Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2017, 4(10): 759-764

Research Article ISSN: 2394 - 658X

# Effect of Reinforcement on stability and Settlement of Embankment: A Finite Element analysis of Different Kinds of Reinforcing and Construction Conditions

**Payam Majedi[1], Babak Karimi Ghalehjough[1], Suat Akbulut[2], Semet Çelik[1]**

*[1]Department of Civil Engineering, Ataturk University, Erzurum, Turkey*
*[2] Department of Civil Engineering Department, Yildiz Technical University, Istanbul, Turkey*
*payam.majedi@gmail.com*

## ABSTRACT

*Due to less shear strength and high compressibility of soft soils, construction of soil embankment on these types of soils leads to problems such as big and non-uniform settlements. Nowadays, soil reinforcement is used as a trustable and efficient way for increasing soil strength and stability of it. Usage of geosynthetics for increasing height of embankments and their stability has been increased significantly in recent years. Using geosynthetics cause decrease of tensile weaknesses and make the soil more stable by decreasing the settlement of it. In the present study, the effect of axial stiffness of geosynthetics, the number of layers, and the angle of slope on embankment manner were analysed on a clayey layer of soil by the use of Plaxis 2D which is a finite element software. The results showed that using geosynthetics led to a decrease of deformations and increasing of stability of embankment. At the same time, decreasing embankment slope and increasing stiffness caused decrease of deformations.*

**Key words:** Reinforced Embankment, Geotextile, Plaxis, Soft Soil, Numerical Modelling

## INTRODUCTION

Soil is known as material that can bear pressure and shear loads but is not stable in front of tensile loads. Reinforcing soil is one of effective and trustable method for improving and treatment of soil properties. Soils reinforcements are composite materials include elements that can bear tensile loads. Soil reinforcement are used at different issues such as earth dams, slopes or retaining walls and even on stabilization of soil layers under shallow foundation or embankments of roads [1]. Concept of reinforced soil has been use by Henry Vidal, a French engineer at 1968. He used metal strips between compacted soil layers for increasing its strength and stability. After decade 80 uses of geosynthetics as reinforcing materials have been increased significantly [2]. They are used vastly because of economic reasons and easy application at reinforcing structures like embankments, dams and slope [3-4].

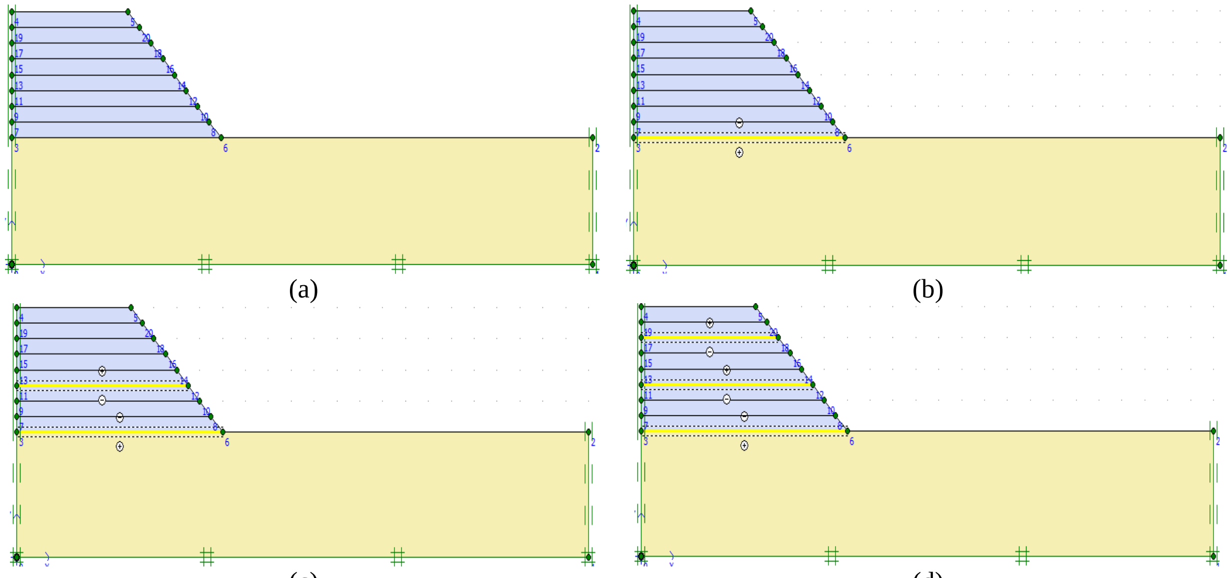
Geosynthetics reinforcement have special rule on increasing of safety factor of slopes. Geosynthetics reinforcements have been divided to groups of geo-membranes, geo-grids, geo-nets and geo-composites. Because of increasing traffic at recent years, many of road embankments have been made on soft soils. At these conditions engineer has been faced with different problems such as settlement and instability of slopes, so lots of studies have been done on geotextiles as a trustable material for reinforcing and improving soil properties [5-12].

