ANALYSIS OF GEOTEXTILE EMBANKMENT BY ANSYS

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ABSTRACT:

The major objectives of this research are to analyze the behavior of road embankments reinforced with geotextiles constructed on soft soil and describe the finite element analysis by using ANSYS program ver. (5.4). The ANSYS finite element program helps in analyzing the stability of geo- structure (embankment) in varied application of geotextiles reinforcement to enhance the best design for embankment.

The results of analysis indicate that one of the primary function of geotextiles reinforcement was to reduce the horizontal displacement significantly. With the inclusions of reinforcement, the horizontal displacement reduced by about (81%), while the vertical displacement reduced by (32%). The effect of geotextiles stiffness modulus on horizontal and displacement is quite significant even a very high modulus of geotextile will have relatively little effect on vertical displacement. Also it is observed from the obtained results that the maximum displacement occurred at the toe of embankment for both horizontal and vertical movement, then decrease gradually to a negligible value for the layer reinforced case. Also the reinforcement reduces the shear stress developed in the foundation soil.

الخلاصة:

ان الهدف الرئيسي من هذا البحث هو لتحليل تصرف الطريق المسلحة بالياف والتي تنشاء فوق التربة الضعيفة ووصف تحليل برنامج (5.4) ANSYS ver العناصر المحددة. برنامج العناصر المحددة ANSYS يساعد في تحليل ثبوتية المنشاءات الجيوتكنيكية (التعليات) مع تطبيقات مختلفة من الياف التسليح (geotextiles) لاختيار التصميم الافضل للتعليات. ان نتائج التحليل تبين ان احد اهداف الياف التسليح هو لتقليل الازاحة الافقية بصورة ملحوظة. مع وجود التسليح ، الازاحة الافقية تقل بحوالي(81%) ، بينما تقل الازاحة الشاقولية بحوالي (31%). ان تاثير معامل صلادة الياف التسليح على الازاحة الافقية يكون ملحوظا بصورة واضحة اما تاثير القيم العالية لمعامل صلادة الياف التسليح يكون قليل على الازاحة الشاقولية. وكذلك تم ملاحظة من النتائج المستحصلة ان اعلى قيمة للازاحة تحدث في حافة التعلية بالنسبة لكل من الحركة الافقية والشاقولية، ثم تقل تدريجيا حتى تصل الى قيمة مهملة بالنسبة لحالة تسليح الطبقات. كذلك ان التسليح يقلل اجهادات القص المتولدة بتربة الاساس.

KEY WORDS: Embankment; reinforced; geotextiles; finite element; numerical analysis; soft soil; displacements.

INTRODUCTION

The most common analysis method used for designing geotextile reinforced embankment fall into two broad categories, namely, conventional limit equilibrium and finite element methods. Limit equilibrium approaches are the most numerous *(e.g., Haliburton 1981; Fowler 1982; Jewell 1982)* and attractive because of their simplicity.
However there are inherent difficulties in the limit equilibrium methods to take into consideration the soil- geptextile interaction. The main advantage of finite element analysis over conventional method is that complete interaction of the embankment foundation system can be simulated.
Several investigators *(e.g., Andraws et.al 1980, Bell et al. 1977, Rowe, 1984)* have used finite element technigues 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, etal. (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.

- Geotextiles Reinforcement

The development of geotextiles utilities in subsurface construction works has been generally increased in the solution of engineering problems. Geotextiles used with foundation soil, rock, or any other geotechnical structure or system *(ASTM D4439)*. The polymers used in manufacture of geotextiles fiber are made from polymer materials. Its properties could be shown in Table (1).

Geotextiles improve the total system by increasing its strength which, created by introducing the geotextiles into a soil or other disjointed and separated material. Soils have no or little tensile strength (due to appearance cohesion). Because of that, a geotextiles placed horizontally in the direction of principle stress in the soil mass will improve the tensile property of soil *(Koerner, 1990)*. Thus the geotextile acts as reinforcement so any normal applied load on the reinforced soil mass will mobilize tensile forces in the geotextile through friction, and therefore limiting the lateral deformation of the soil mass.

In design, the geotextile reinforcement to enhance soil stability, various factors involve, stiffness of reinforcement in relation to the surrounding soil, orientation of the reinforcement on the purpose embankment, form of reinforcement, creep performance of the reinforcement during the life time of the embankment and corrosion resistance during life time. Figure (1) shows the common scheme use in designing the reinforcement layers.

- 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 (**AN**alysis **SYS**tem) 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 Embankment

In the present study, the ANSYS program of version (5.4) was employed for analyzing embankment foundation system as well as the finite element modeling for geotextile reinforcement. 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 elasto-plastic material (plane strain condition) based on Darger –Parger model with isotropic material therefore a stiffness elastic modulus

(E) and 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) as shown in Figure (3).

The cross section of road embankment used in this study of 18 m crest width and 1:2 side slops are shown in Figure (2). The depth of the soft foundation soil is 20m finite element discretization of the problem is shown in Figure (3). Due to symmetry along the center line only half of the geometry was simulate.

In the present study, the geotextiles reinforcement was represented by the smeared model as shown in Figure (4) which assumes that the reinforcement is uniformly spread in a layer throughout the embankment soil element in a defined region of the finite element mesh. This model used for large scale model.

The finite element program ANSYS version (5.4) is used to analyze the embankment and geotextiles theoretically using a plane 42, 2-D structural solid that has been adopted in this research. 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.

- Analysis Results and Discussions

The geotextiles reinforcement was placed as layer of 0.5 m thickness working mat spread through the embankment and above the embankment foundation interface as shown in Figure (3).

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 (v), 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 (1).

