolin (provided by the General Company of Geological Survey and Mining).

Fe_2O_3%	**SiO_2%**	**Al_2O_3%**
1.4 Max	50 Max	32 Min

Fiber-reinforced soil samples were prepared at maximum dry unit weight and optimum moisture content obtained by conducting Standard Proctor compaction test. Samples were prepared by adding 1.0%, 1.5%, 2% and 3% by weight of soil, and the fiber glass used with aspect ratio (Length/Diameter) equal to 80, 250, and 500 as shown in Table (3). Fiber glass was mixed with soil to produce a homogenous mixture. The Direct shear test was conducted in this work carried out according to ASTM, D3080-98. All the tests were performed as per ASTM, vol. 4, 08- 2003.

Table (3): Properties of the reinforcing material.

Type of Reinforcement	**Diameter of Thread**, mm	**Aspect Ratio, Length Diameter**	**Reinforcement Mixed in Soil,** %
Pieces cut as per the aspect ratio from fiber glass	0.1	80, 250 and 500	1.0, 1.5, 2 and 3

Experimental Results Discussions

Figure (3) and (4) show the influence of fiber glass inclusion on strength parameters, cohesion and angle of internal friction respectively, which obtained from direct shear test. It can be observed that increase in fiber glass content, the cohesion increased while the angle of internal friction is almost reduced compared with initial value. In other word, the inclusion of fiber glass had a positive effect on cohesion rather than on angle of internal friction. The maximum value of cohesion is observed in 2% fiber glass content as 49 kPa, at (L/D = 500) and 47 kPa, at (L/D = 250), which is about 1.4 and 1.38 times more than the unreinforced soil for (L/D= 500 , 250) respectively. The same behavior is clear when increasing the length of fiber at constant inclusions percentages. Increase in fiber result in increasing of cohesion about 38% [e.g. ((47-34)/34)*100] for (L/D= 250) and 44% for (L/D= 500) except for (L/D= 80) which their results show that for small L/D, the fiber had adverse effect on cohesion strength. This can be attributed to increase of cohesion between soil particles which result a higher shear strength resistance, in other word its can be explained as that, reduce the fiber length filaments soil without any significant improvement unless for high percent fiber content (3%) when its improvement significantly appears. This implies that the fiber glass improvement should be with L/D greater than 80.

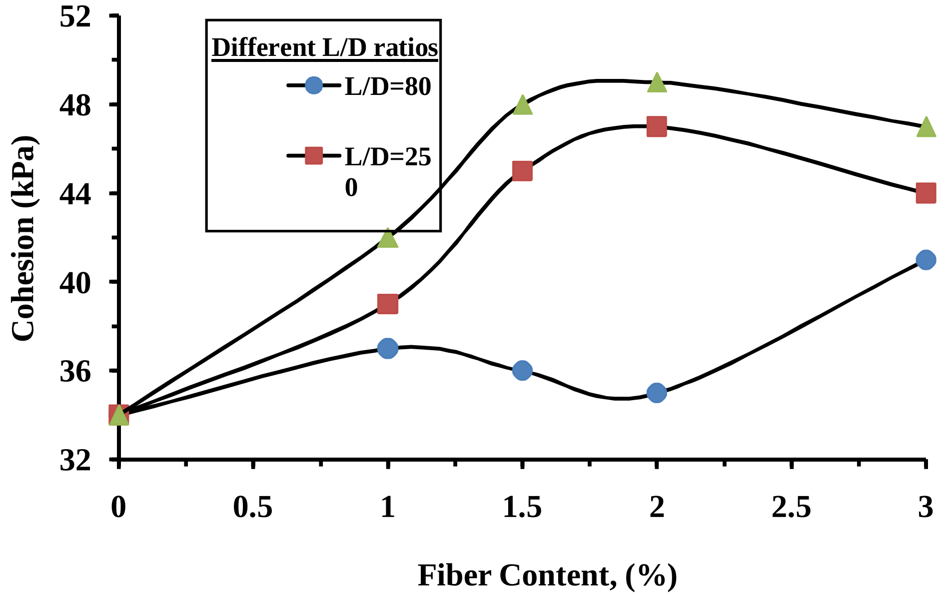

Figure (3): Effect of % fiber glass content on cohesion.

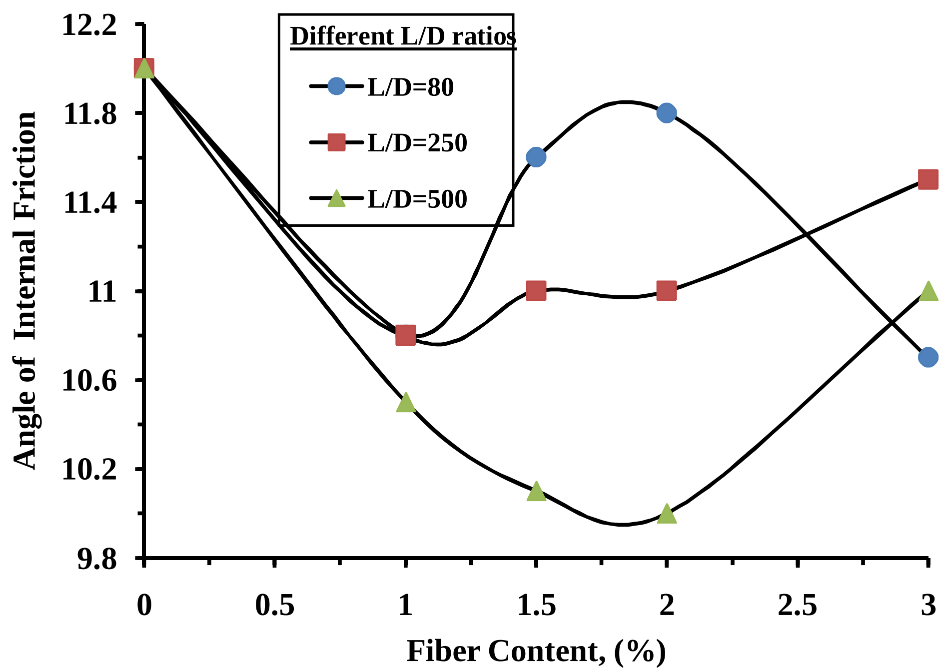

Figure (4): Effect of % fiber glass on angle of internal friction.

