Performance of Geocell and Geogrid Reinforced Weak Subgrade Soils

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Abstract. A significant number of the pavement structures fail a long time before their design life due to the poor quality of construction materials, inadequate compaction, inadequate preparation of the subgrade, overloading etc. There are two methods to overcome this issue. The primary choice is by increasing the thickness of various layers and the other alternative is by increasing the strength and rigidity of the pavement layers which lowers stresses on the pavement layers. Rutting is a common feature observed in flexible pavements supported on weak subgrades. Reinforcing the weak subgrades is one of the promising alternatives to alleviate the pavement surface rutting. Geocell reinforcement, three dimensional confinement provided increases the load carrying capacity of soil.
In the present research work, the improvement in the strength and stiffness of flexible pavement system using geocell confinement was investigated by placing geocell in the subgrade soil.
The finite element analysis of model will be done by using ANSYS tool and analytical results such as Strains generated in each layer and propagation of stresses are studied.

Keywords: FEM; Geocell; Flexible Pavement; ANSYS.

1 Introduction

A flexible pavement is a structure comprising of different layers consisting of different materials. The longevity of flexible pavement depends on various parameters such as thickness of various layers comprising of the pavement, the properties materials used, environmental and climatic factors. Many a times the pavements fail due to structural distress or environmental distresses. In order to enhance the strength of pavement it is essential to reinforce subgrade layers of pavement.

Use of Geo-synthetics to reinforce the flexible pavement is one of the alternative and promising to address the problem of scarcity of resources, poor quality subgrade soil and durability. A geogrid is geosynthetic material used to reinforce soils and similar materials. Geogrids are commonly used to reinforce retaining walls, as well as subbases or subsoils below pavements or structures. Soils pull apart under tension. Compared to soil, geogrids are strong in tension. Geogrids are commonly made of polymer materials, such as polyester, polyvinyl alcohol, polyethylene or polypropylene. They may be woven or knitted from yarns, heat-welded from strips of material, or produced by punching a regular pattern of holes in sheets of material, then stretched into a grid. It is essential to study the behavior of geosynthetic reinforced pavements to understand the applications and their compatibility for various crucial conditions to address the strength parameters.

The geocell reinforcement is a three dimensional honeycomb-like structure of cells that contains and confines the soil within, which leads to substantial performance improvement (Webster and Watkins 1977; Rea and Mitchell 1978; Bush et al. 1990; Schimizu and Inui 1990; Cowland and Wong 1993; Mandal and Gupta 1994; Dash et al. 2001a; Sitharam et al. 2005; Sitharam and Dash 2007; Madhavi Latha et al. 2006; Madhavi Latha and Murthy 2007; Zhou and Wen 2008; Emersleben and Meyer 2008; Pokharel et al. 2010; Dash 2012; Tanyu et al. 2013; Hegde and Sitharam 2015). Krishna swami et al (2000) concluded that geocell base improved the performance of the embankment in terms of the maximum surcharge load and the deformations. The properties like tensile strength and aspect ratio of the geocell influence the overall performance of the geocell reinforced pavement.

Geocells not only provide a lateral confinement to the fill but also workability and serviceability. Geocells are extensively used in various geotechnical applications by reinforcing soft soil strata and stabilizing slopes and embankments (Chen et al ; 2013).

The Geocell imparts stiffness to the soil layer and distributes the loads over a wider area and, results in lower settlement of the underlying layer (Huang et al, 2013). Triaxial tests carried out on granular soil samples reinforced by single cell of geocell and two, three, and four cells of geocell suggest that geocell strengthens the granular soil by developing apparent cohesion (Cr) and making a negligible change in internal friction angle (Bathurst et al, 1993;).

Objectives of the Study

- To study the effect of geogrid and geocell in flexible pavement.
- To study the deformation and principal stresses in unreinforced, geogrid and geocell reinforced pavements.
- To study the influence of location of reinforcement in flexible pavement.

2. Model Description

Un-reinforced Flexible pavement is designed as per IRC: 37-2012. IRC-37-2012 deals with 5 design alternate pavement compositions. In the present study Geogrid as well as Geocell are considered. Total four models are considered for the analysis. Finite Element method is one of the appropriate structural method for analysis of flexible pavements. Modeling in ANSYS software includes creation of geometrical model, assignment of material properties, discretization, contact between the layers and assignment of loads. Three 3D models of Road pavement with Geocell and geogrid are modeled in ANSYS software. 8-Noded constant stress solid elements were used to model sub structure layers.

Table 1. Model -I Unreinforced Flexible Pavement

Thickness of Wearing Course	50 mm.
Thickness of Base coarse layer	172 mm.
Thickness of Sub base layer	250 mm.
Thickness of Sub grade layer	300 mm.

Table 2. Model -II Flexible Pavement with Geocell Between Sub Base and Subgrade

Thickness of Wearing Course	50 mm.
Thickness of Base coarse layer	172 mm.
Thickness of Sub base layer	250 mm.
Geocell	150 mm.
Thickness of Sub grade layer	300 mm.