Some studied had done on effect of geotextiles on soil slopes stability in front of seismic loads [13-17]. Reference [18] investigated the applications of finite element method on embankments reinforced by geotextiles. At this study application of finite element method has been studied on effect of angle of sloe on stabilization of a soil embankment. At the same time effect of layers numbers and geotextile stiffness on increasing stability and decreasing settlement and horizontal movement of embankment have been studied. Modeling has been done by Plaxis 2D that is a finite element software.

## MATERIALS AND METHODS

### Geometry of Model

At this part geometry of model has been explained completely. Modeling includes geometric properties of model such as: slope of embankment, crest width, width of embankment base and geometric properties of construction place of embankment. Main model embankment with 4m height, 10m crest with and slope of 1:1 placed on a clayey layer with thickness of 4m. An impermeable sandy layer has been placed under clayey layer, so it had not used on modeling. Because of symmetric geometry of embankment just half of it has been modeled and analyzed. For purpose of simulating construction of embankment, body of embankment has been divided to layers with 0.5m of thickness. For reinforcing embankment, geotextile layers with different stiffness have been used at the contact point of base and embankment and height of 1.5m and 3m. Geometry that used for modeling and analyzing has been shown at Fig.1. Because of bed rock existence under clay layer boundary conditions of bottom part modeled in a condition that horizontal and vertical movement was limited. At the same time horizontal movement at lateral bounds has been limited too but as these boundaries have no any effect on vertical settlements so vertical movement for these bounds were open and model can move vertically at these points.



(a) (b) (c) (d)

**Fig. 1 Geometry of model and geotextile placements. (a) Unreinforced state (b) Reinforced with one layer (c) Reinforced with two layers (d) Reinforced with three layers**

**Table -1 Properties of Materials Used in Modelling**

| | **Parameter** | **Specification** | **Value** | **Units** |
|---|---|---|---|---|
| **Embankment** | Material model | Model | Mohr-Coulomb | - |
| | Material behavior type | Type | Drained | - |
| | Unit weight | $\gamma$ | 19.2 | kN/m$^3$ |
| | Saturated unit weight | $\gamma_{sat}$ | 19.2 | kN/m$^3$ |
| | Module of elasticity | $E_{ref}$ | 6130 | kN/m$^2$ |
| | Poisson's rate | $\upsilon$ | 0.33 | - |
| | Cohesion | C | 10 | kN/m$^2$ |
| | Interface strength | $R_{intr}$ | 0.9 | - |
| | Friction angle | $\varphi$ | 38 | degree |
| **Clay** | Material model | Model | Soft soil creep | - |
| | Material behavior type | Type | Undrained | - |
| | Unit weight | $\gamma$ | 16 | kN/m$^3$ |
| | Saturated unit weight | $\gamma_{sat}$ | 18.5 | kN/m$^3$ |
| | Poisson's rate | $\upsilon$ | 0.15 | - |
| | Cohesion | c | 20 | kN/m$^2$ |
| | Modified swelling index | $\kappa$ | 0.026 | - |
| | Modified compression index | $\lambda$ | 0.13 | - |
| | Interface strength | $R_{intr}$ | 0.9 | - |
| | Friction angle | $\varphi$ | 23 | degree |
| **Geotextile** | Material model | Type | Lineer Elastik | - |
| | Axial rigidity | EA | 1250, 2500, 5000 | kN/m |