Figures (5) and (6) show the variation of maximum dry unit weight and optimum moisture content with fiber glass percent added for different aspect ratio respectively. Effects of fiber glass content on maximum dry unit weight and optimum moisture content as a function of fiber length and content were determined. The moisture-unit weight relationship obtained from compaction test showed that increasing fiber glass from 1 % to 3% had a significant effect on the magnitude of both maximum dry unit weight and optimum moisture content of soil mixture. With 1.5% add fiber to the soil mixture, the maximum dry unit weight decreased approximately 7.1% and optimum moisture content increased by approximately 26.7% at 2% fiber content. The decreased in unit weight is most likely a result of the fiber filaments having less specific weight in comparison with the soil grains. The increasing moisture content is most likely the fibers having a greater water absorption capacity than the surrounding soil.

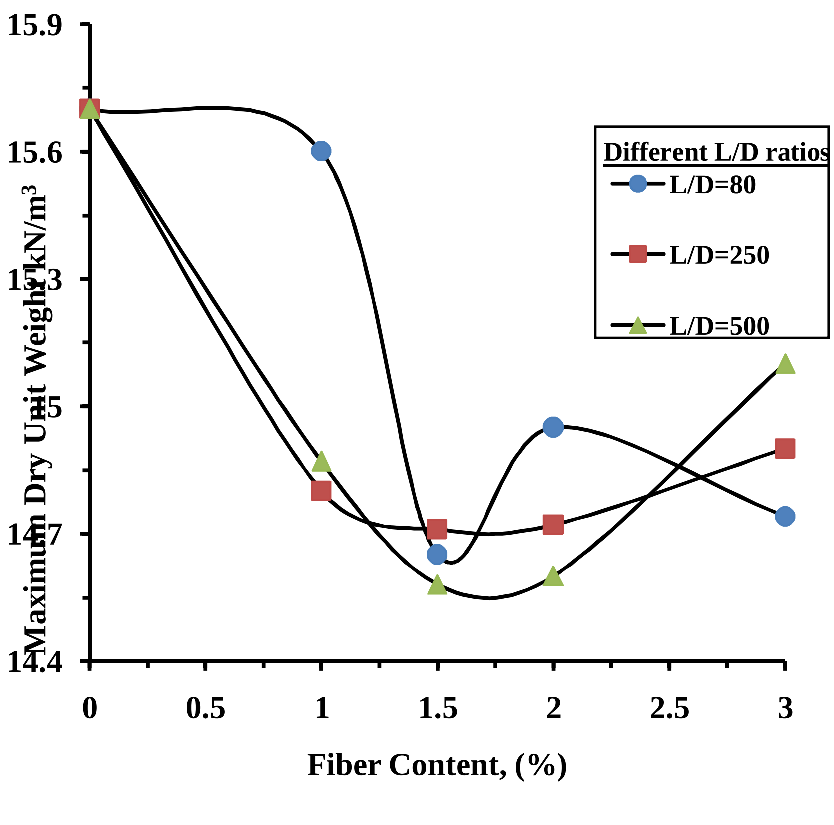

Figure (5): Effect of % fiber glass on maximum dry unit weight.

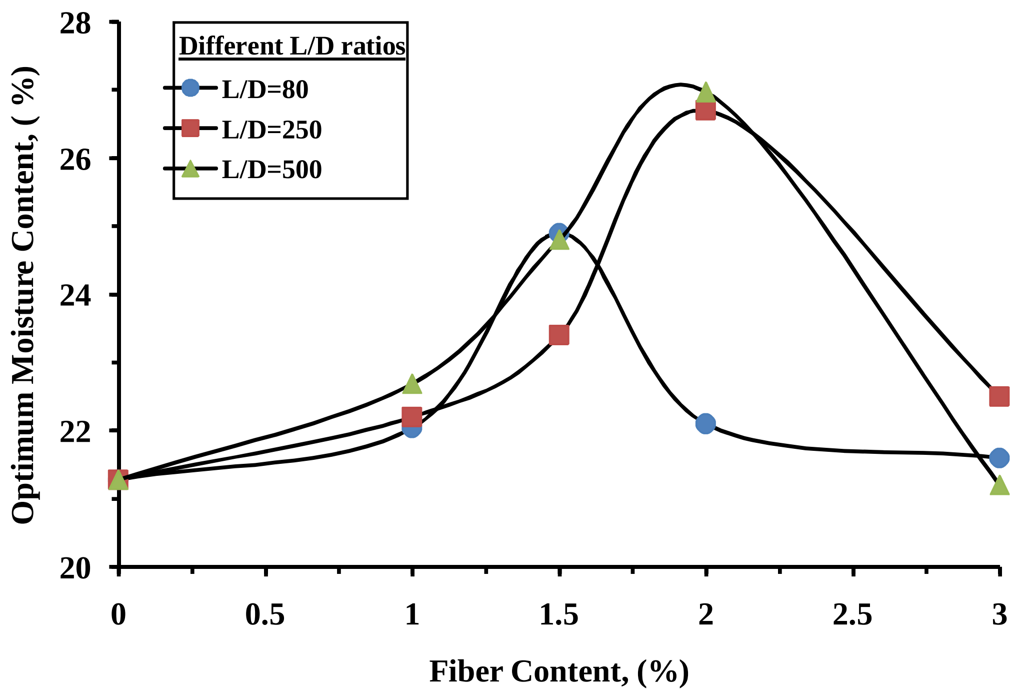

Figure (6): Effect of % fiber glass on optimum moisture content.

