VOL. 7, NO. 10, OCTOBER 2012 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

FININTE ELEMENT ANALYSIS OF FLEXIBLE PAVEMENTS STRENGTHED WITH GEOGRID

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ABSTRACT

The axisymmetric finite element simulations through ANSYS software are carried out to evaluate the benefits of using geogrid in flexible pavements. This paper describes the behavior of asphalt concrete (AC) pavement under axisymmetric conditions and subjected to static loading. The results of flexible pavements improvement using geogrid are presented. Analytical results for four different most possibilities of geogrid reinforcement in the paved road layers have been evaluated. The optimum position was decided based upon the predicated tension and compressive stress reduction and, deformation reduce rate. Four types of reinforcing model and one type of unreinforced model of paved road were selected. The results showed that a higher tension stress absorption when the geogrid is placed between the base course layer and subbase layer in the selected model.

Keywords: geogrid, pavements, finite elements, flexible.

1. INTRODUCTION

Geogrid is used in flexible pavements in two major application areas - base reinforcement and subgrade stabilization. In base reinforcement applications, the geogrid is placed within or at the bottom of unbound layers of a flexible pavement system and to improve the load-carrying capacity of the pavement under repeated traffic. In subgrade stabilization applications, the geogrid is used to build a construction platform over weak subgrades to carry equipment and facilitate the construction of the pavement system without excessive deformations of the subgrade (Giroud *et al*., 1985).

The geogrid is designed to carry the shear stresses induced by vehicular loads at the interface between base course and subgrade soil (Milligan and Love, 1984; Perkins, 1999). The interlocking between the geogrid and the base course aggregate results in reduced lateral movement of the base course aggregate as a result, no outward shear stresses are transmitted to the subgrade. At the same time, the bottom surface of the base course, with confined aggregate striking through geogrid apertures, provides a rough surface that resists lateral movement by the subgrade and increases the subgrade bearing capacity.

The geogrid has an elastic-plastic material behavior so that they quickly react to applied loads; in the case of short term impact loading, creep phenomenon does not occur, therefore the whole tensile resistance of the geogrid can be mobilized. Further, geogrid allow an increase of the dynamic dumping characteristics of the reinforced soil compared to unreinforced soil, both through the energy that is directly absorbed by the geogrid itself and due to friction generated in the dynamic stage (Carotti and Rimoldi, 1998).

Giroud *et al*. (1985) showed that the geogrid could improve the performance of subgrade soil through three mechanisms, namely: confinement, improved load distribution through the base layer, and tensioned membrane effect, which reduces stresses. For pavements constructed on soft subgrades, the reinforcement should be placed at or near the bottom of the base.

Barksdale *et al.* (1989) utilized the results of a 2D finite element method to estimate the reduction in base thickness for a stiff geogrid. Dondi (1994) performed a 3D FE analysis of a pavement structure using non-linear constitutive models for the base and subgrade and a linear elastic model for the hot mixed asphalt and geogrid layers. Wathugala *et al.* (1996) used the ABAQUS finite element program to explore the decrease in the rut depth as a result of placing the geogrid membrane at the base - subgrade interface of a flexible pavement system. A series of finite element simulations are carried out to evaluate the benefits of integrating a high modulus geogrid into the pavement foundation. Three locations of the geogrid is studied, namely the base - asphalt concrete interface, the base - subgrade interface, and inside the base layer at a height of 1/3 of its thickness from the bottom. It is found that placing the geogrid reinforcement at the base - asphalt concrete interface leads to the highest reduction of the fatigue strain (46 - 48%).

All these findings indicate that the position of geogrid in a layer is still a subject for research. The present study was undertaken to investigate the optimum position of the geogrid in a layer of silty-clay subgrade soil. The geogrid was placed at different positions and effectiveness of reinforcement layer was investigated through analytical modeling (ANSYS software).

2. FINITE ELEMENT ANALYSIS

An axisymmetric analysis was carried out using Drucker-Prager's criterion. The parameters required for all materials used in the analysis are presented in Table-1. The typical finite element mesh consisted of 15473 nodes and 5006 eight-node axisymmetric quadrilateral elements (PLANE82 elements). Geogrid has been modeled using 360 three- node axisymmetric shell element (SHELL 209 elements). The deformation modulus of unbound material is usually strongly dependent on the stress state. The base and subbase layer were divided into thinner layers with the same strength parameters but with different modulus values. The element mesh and boundary conditions of the reinforced structure are shown in Figure-1.