Figures (5) and (6) show the horizontal and vertical movement against vertical direction at the toe of embankment. And from these results, it would appear that the primary function of the geotextiles reinforcement was to reduce the horizontal displacement significantly. With the inclusions of reinforcement, the horizontal displacement reduced by about (81%), while the vertical displacement reduced by (32%). This shows that the reinforcement may be considered as important role in reducing horizontal and lateral movements.

The modulus and strength of geotextiles also appears to be of an important effect. Therefore its effect was studied and were shown in Figures (7) and (8) for horizontal and vertical displacement respectively. It's clear from these figures that the effect of geotextiles stiffness modulus on horizontal and displacement is quite significant. Even a very high modulus of geotextile will have relatively little effect on vertical displacement.

Figures (9) and (10) show the distribution of horizontal and vertical displacement with horizontal distance along the embankment surface from the toe of embankment. The maximum displacement occurred at the toe of embankment for both horizontal and vertical movement, then decrease gradually to a negligible value for the layer reinforced case. The contour lines for horizontal and vertical movements are also shown in Figures (11) to (14) for both cases studied.
Figures (15) and (16) show the shear stress developed in the embankment foundation system for both cases. It can be observed that the reinforcement reduce the shear stress developed in the foundation soil by 50%.
Figure (16) shows the deformation mesh of embankment foundation using the geotextiles reinforcements.

- CONCLUSIONS

The behavior of reinforced embankment with geotextiles have been investigated using the ANSYS ver. (5.4) finite element program and the following conclusions can be drawn:

- With the inclusions of reinforcement, the horizontal displacement reduced by about (81%), while the vertical displacement reduced by (32%). This shows that the reinforcement may be considered as important role in reducing horizontal and lateral movements.

- The effect of geotextiles stiffness modulus on horizontal and displacement is quite significant. Higher values of geotextile modulus will have relatively little effect on vertical displacement.

- The maximum displacement occurred at the toe of embankment for both horizontal and vertical movement, then decrease gradually to a negligible value for the layer reinforced case.

- The reinforcement reduces the shear stress developed in the foundation soil by 50%.

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Table (1): Polymer used in Manufacture of Geotextile.

Polymer Composition of Geotextile			
Polypropylene (65%)	Polyester (32%)	Poly Amide (2%)	Polyethylene (1%)

Table (2): Input Parameter for F.E. Program Analysis *(Neher and Cudny, 2003)*.

Material	Embankment Soil (fill materials)	Foundation Soil
E (MPa)	50	20
Poisons Ratio (v)	.15	.2
Friction Angle (^{o})	35	25
Cohesion (kPa)	3.0	5.7
Unit weight (kN/m^3)	21	15
Diltency Angle (^{o})	0	0
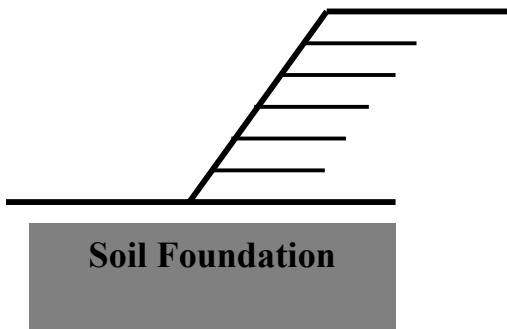
a) Even space - even length.
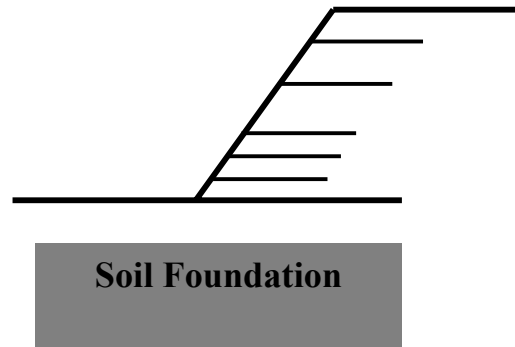
b) Uneven space- even length.
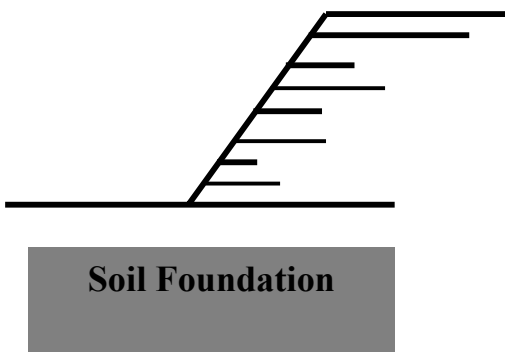
c) Even space – Uneven length with short facing
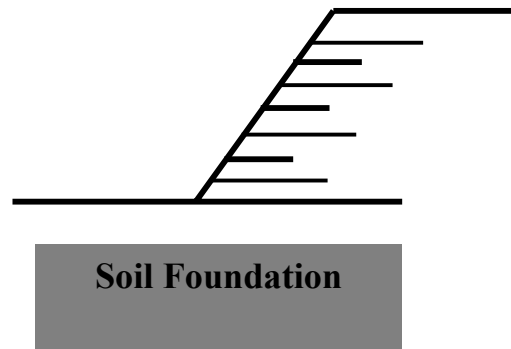
d) Uneven space –Uneven length with short facing layers.