The effect of adding fiber glass on the stress – strain behavior is shown in Figure (7) through (9) for (L/D = 500, 250, 80) respectively. First the unconfined compression test is carried out on the unreinforced soil to determine the base unconfined compressive strength and the gain improvement in the unconfined compressive strength due the addition of fiber glass is determined. As shown in Figures (7) to (9), the stress- strain behavior of unreinforced soil is rigid and brittle while the fiber glass reinforced specimens exhibited more ductile and increase the unconfined compressive strength by about 3.45 times the base unconfined compressive strength. The failure axial strain reached is 2.3% for unreinforced soil and 4.47%, 14.47%, 10.53 % and 13.68 for 1%, 1.5%, 2% and 3% fiber content respectively as shown in Figure (13), which implies that the inclusion of fiber glass will hold the soil particles together and keep close to each other resulting in higher contact between them and higher cohesion also increase the unconfined compressive strength and increase the absorbing strain energy or ductility of soil as shown in Figure (10). The soil sample after and before the unconfined compression test can be seen in Figure (11). Also, Figure (12) shows the effect of fiber glass on elastic modulus of soil, increasing fiber glass inclusion increase the elastic modulus as well due to the ability of absorb energy.

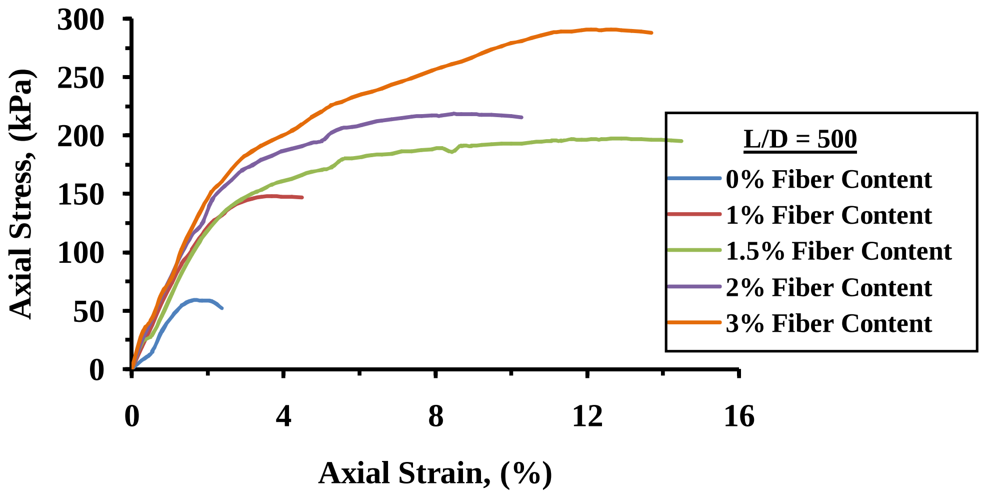

Figure (7): Effect of % fiber glass on stress – strain behavior of soil for L/D = 500.

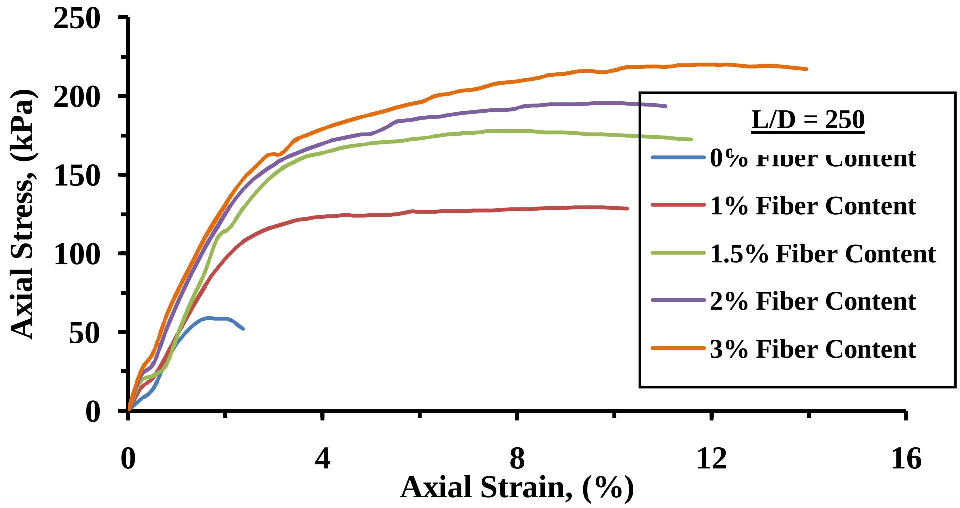

Figure (8): Effect of % fiber glass on stress – strain behavior of soil for L/D = 250.

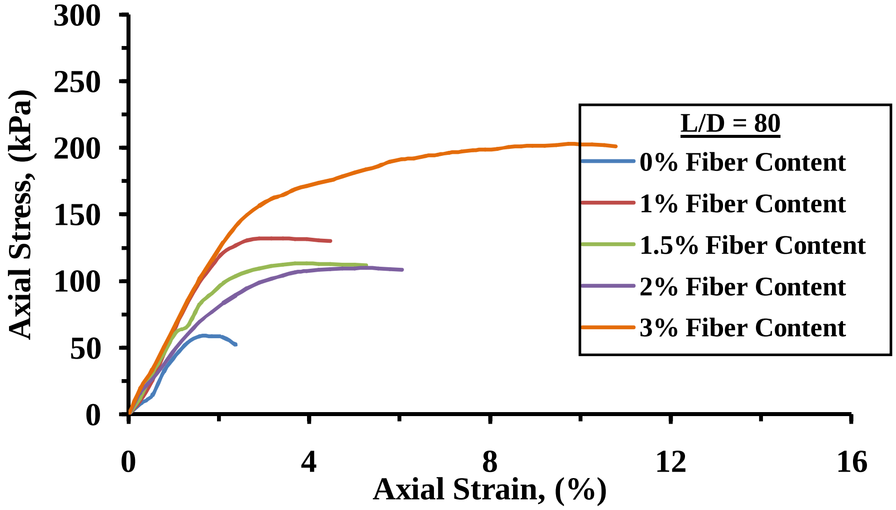

Figure (9): Effect of % fiber glass on stress – strain behavior of soil for L/D = 80.