Table-1. Material and section properties.

Material	Depth (mm)	Elastic modulus (MPa)	Poisson's ratio (ν)	Unit weight (kN/m^3)	Cohesion (kPa)	Friction angle (^{o})
Surface	50	2600	0.35	22.8	-	-
Binder	100	2200	0.35	22.8	-	-
Base Course	150	1650	0.35	23.3	-	-
Subbase	300	110	0.40	23.5	20	40
Soil	3000	30	0.49	18	100	20

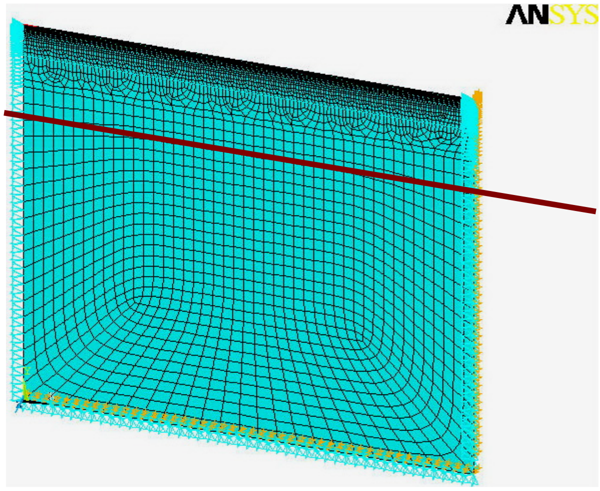

Figure-1. Finite element mesh and boundary conditions.

The unreinforced structure was modeled for a loading of 600 kPa having a radius of 100 mm as shown in Figure-2. The analysis was carried out for drained condition without pore water pressure.

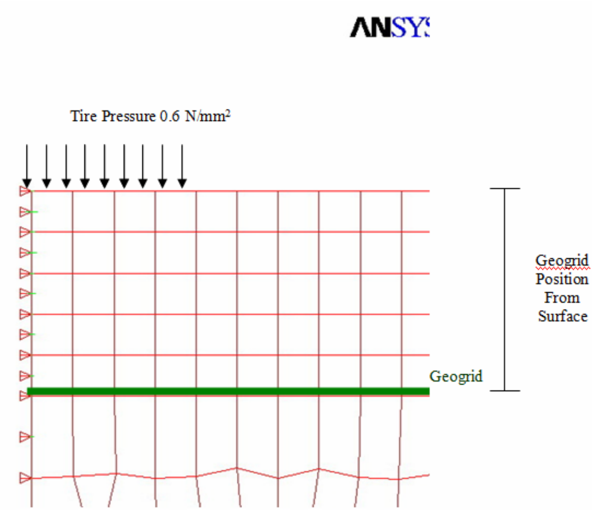

Figure-2. Loading and geogrid.

To simulate the stress dependency of the moduli, the structural layers were divided into sub-layers with the different strength parameters. The axisymmetric analysis was used in the analysis of the problem. The material and section properties are given in Table-1.

The biaxial geogrid products which are selected for this study are given in Table-2. The geogrid is placed at different positions to find the optimum position of geogrid and the improvement in behavior that will be gained.

Table-2. Tested index properties of the geogrid.

Structure	Mono - oriented geogrid
aperture shape	oval apertures
aperture size (*mm*×*mm*)	(13/20)×220
weight (2 gm/m)	300
polymer type	HDPE
tensile strength @ 2% strain (kN/m)	11
tensile strength @ 5% strain kN/m)	25
peak tensile strength (kN/m)	45
yield point elongation (%)	11.5
long term design strength (kN/m)	21.2
EA (kN/m) (thickness= 1mm)	2000

3. RESULTS AND DISCUSSIONS

The results of modeling the problem are presented in Figures 3 to 8. From these figures, the geogrid will reduce the vertical deflection and stresses developed in the model. The optimum position of geogrid is found to be under the base course layer or above the subbase layer as shown Figures 9 to 13. This is due to the increased of strength for this model as tensile stresses produced at the interface between the base course and subbase layers is reduced due to the inclusion of geogrid.