Figure (1): Common Scheme use in designing the Reinforcement Layers.
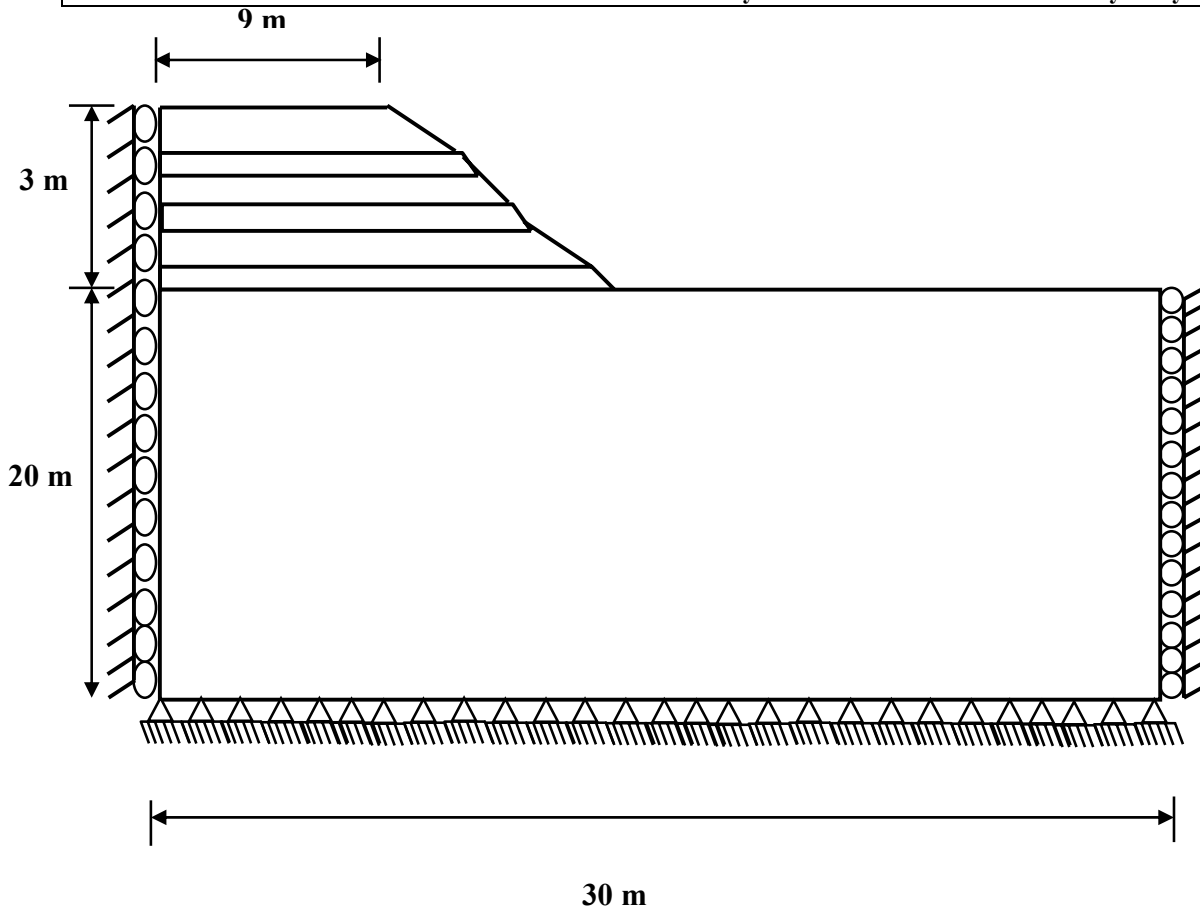
Figure (2): The Cross Section of Embankment Foundation System with Geotextiles Reinforcement.
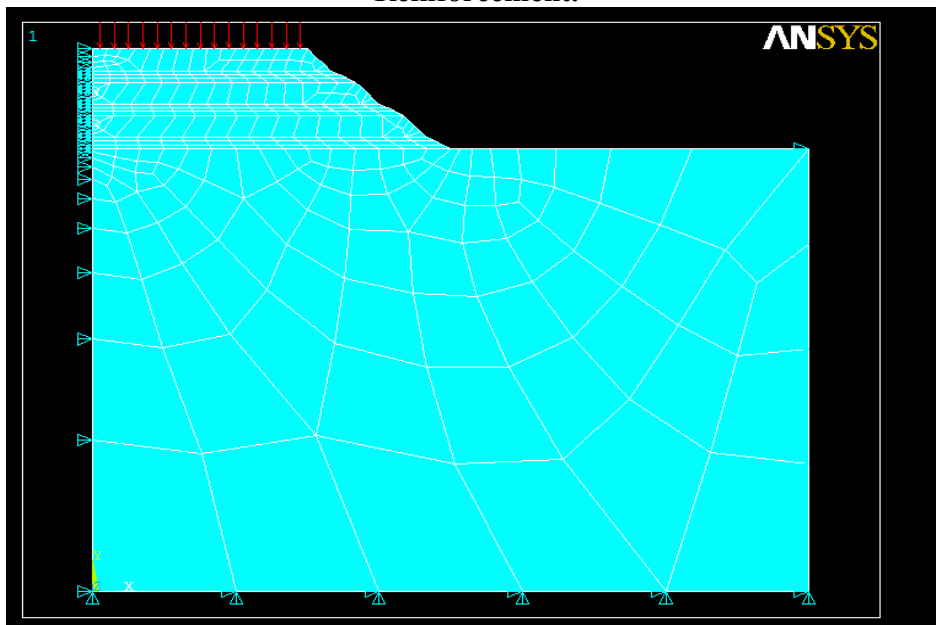
Figure (3): Finite Element Mesh of Embankment Foundation System.