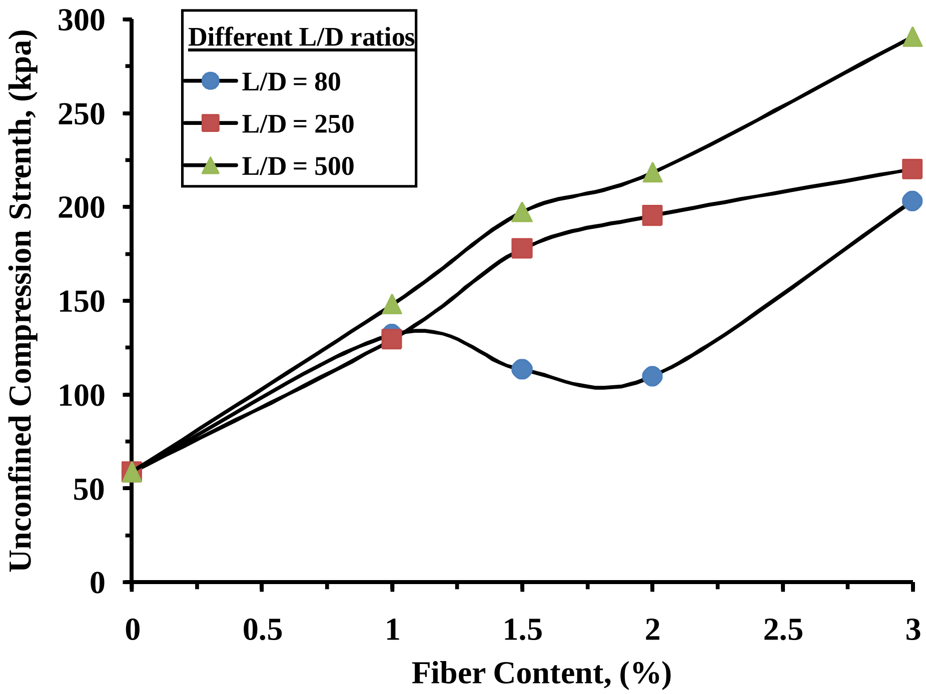

Figure (10): Effect of % fiber glass on unconfined compressive strength.

Figure (11): failure sample before and after the unconfined compression test.

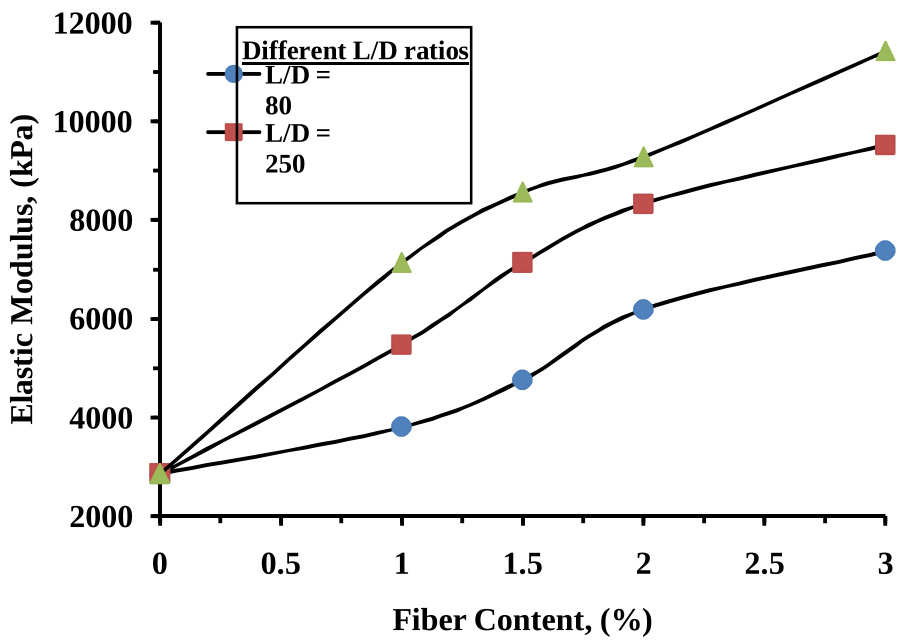

Figure (12): Effect of % fiber glass on elastic modulus.

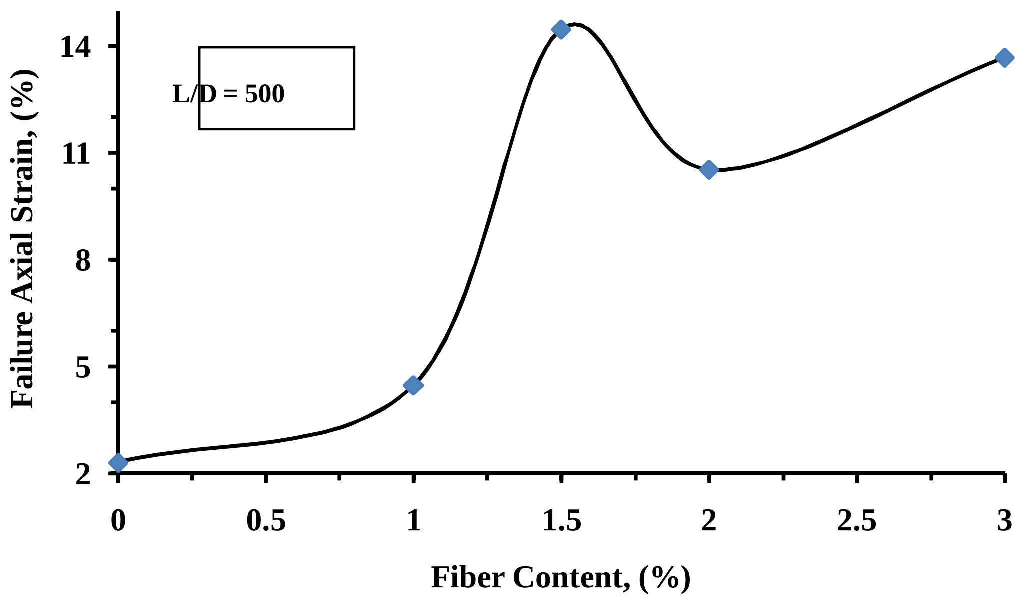

Figure (13): failure axial strain vs % fiber glass.