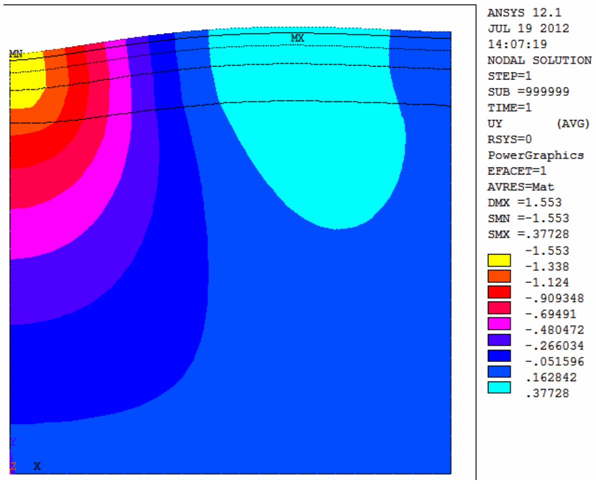

Figure-3. Vertical displacement for the model without geogrid (unreinforced).

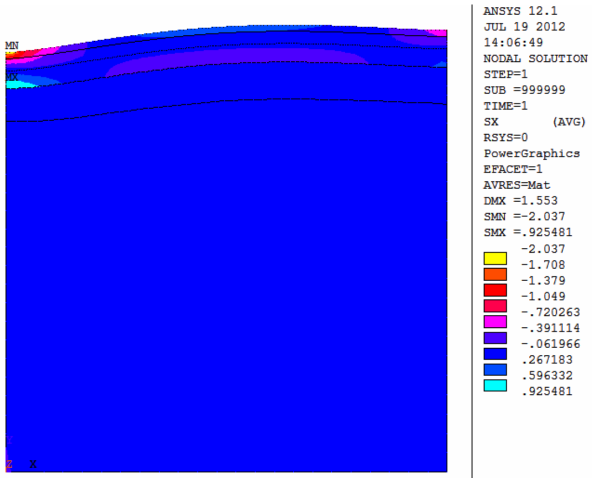

Figure-4. Horizontal stress for the model without geogrid.

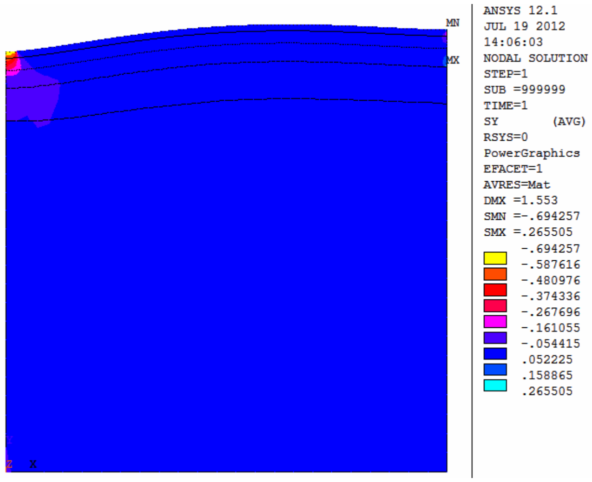

Figure-5. Vertical stress for the model without geogrid.

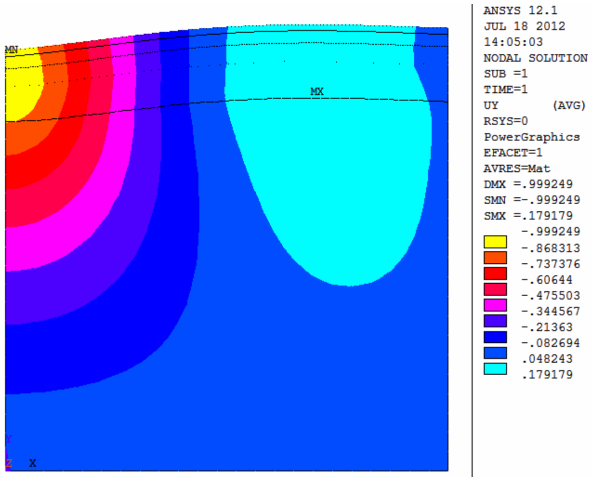

Figure-6. Vertical displacement for the model with geogrid above subbase layer (reinforced).