Soil node   Soil element

Smeared properties of geotextiles in embankment
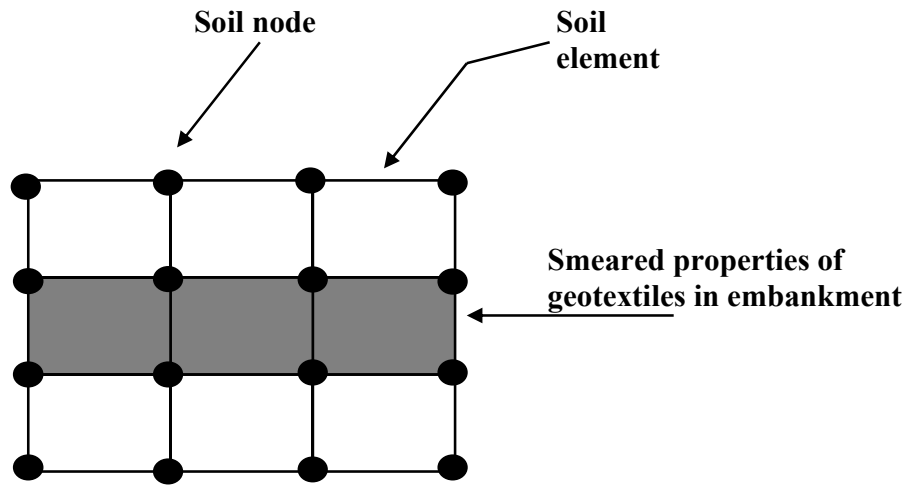
Figure (4): Model for Geotextiles Reinforcement in Embankment Foundation System.
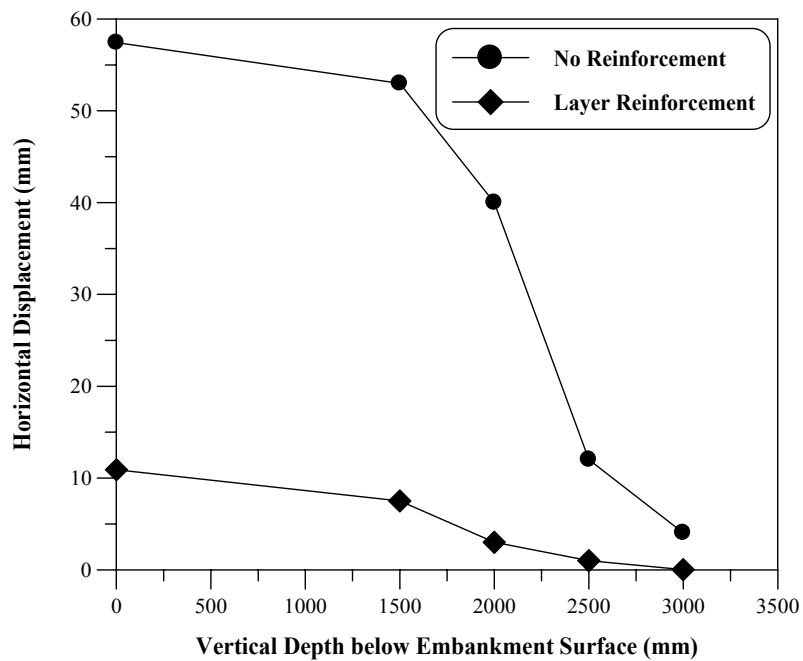
Figure (5): Variation of Horizontal Displacement with Vertical Depth below Embankment Surface.
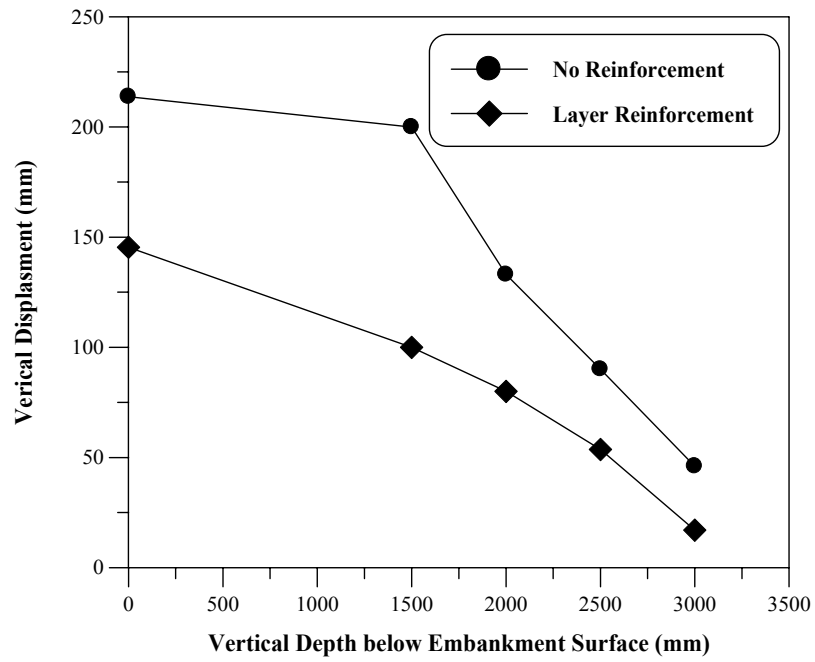
Figure (6): Variation of Vertical Displacement with Vertical Depth below Embankment Surface.
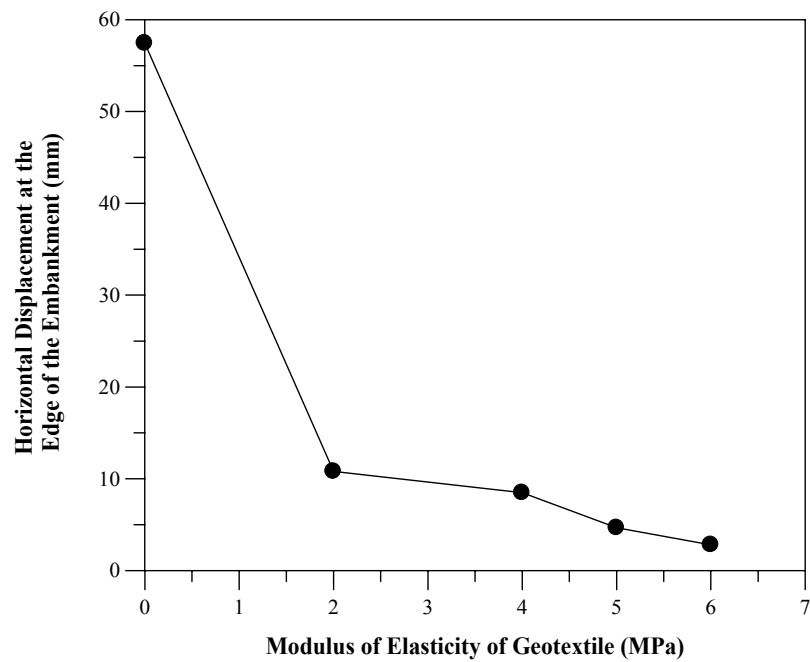