ANALYSIS OF THE RESULTS AND DISCUSSION

The embankment foundation soil modeled as elasto-plastic material (plane strain condition) based on Darger –Parger model with isotropic material therefore a stiffness elastic modulus (E) and Poisson's ratio (ν), cohesion (c), angle on internal friction and Diletency angle are used to represent their behavior. These parameters are used to characterize the elasto –plastic model for soft soil foundation and fill materials are listed in Table (4). To study the effect of fiber reinforcement on embankment performance, cohesion and angle of internal friction after adding the fiber glass was determined using the direct shear test as mentioned in previous section of experimental works of this research.

Table (4): Input parameter for finite element analysis.

Material	**Aspect Ratio**		**Poisons Ratio (ν)**	**Friction Angle** (degree)	**Cohesion** (kPa)	**Elastic Modulus** (kPa)
Soil without fiber reinforcement	-		0.35	12	34	2854.0
Soil with Fiber reinforcement	80	1% 1.5% 2% 3%	0.35 0.35 0.35 0.35	10.8 11.6 11.8 10.7	37 36 35 41	3804.6 4755.9 6182.9 7371.9
	250	1% 1.5% 2% 3%	0.35 0.35 0.35 0.35	10.8 11.0 11.0 11.5	39 45 47 44	5469.5 7134.2 8322.8 9512.2
	500	1% 1.5% 2% 3%	0.35 0.35 0.35 0.35	10.5 10.1 10.0 11.0	42 48 49 47	7134.2 8560.8 9273.8 11414.4

Figure (14) to (22) show the variation of vertical and horizontal displacement, and strains respectively at the percent of fiber glass (0%, and 3.0%) respectively. The rest of the results for (1, 1.5, 2 and 3)% and for aspect ratio L/D (80, 250 and 500)% are shown in appendix.

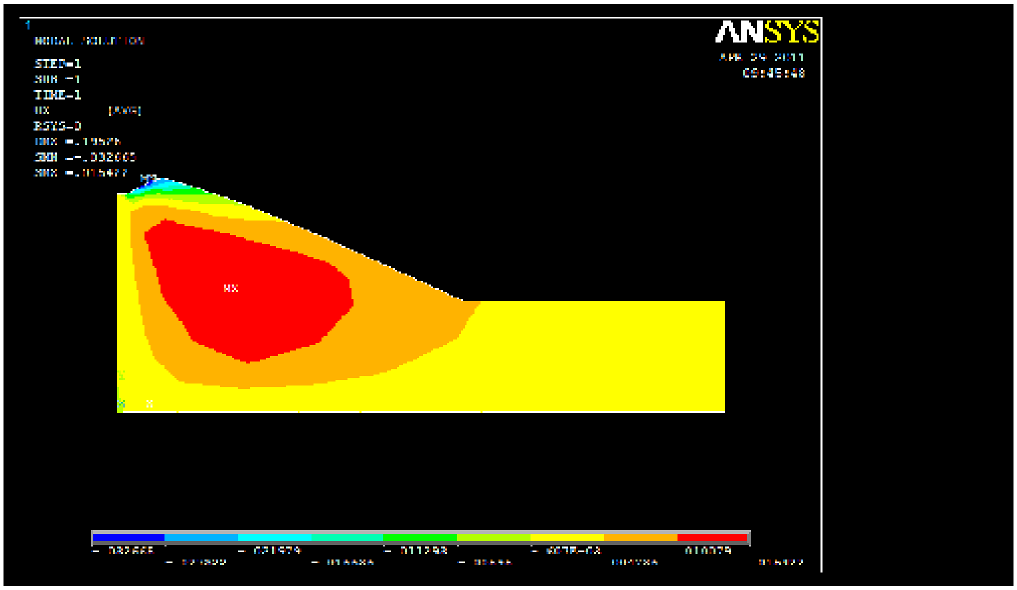

Figure (14): Distribution of horizontal displacement at 0.0% fiber content.

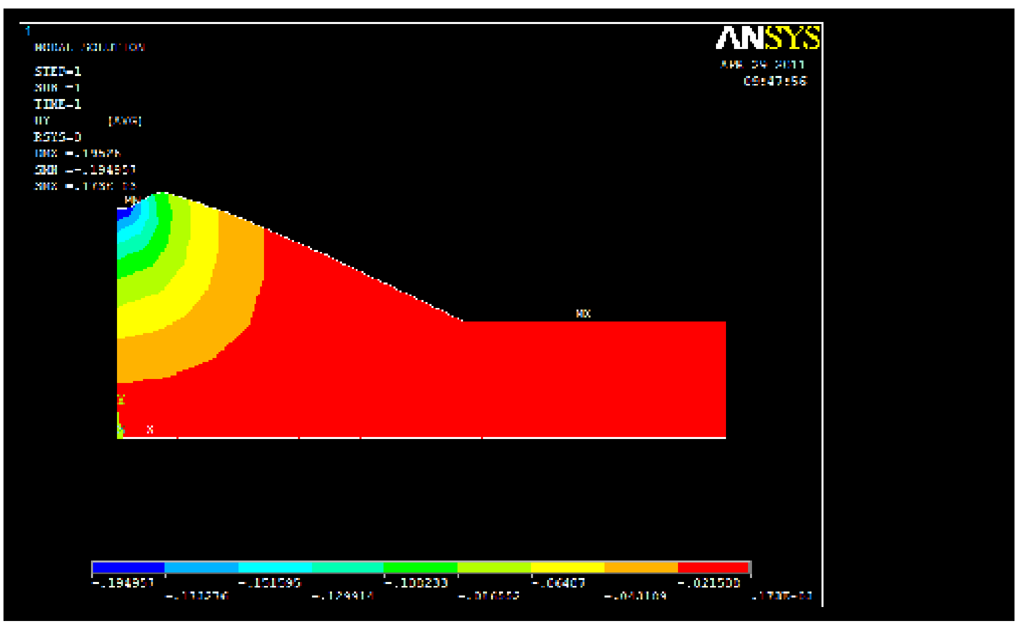

Figure (15): Distribution of vertical displacement at 0.0% fiber content.