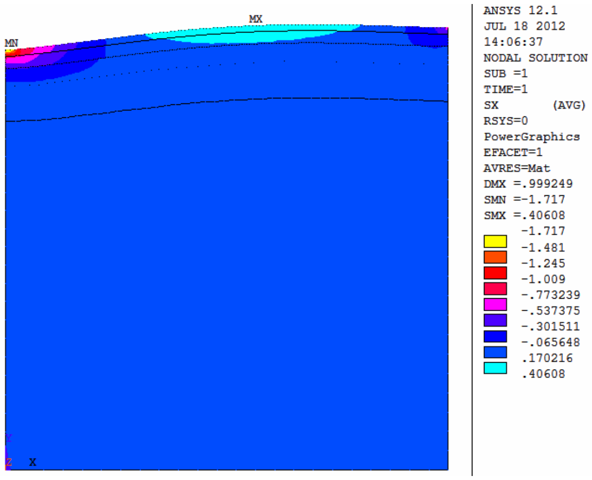

Figure-7. Horizontal stress for the model with geogrid above subbase layer.

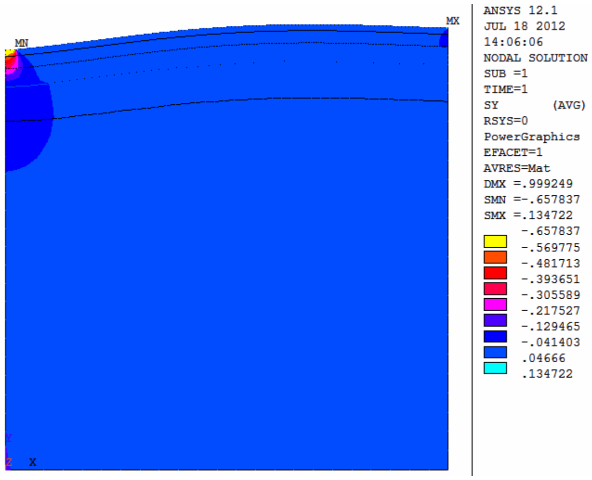

Figure-8. Vertical stress for model with geogrid above subbase layer.

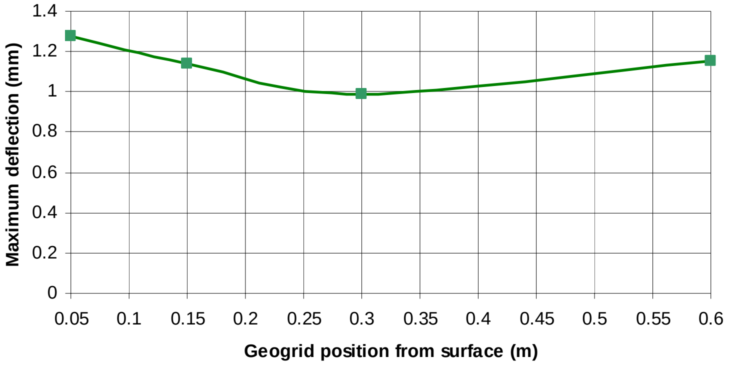

Figure-9. Effect of geogrid position on maximum deflection.

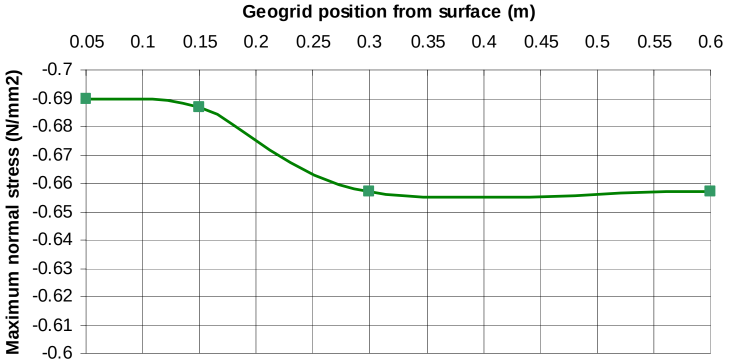

Figure-10. Effect of geogrid position on maximum normal compressive stress.