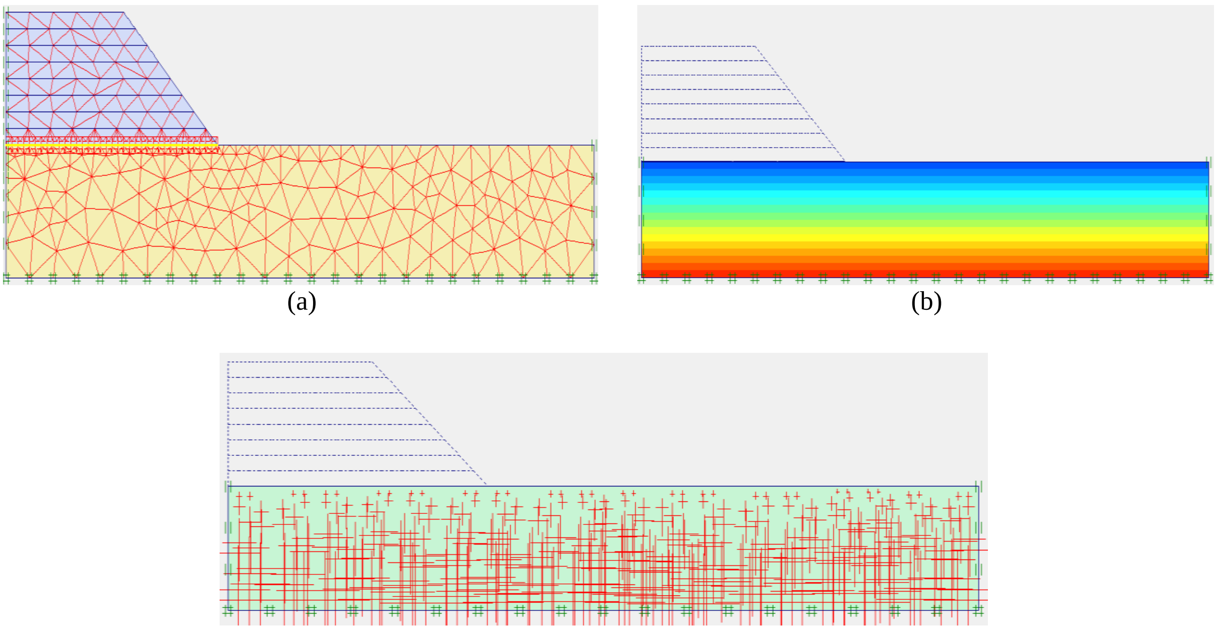
**Material Properties**

Other main part of modeling is definition of materials and their properties. There are two kind of materials with different properties has been used at this model. Moher-Columb model has been used for embankment materials and by considering the type of materials they have been modeled as drained materials. But because of base of earth materials is clay with low shear strength and permeability, soft soil creep has been used for modeling it that in this case consolidation behavior of clay depends on time can be modeled. This model has additional parameters such as μ, κ and λ that earned by odometer tests. Because of lees permeability of clay manner of this material has been modeled as undrained material. At this study geotextile with axial stiffness has been used for reinforcement. This case is shown by EA at Plaxis software. The amount of EA=2500 kN/m has been used in the model as default value, but for study effect of axial stiffness, values of EA=1250 kN/m and EA=5000 kN/m has been used in model too.

To modeling soil geotextile interaction, interface element has been used at the contact point of soil and geotextile. Rintr parameter has been used for definition shear strength between soil and reinforcement. According to [10], $R_{intr}$ has been considered as 0.9 ($R_{intr}$ = 0.9). Properties used for materials have been showed on Table 1 that gained from [16].