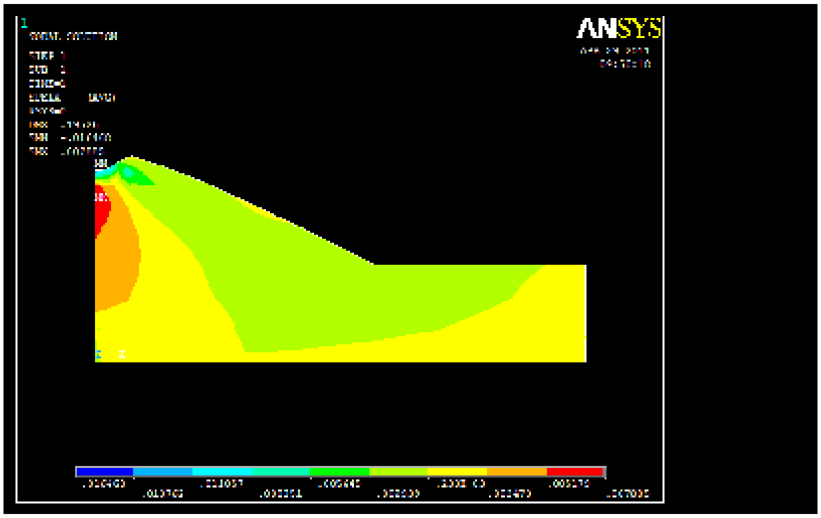

Figure (16): Distribution of horizontal strain at 0.0% fiber content.

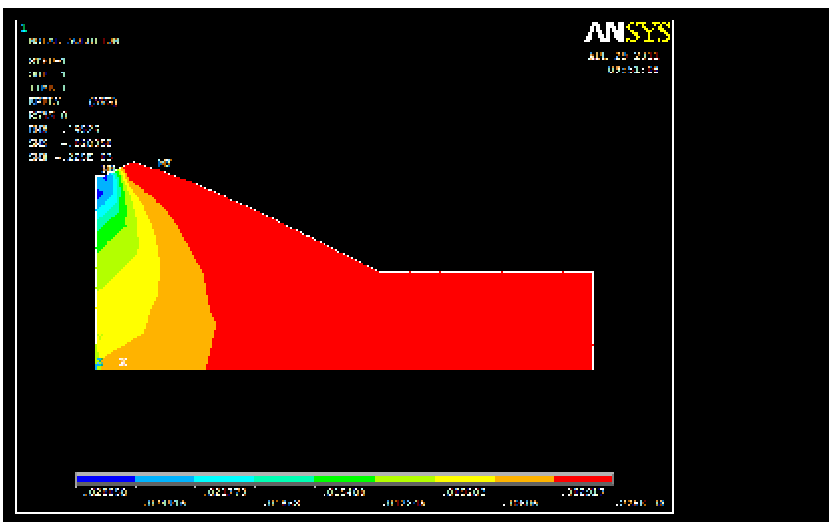

Figure (17): Distribution of vertical strain at 0.0% fiber content.

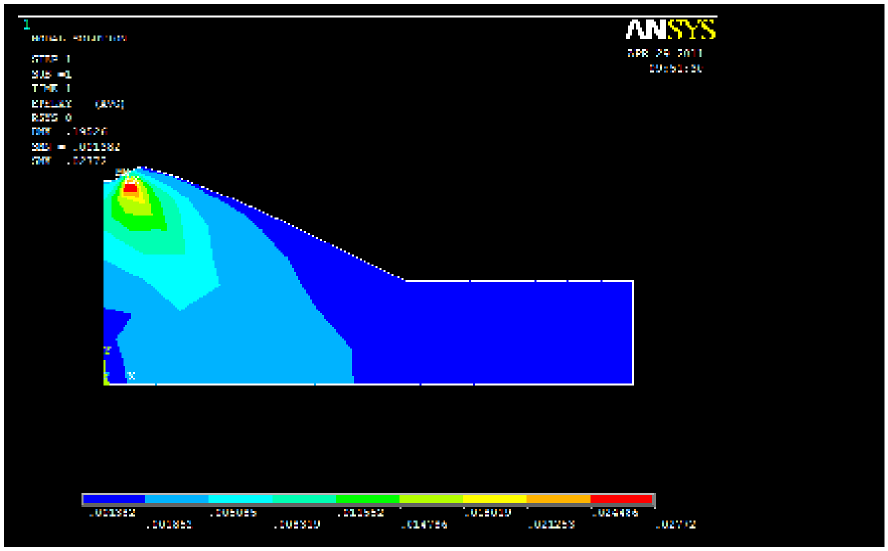

Figure (18): Distribution of shear strain at 0.0% fiber content.

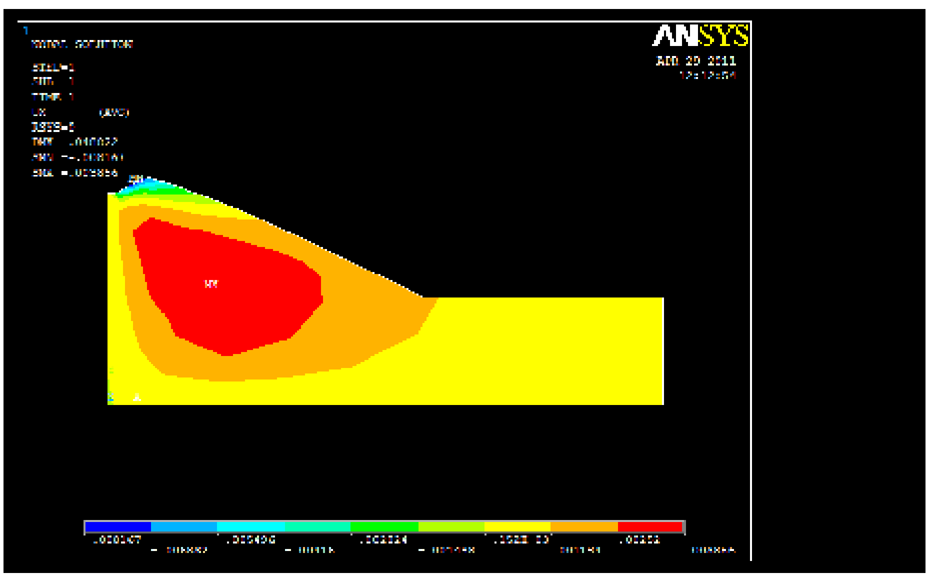

Figure (19): Distribution of horizontal displacement at 3.0% - (L/D=500).