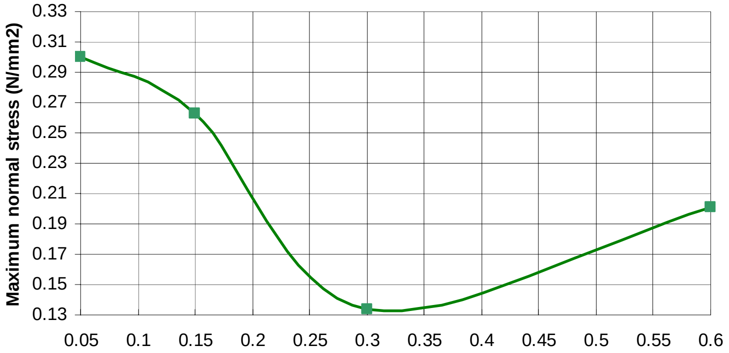

Figure-11. Effect of geogrid position on maximum normal tensile stress.

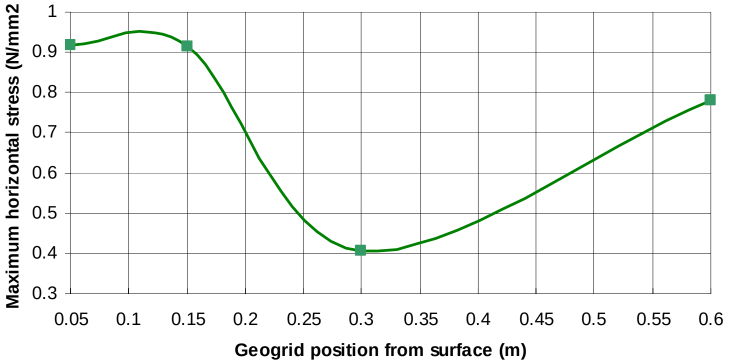

Figure-12. Effect of geogrid position on maximum horizontal tensile stress.

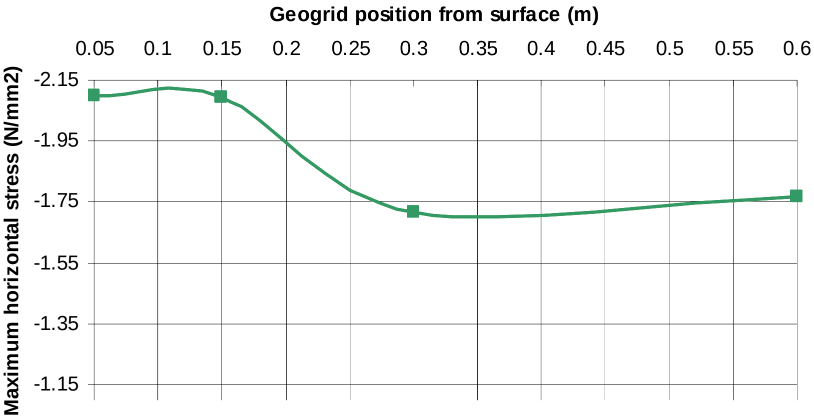

Figure-13. Effect of geogrid position on maximum horizontal compressive stress.

4. CONCLUSIONS

The finite element modeling of geogrid is presented for the analysis of soil-geogrid interaction system. An axisymmetric finite element type of analysis to study the behavior of geogrid embedded in paved roads is presented. The results showed the restraining effects of geogrid in the asphalt pavement system. When the load is applied to the surface of the pavement, a zone of tension is developed at the lower section of the asphalt concrete layer. To improve the rigidity of the asphalt concrete layer, the geogrid is included as tensile reinforcement. The tensile stress acting in the asphalt concrete is thus transferred to the geogrid as tensile force. When the geogrid is placed at the bottom of the base course layer, it leads to a higher reduction in the vertical deflection. The overall performance of the asphalt pavement is improved if an effective bonding is maintained between the asphalt concrete and geogrid. Also, the settlement over the loading area of reinforced pavement reduced when compared with unreinforced pavement.

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