**Element and Initial Conditions**

After introducing geometry of model and materials properties, it is necessary meshing the geometry of model for analysing it. This has been done automatically by software. Fine mesh has been used for meshing embankment. For increasing accuracy of model, meshes have defined finer around geotextiles and levee paw. After meshing the geometry, for analysing embankment under pre construct tensions, initial conditions have been defined to model at two steps. Initial conditions consist gravity loads and initial water level conditions. At initial gravity load conditions, model is under loading of weight of basement material before constructing the embankment. At this step, embankment has been disabled and basement has been analysed by its own weight and initial effective tensions have been calculated. Basement soil used at this analyse is saturated so level of water is matched to top of basement level. For preventing water loose from left and right boundaries of model, they have been closed and water can be drained only from top or bottom of model. After doing all of these, initial tensions caused by water have been gained. Meshing, initial effective tensions and initial tensions caused by water have been showed at Fig. 2.



(a) (b) (c)

**Fig. 2 (a) Meshed Model (b) Tensions caused because of water (c) Initials effective tensions**

**RESULT AND DISCUSSION**

**Pore Water Pressure**

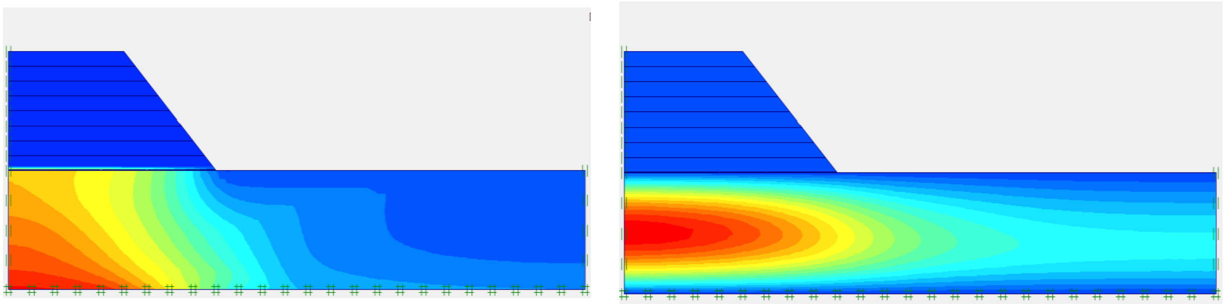
Pore pressure water at clayey basement after construction and consolidation has been showed at Fig 3. As seen at this picture because of high speed of construction and less permeability of clay layer, water of clay layer could not be drained, but after finishing consolidation pore water pressure has been finished.

**Effective Stress**

Fig 4. shows changes on effective stress at main model after finishing construction of embankment and consolidation. According to previous explanations after finishing the consolidation step and dissipating pore water pressure, effective stress will be increased at mass of basement.

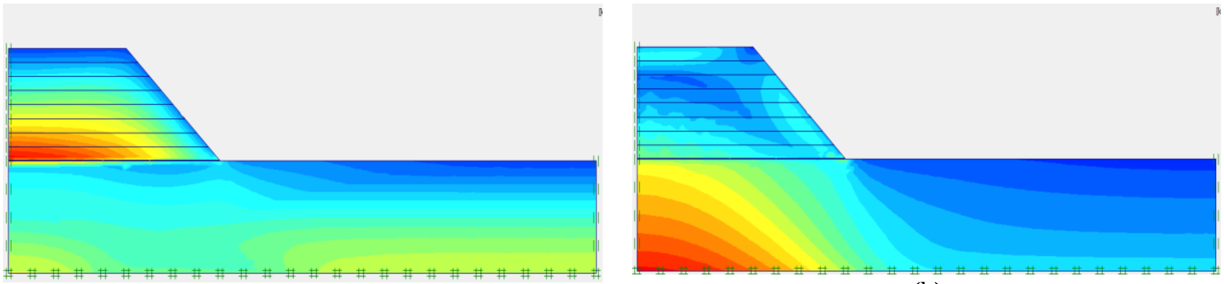
**Basement and Embankment Deformation**

Deformation of embankment after construction and finishing consolidation step has been showed at Fig.5. Because of not existing of drainage at basement, deformations created at embankment after construction is because of deformation and sinking of embankment materials. After finishing consolidation, effective stress of soil mass has been increased and deformation has been happened at basement of embankment. It can be concluded that embankment deformations are because of basement deformations.