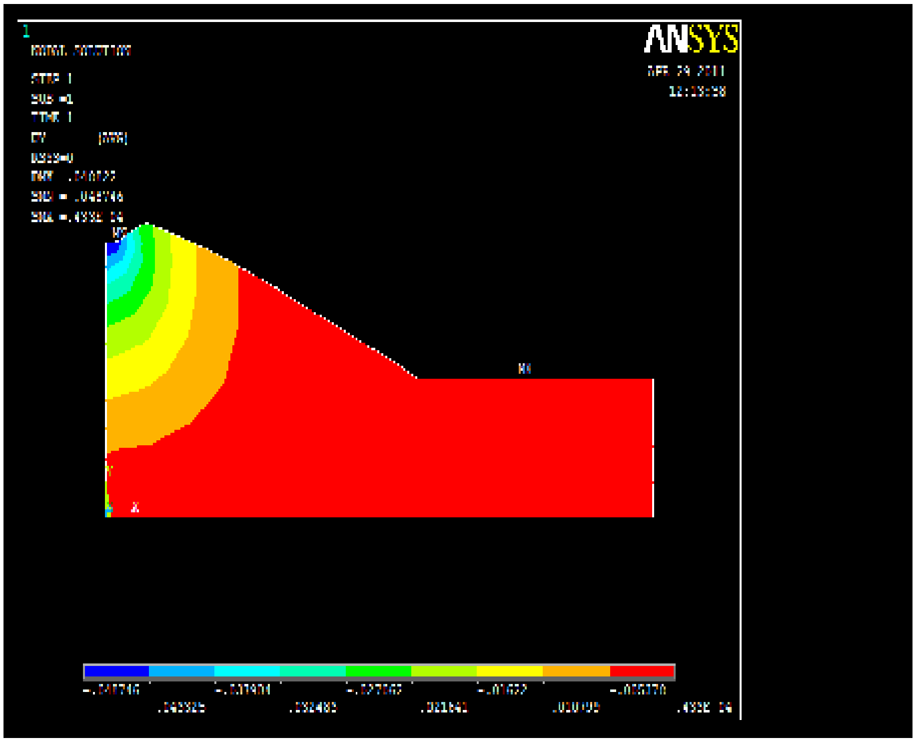

Figure (20): Distribution of vertical displacement at 3.0% - (L/D=500).

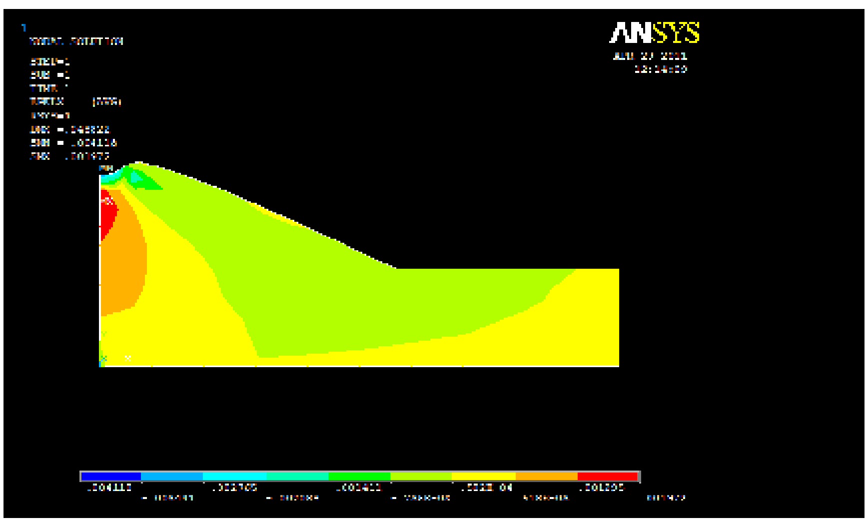

Figure (21): Distribution of horizontal strain at 3.0% - (L/D=500).

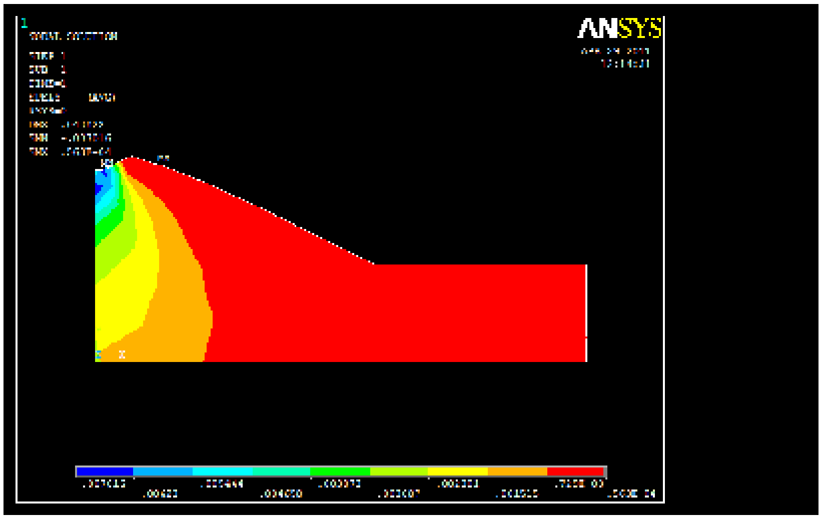

Figure (22): Distribution of vertical strain at 3.0% - (L/D=500).