Figure (7): Effect of Elastic Modulus of Geotextile on Horizontal Displacement.
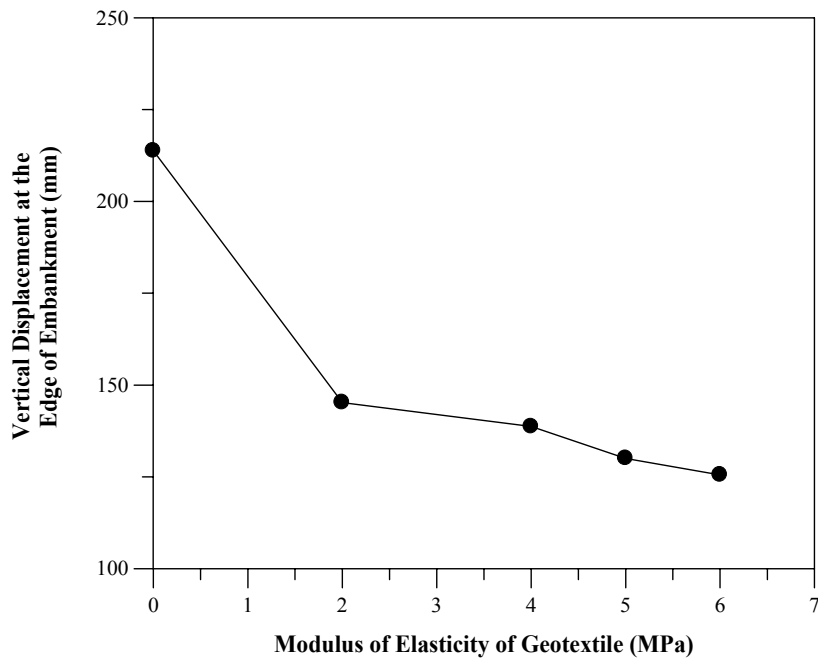
Figure (8): Effect of Elastic Modulus of Geotextile on Vertical Displacement.
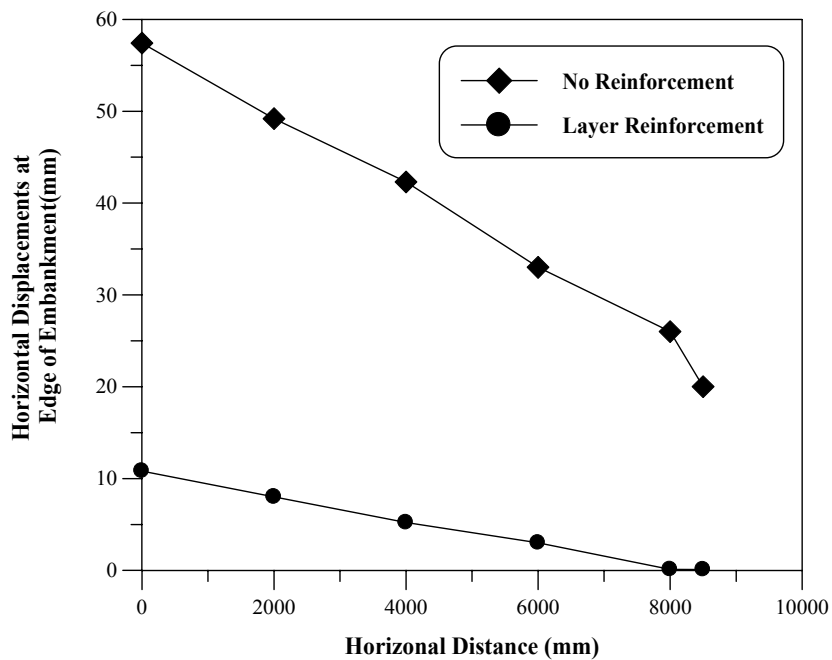
Figure (9): Variation of Horizontal Displacements with Horizontal Direction along Ground Surface.
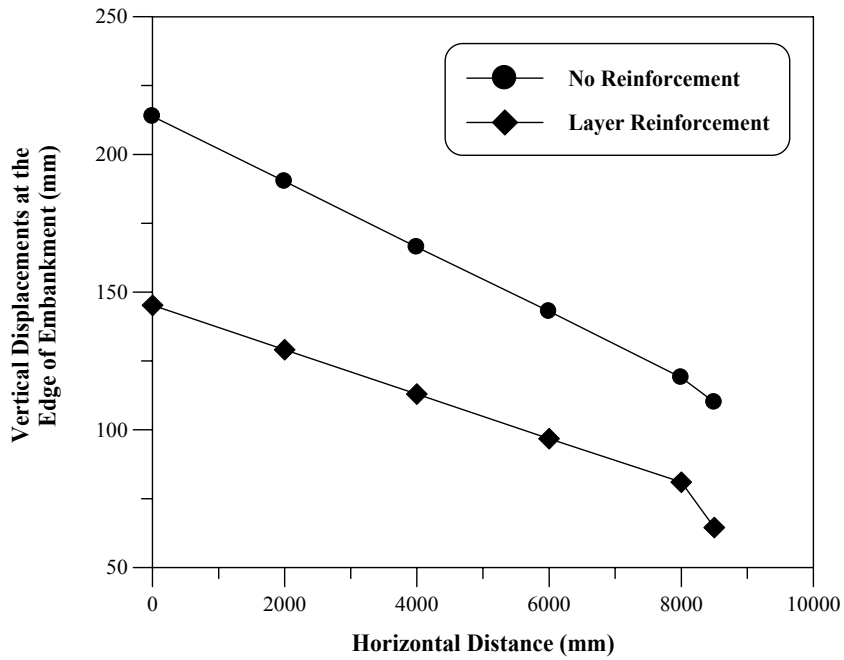
Figure (10): Variation of Vertical Displacements with Horizontal Direction along Ground Surface.
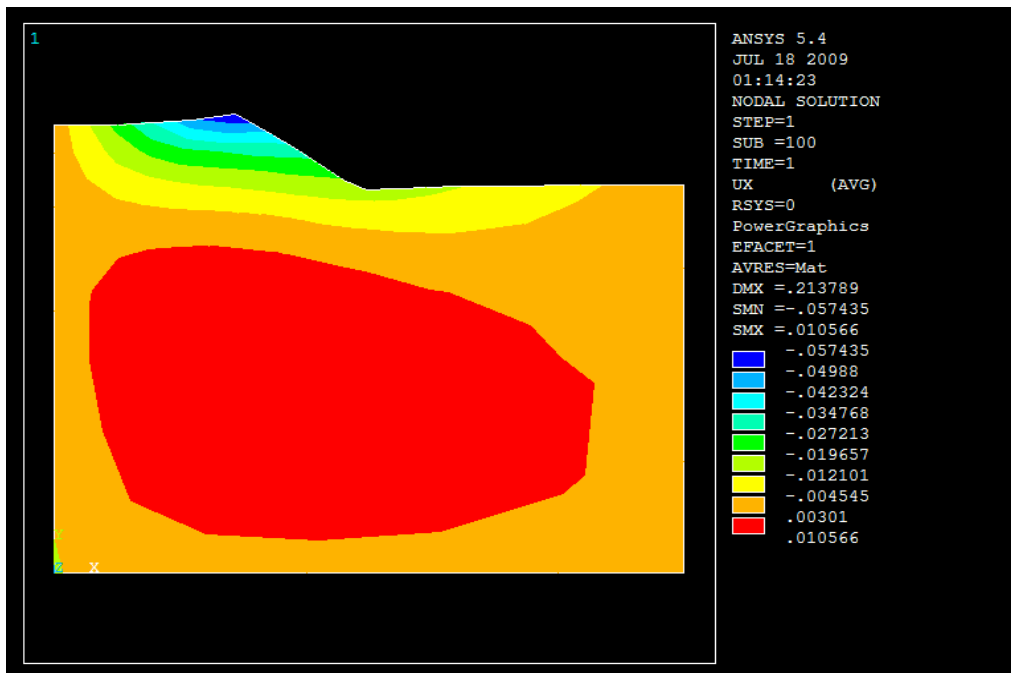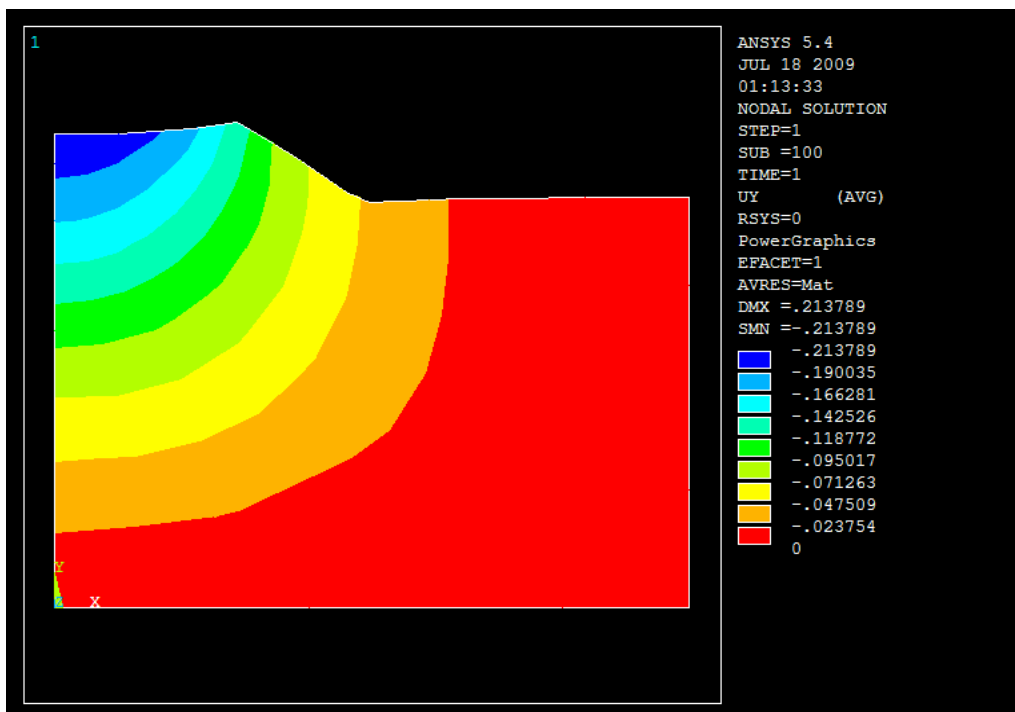