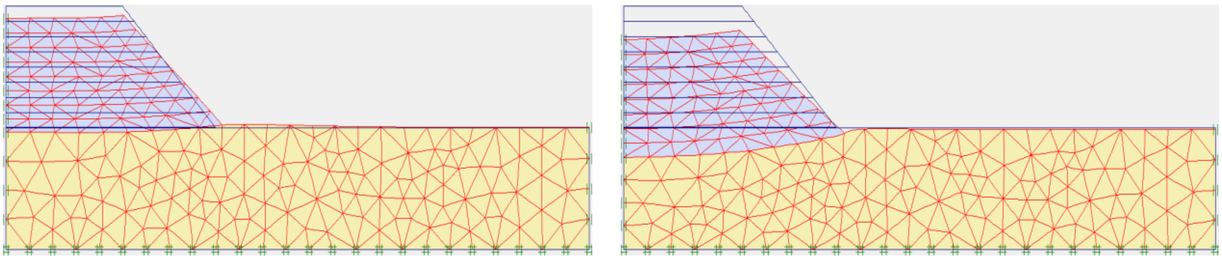
(a) (b)

**Fig 3. Changes of Pore Water Pressure (a) exactly after Construction (b) After Consolidation**



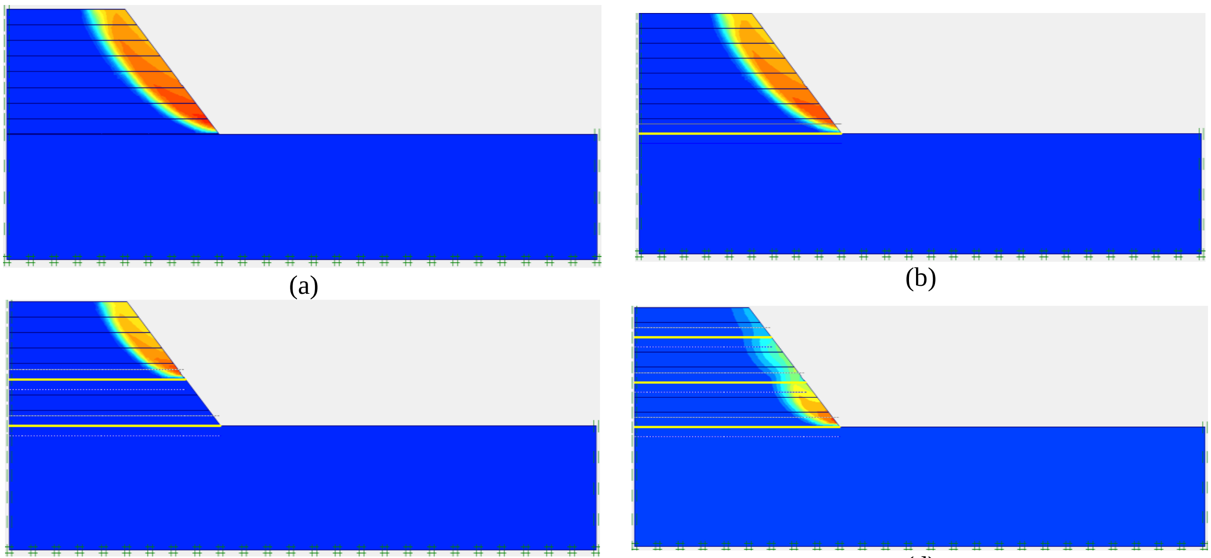
(a) (b)

**Fig 4. Changes of effective Stress of Soil (a) After Construction (b) After Finishing Consolidation**



(a) (b)

**Fig 5. Deformation at Embankment a: After Finishing Construction b: After Finishing Consolidation**



(a) (b)