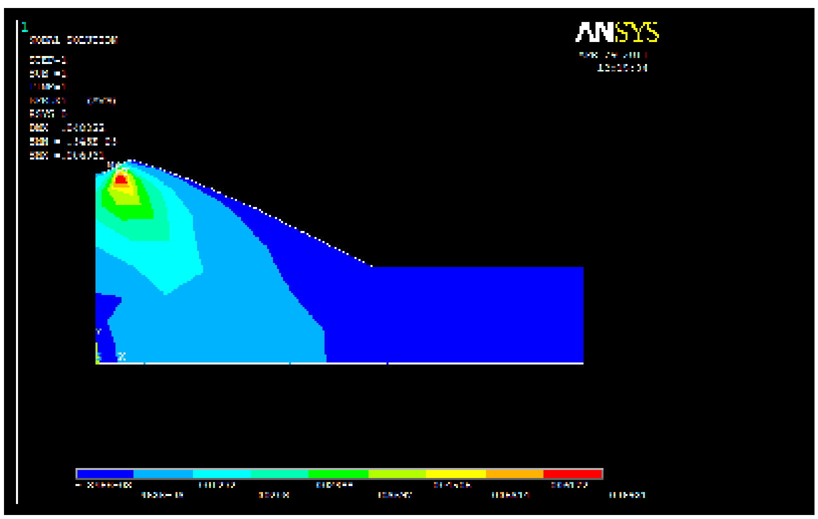

Figure (23): Distribution of shear strain at 3.0% - (L/D=500).

The maximum displacement occurred at the toe of embankment for both horizontal and vertical movement, then decrease gradually to a negligible value. Increasing the percent of fiberglass from (1 to 3%) reduce the vertical and horizontal displacement about (75%) at 3% fiber glass. And reduced the horizontal and vertical strain about (75% & 85%) respectively at the same fiber glass content (3%). This mean the general role of adding the fiber glass works as a tender to soil mixture not as fiber reinforcement. This can be attributed to that the fiber glass act as cementing agent as shown in the obtained experimental results for strength parameters (cohesion and angle of internal friction) from the direct shear test that carried out in this works.

CONCLUSIONS

Based on the results obtained from this research, it can be concluded the following:

1. Increase in fiber glass content, the cohesion increased while the angle of internal friction is almost reduced. In other word, the inclusion of fiber glass had a positive effect on cohesion rather than on angle of internal friction. The maximum value of cohesion observed in 2% fiber glass content for (L/D = 500) & for (L/D = 250), which is about 1.4 and 1.38 times more than the unreinforced soil for (L/D= 500, 250) respectively.
2. Increase in fiber result in increasing of cohesion about 38% for (L/D= 250) and 44% for (L/D= 500) except for (L/D= 80) which their results show that for less L/D the fiber had adverse effect on cohesion strength and fiber glass improvement should be with L/D greater than 80.
3. Increasing fiber glass from 1 % to 3% had a significant effect on the magnitude of both maximum dry unit weight and optimum moisture content of soil mixture. With 1.5% adding fiber to the soil mixture, the maximum dry unit weight decreased approximately 7.1% and optimum moisture content increased by approximately 26.7% at 2% fiber content.
4. The stress- strain behavior of unreinforced soil is rigid and brittle while the fiber glass reinforced specimens exhibited more ductile and increase the unconfined compressive strength by about 3.45 times the base unconfined compressive strength. The failure axial strain reached is 2.3% for unreinforced soil and 4.47%, 14.47%, 10.53 % and 13.68 for 1%, 1.5%, 2% and 3% fiber content respectively which implies that the inclusion of fiber glass increase the unconfined compressive strength and increase the absorbing strain energy or ductility of soil.
5. Increasing the percent of fiberglass from (1 to 3%) reduce the vertical and horizontal displacement about (75 %,) at 3%, and reduced the horizontal and vertical strain about (75% & 85%) respectively at the same fiber glass content (3%). This mean the general role of adding the fiberglass works as a tender to soil mixture not as fiber reinforcement.

REFERENCES

[1]."ANSYS Manual", Version (12.1), USA, 2010.

[2]. Andrawes, K.Z., McGowna, A., Mashhoumr, M. M., and Wilson-Fahmy, R. F., (1980); "Tension Resistant Inclusions in Soils". ASCE Journal of the Geotechnical Engineering Division, 106(GT12), pp. 1313-1326.

[3]. ASTM, American Society for Testing and Materials Standards; 1991, 1998, 2000 & 2002.

[4]. Bell, J. R., Greenwayd, D. R., and Vischerw, W., (1977); "Construction and Analysis of a Fabric Reinforced Low Embankment on Muskeg". Proceedings, 1st International Conference on the Use of Fabrics and Geotechnics, Paris, France, pp. 71-76.

[5]. Marcin Cudny and Heiko P. Neher, (2003); " Numerical analysis of a test embankment on soft ground usingan anisotropic model with destructuration". In P.A. Vermeer, H.F. Schweiger, M. Karstunen & M. Cudny (ed.), Proc. Int. Workshop on Geotechnics of Soft Soils / Theory and Practice, Noordwijkerhout, 265-270, VGE

[6]. Ramesh H. N., ManojKrishna K. V. and Mamatha H. V., (2010); "Compaction and strength behavior of lime-coir fiber treated Black Cotton soil". Faculty of Engineering (Civil), UVCE, Bangalore University, Bangalore-560 056, India.

[7]. Rowe, R. K., Macleanm, M. D., and Barsvaray, A. K., (1984); "The Observed Behaviour of a Geotextile-Reinforced Embankment Constructed on Peat". Canadian Geotechnical Journal, 21, pp. 289-304.

[8]. Kamal, A. A., Pauleen, A. L., and Heshmati, A. R., (2005); "Parametric Study of Reinforced and Unreinforced Embankment on Soft Soil". 13th ACME Conference: University of Sheffield March 21-22.

[9]. Yetimoglu T., Inanir M., Inanir O.E., (2005); "A Study on Bearing Capacity of Randomly Distributed Fiber-Reinforced Sand Fills Overlying Soft Clay". Geotextiles and Geomembranes 23 (2005) 174-183.