Figure (11): Horizontal Displacements Distribution in Embankments Foundation without Geotextiles Reinforcements.
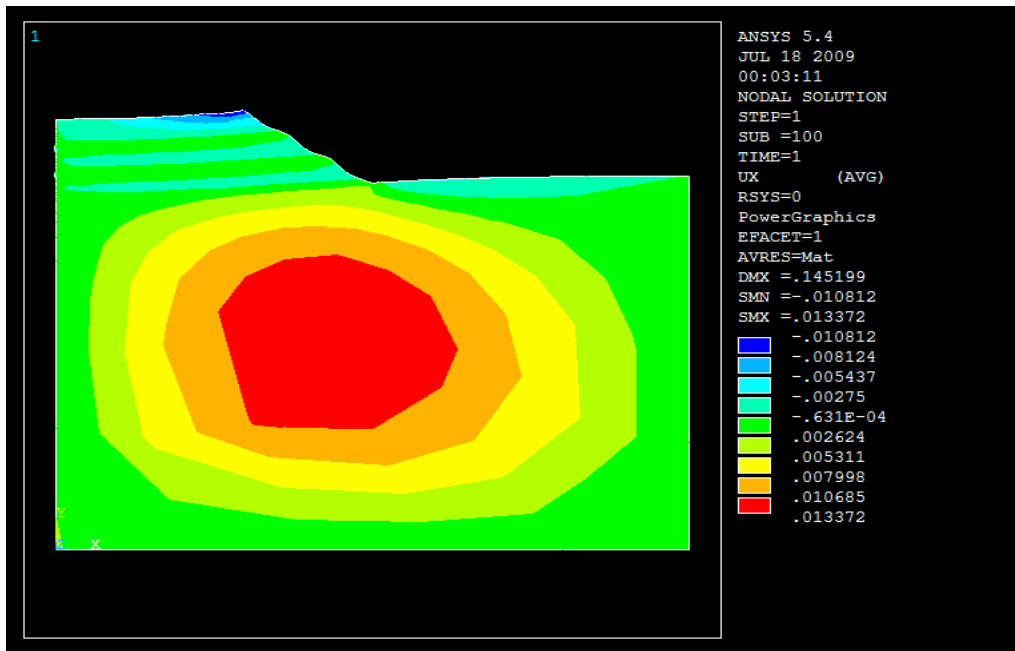
Figure (12): Horizontal Displacement Distribution in Embankments Foundation with Geotextiles Reinforcements.