(c) (d)

**Fig 6. Sliding Surfaces of Embankment Slope (a) Unreinforced (b) Reinforced with one layer of geogrid (c) Reinforced with two layers of geogrid (d) Reinforced with three layers of geogrids**

**Effect of Stiffness and Number of Geogrids Layers on Stability of Embankment**

Different embankments with layers' numbers of 1, 2 and 3 and different stiffness have been modelled for analysing effect of stiffness and number of layers on embankment stability. Default axial stiffness has been considered as 2500 kN/m and for considering effect of axial stiffness two other kinds of geogrids has been studied with stiffness of 1250 kN/m and 500 kN/m.

By looking to Fig 6 (a) the most horizontal deformation happens at embankment toe so at unreinforced condition slope will be failed and structure will be unstable. Safety factor for slope stability has been gained 1.43 that is an unacceptable value. But after reinforcing soil, because of increasing soil tensile strength, horizontal displacement of soil will be decrease so stability of slope will increase. Horizontal displacement showed 15% to 20% decrease depends on geogrids stiffness at slopes reinforced with one layer. According decrease on lateral movement safety factor has been increased to1.78 in front of sliding at the slopes reinforced with one layer of geogrid with 2500 kN/m. This value is 1.68 and 1.84 for axial stiffness of 1250 kN/m and 5000 kN/m respectively. Results showed that increasing axial stiffness caused increase on safety factor of embankment slope. By considering the results by using on layer of reinforcing there is not any need for using other layers and best place for putting reinforcement is base soil and embankment.

**Effect of Stiffness and Number of Geogrids Layers on Embankment Deformation**

Amount of horizontal and vertical deformation for reinforced and unreinforced embankment at different analytical conditions has been showed at Table 2. According to information earned from this table reinforcing by geogrids has not any special effect on decreasing vertical settlement but it causes a decrease on horizontal movement and so existence of geogrid as reinforcement will lead to increasing stability of embankment.

**Effect of Angle of Embankment Slope on its Stability**

At this part, results of analysis of 3 different embankments with different angles of slope have been reviewed. Three different soil embankments with same materials and slopes of 1:1, 1:1.5 and 1:2 has been modelled and analysed. Results showed that by decreasing embankment slope, horizontal movements will decrease and therefore safety factor of embankment in front of sliding will increase. Analysis results have been showed at Table 3.

**Table -2 Horizontal and Vertical Displacements of Embankment Due to Number of Layers and Geogrid Stiffness**

| Geotextile Stiffness, EA (kN/m) | Number of Layer(s) | Horizontal Displacement (cm) | Vertical Displacement (cm) |
|---|---|---|---|
| 0 | 0 | 16.5 | 57.45 |
| 2500 | 1 | 16.3 | 55.18 |
| 2500 | 2 | 16.25 | 52.39 |
| 2500 | 3 | 16.15 | 50.29 |

**Table -3 Horizontal and Safety Factor of Embankment at Different Slopes**

| Embankment Slope | Horizontal Displacement (cm) | Safety Factor |
|---|---|---|
| 1:1 | 17.7 | 1.43 |
| 1:1.5 | 14.4 | 1.65 |
| 1:2 | 13.72 | 1.91 |

## CONCLUSION

By considering all results of analysis and putting all of them beside each other, below results and conclusions can be gain.

- Using of geogrid cause a decrease on horizontal movement of embankment and lead to an increase of safety factor.
- Best place for using geogrids as reinforcing is between base soil and embankment.
- Using different layers of reinforcement is uneconomic way of stabilization.
- Increasing stiffness of geogrid leads to decrease on horizontal movements.
- Increasing geogrid stiffness has not any special effect on vertical settlement.
- Decreasing angle of slope of embankment will decrease horizontal movement of embankment.

After all of these using geogrid as reinforcement can increase an embankment safety factor and stability. But before using it, embankment should be analysed at different conditions to get the best and economic situation of reinforcement.

## REFERENCES

[1] MS Keskin, *Güçlendirilmiş Kumlu Şevlere Oturan Yüzeysel Temellerin Deneysel ve Teorik Analizi*, Turkish PhD Thesis (With English Abstract), Çukurova University, 368s, Turkey, **2009.**

[2] A Yıldız, *Donatılı Zeminler Üzerine Oturan Yüzeysel Temellerin Analizi*, Turkish PhD Thesis (with English Abstract), Çukurova University, 213s, Turkey, **2002.**

[3] VR Schaefer, Ground Improvement, Ground Reinforcement, Ground Treatment: Developments, *American Society of Civil Engineers*,**1997**, 69, 1987-1994.

[4] EM Palmeira, JHF Pereira, RLD Antonio, Backanalyses of Geosynthetic Reinforced Embankments on Soft Soils,*Geotextiles and Geomembranes*, **1998**, 16 (5), 273-292.

[5] D Apriald, S Lambert, O Jenck and M Widyarti, An Original Testing Apparatus for Rapid Pull-Out Test, *Civil Engineering Dimension*, **2014**,16 (2), 61-67.

[6] L Briancon and P Villard, Design of Geosynthetic-Reinforced Platforms Spanning Localized Sinkholes, *Geotextiles and Geomembranes*, **2008**, 26 (5), 416-428.

[7] YM Chen, WP Cao and RP Chen, An Experimental Investigation of Soil Arching Within Basal Reinforced and Unreinforced Piled Embankments, *Geotextiles and Geomembranes,* **2008**, 26 (2), 164-174.

[8] AL Li, and RK Rowe, Effects of Viscous Behaviour of Geosynthetic Reinforcement and Foundation Soils on Embankment Performance, *Geotextiles and Geomembranes,* **2008**, 26 (4), 317-334.

[9] RK Rowe and C Taechakumthorn, Combined Effect of PVDs and Reinforcement on Embankments over Rate-Sensitive Soils, *Geotextiles and Geomembranes,* **2008**, 26 (3), 239-249.

[10] DT Bergado and C Teerawattanasuk, 2D and 3D Numerical Simulations of Reinforced Embankments on Soft Ground, *Geotextiles and Geomembranes*, **2008**, 26 (1), 39-55.

[11] RS Sarsby, Use of 'Limited Life Geotextiles' (LLGs) for Basal Reinforcement of Embankments Built on Soft Clay, *Geotextiles and Geomembranes*, **2007**, 25 (4-5), 302-310.

[12] PS Wulandari and D Tjandra, Determination of Optimum Tensile Strength of Geogrid Reinforced Embankment, *International Civil Engineering Conference Towards Sustainable Civil Engineering Practice*, Surabaya, **2006**, 187-193.

[13] K Faizi, D Jahed Armaghani and K Azma, Evaluation of Geotextiles on Embankment Displacement under Seismic Load, *Electronic Journal of Geotechnical Engineering*, **2013**, 18 (c), 439-449.

[14] L Wang, G Zhang and J Zhang, Centrifuge model tests of Geotextilereinforced Soil Embankments During an Earthquake, *Geotextiles and Geomembranes Journal*, **2011**, 29 (3), 222-232.

[15] F Kasim, A Marto, BA Othman, I Bakar and MF Othman, Simulation of Safe Height Embankment on Soft Ground Using Plaxis, *4th International Conference on Environmental Science and Development*, **2013**, 5, 152-156.

[16] M Siaovashnia, F Kalantari and A Shakiba, Assessment of Geotextile Reinforced Embankment on Soft Clay Soil, *The 1st International Applied Geological Congress*, **2010**, 1779-1784.

[17] AB Salahudeen and JA Sadeeq, Numerical Modelling Of Soil Reinforcement Using Geogrids, *Proceedings of the Fourth International Conference on Engineering and Technology Research*, **2016**, 345-358.

[18] P Majedi, S Çelik and S Akbulut, Finite Element Modelling of Road Embankments Designed as Reinforced Slope, *1st National Young Geotechnic Engineers Symposium,* Turkey, **2016**, 99-106.