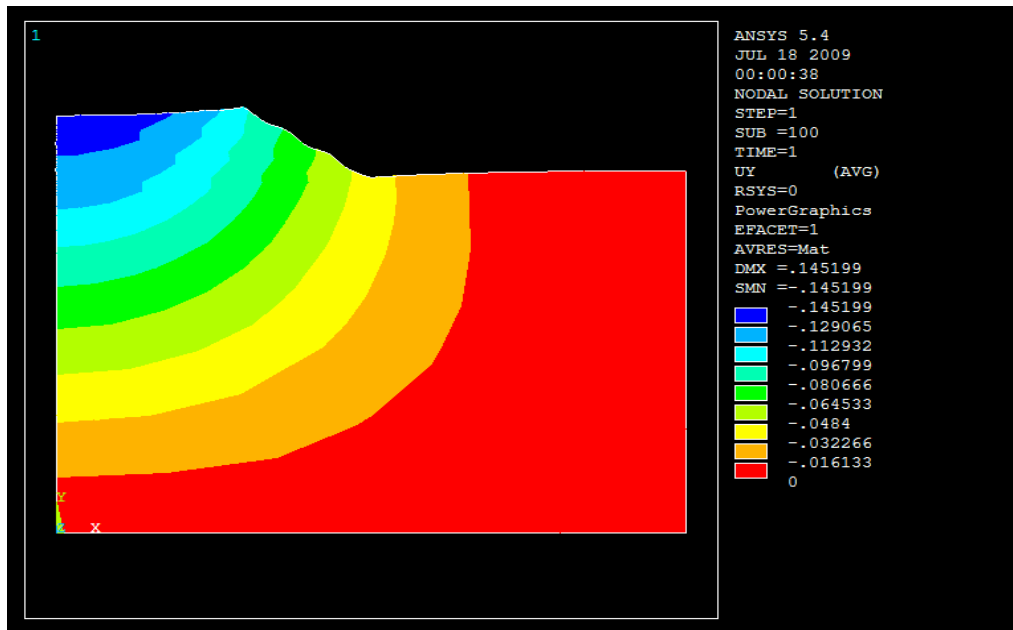**Figure (13): Vertical Displacements Distribution in Embankments Foundation without Geotextiles Reinforcement.**

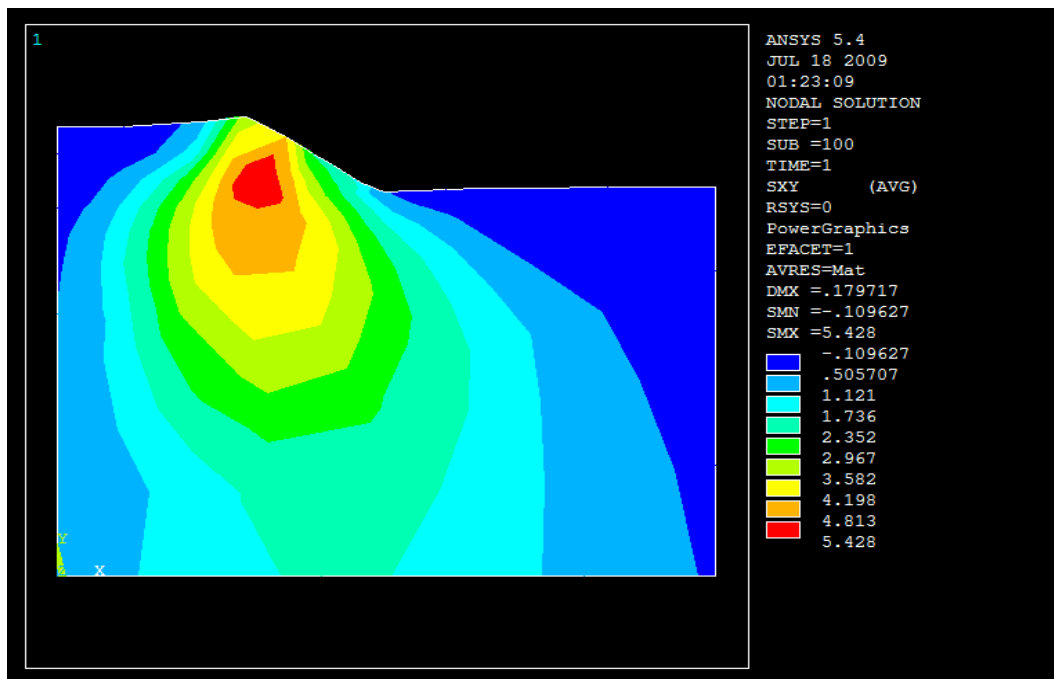**Figure (14): Vertical Displacements Distribution in Embankments Foundation with Geotextiles Reinforcement.**

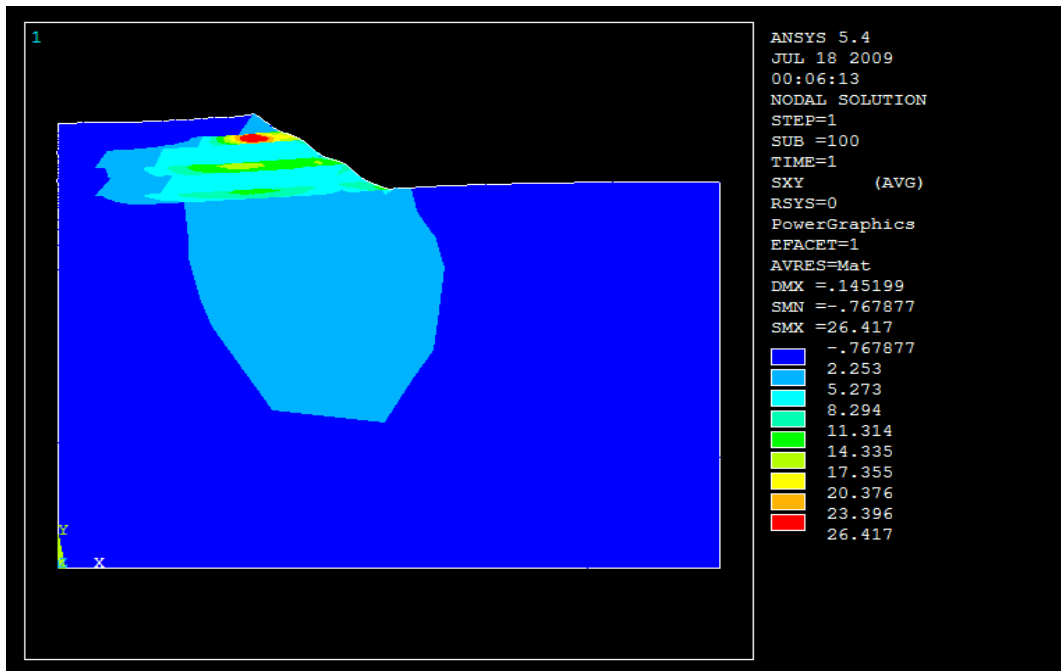**Figure (15): Shear Stress Distribution without Geotextiles Reinforcements.**

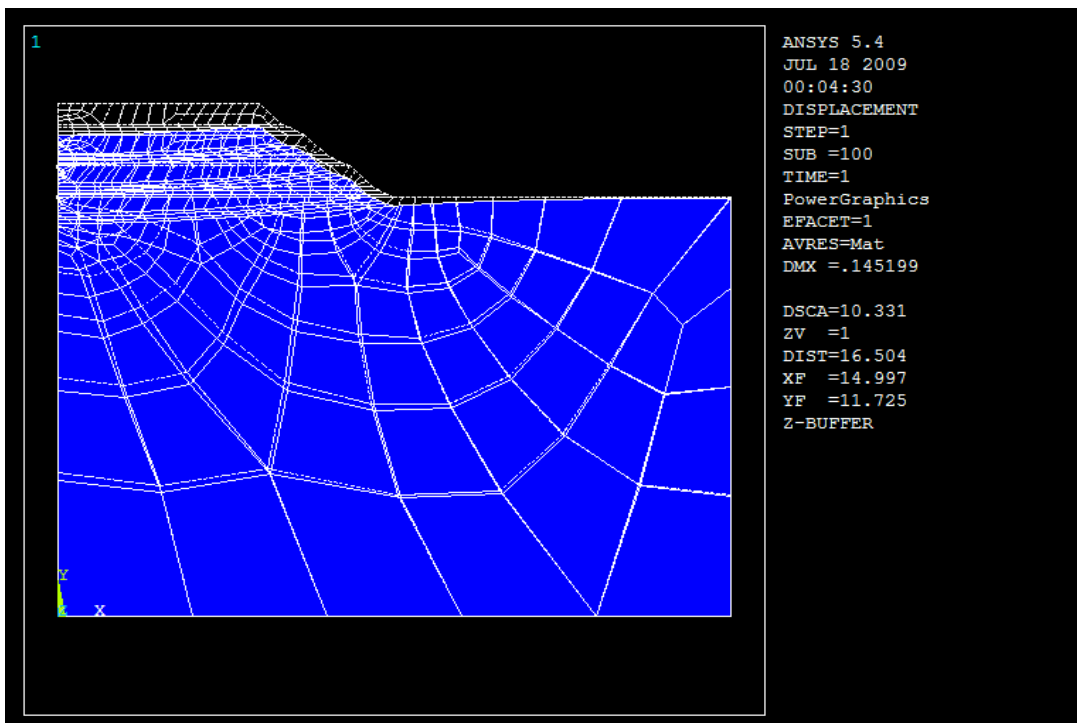**Figure (16): Shear Stress Distribution with Geotextiles Reinforcements.**

Figure (17): Deformation of Embankment Foundation with Geotextiles Reinforcements.