Table 3. Model -III Flexible Pavement with Geogrid Between Wearing Course and Base Course

Thickness of Wearing Course	50 mm.
Geogrid	5 mm.
Thickness of Base coarse layer	172 mm.
Thickness of Sub base layer	250 mm.
Thickness of Sub grade layer	300 mm.

Table 4. Model -IV Flexible Pavement with Geogrid Between Wearing Course - Base Course and Geocell at Sub Base – Subgrade

Thickness of Wearing Course	50 mm.
Geogrid	5 mm.
Thickness of Base coarse layer	172 mm.
Thickness of Sub base layer	250 mm.
Geocell	150 mm.
Thickness of Sub grade layer	300 mm.

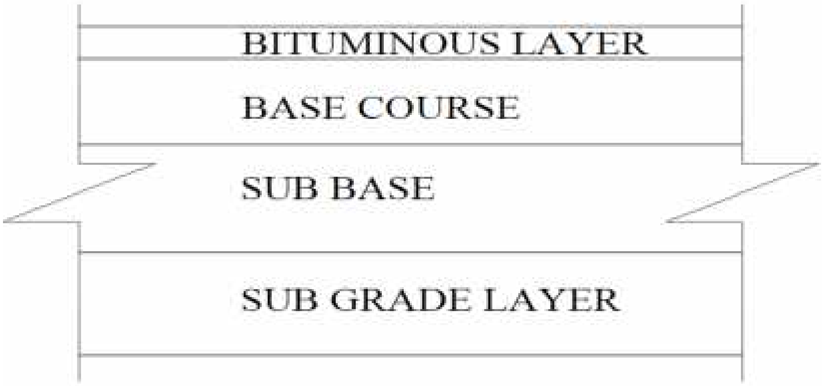

Fig. 1. Cross Section of Flexible Pavement

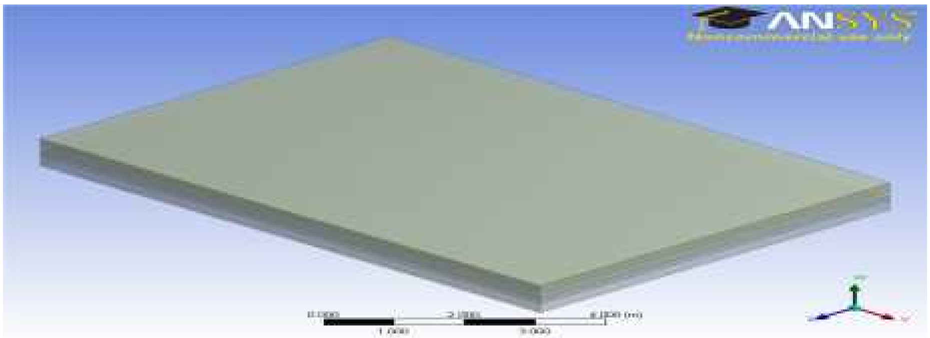

Fig. 2. ANSYS Model of Flexible Pavement

Table 5. Material Properties of Sub Structure Layers

	E (mpa)	Poissons ratio µ	Unit weight kN/m^3
Bituminous layer	1000	05	22.3
Base Course	20	0.4	22.2
Sub base	42	0.4	20
Sub grade	50	0.4	16

Table 6. Material Properties of Geocell Layer

Density (kg/m^3)	1809.2
Modulus of elasticity (N/mm^2)	1.1×10^9
Poisson's ratio (µ)	0.42
Thickness of layer (mm)	150

Table 7. Material Properties of Geogrid Layer

Density (kg/m^3)	950
Modulus of elasticity (N/mm^2)	1.1×10^9
Poisson's ratio (µ)	0.42
Thickness of layer (mm)	5

3. Results and Discussions

Analysis of all 4 models have been done in ANSYS software and compared for Principal stress and Deformation results with geocell and geogrid reinforcement. The use of geosynthetics to improve the performance of flexible pavements is increasing significantly because of their improved performance. The use of geosynthetics to improve the physical, mechanical, and hydraulic properties of the soils is prompting the civil engineers to use them in various infrastructure projects. Geogrid is commonly used for subgrade improvement and base reinforcement by interlocking with granular bases. Geocells are three-dimensional honeycombed cellular structures and provide confinement to compacted infill soil. Their confinement reduces the lateral movement of the soil particles and forms a stiffened mattress or slab to distribute applied loads over a wider area. The main mechanisms of the confinement include soil confinement in the cells, and hoop stresses in the cell walls. Under vertical loading, hoop stresses within the cell walls and soil resistance in the adjacent cells are mobilized and increase the strength and stiffness of the soil. The geocell-reinforced base layer acts as a stiff mattress or slab to distribute the vertical traffic load over a wider area of the subgrade. As a result, the vertical stresses applied on the subgrade are reduced and the bearing capacity is increased. The influence of Geogrid and geocell reinforcement in all the 3 models is studied and the responses such as principal stresses and total deformation and compared with the unreinforced base case model and are presented in Fig. 1 to Fig. 8.

Static Structural Analysis Results of Unreinforced Pavement

The maximum principal stress and total deformation in unreinforced pavement are given in Fig.3 and Fig.4. From the analysis it is found that the principal Stress and total deformation are observed to be 2.186 Mpa and 0.00605 mm.

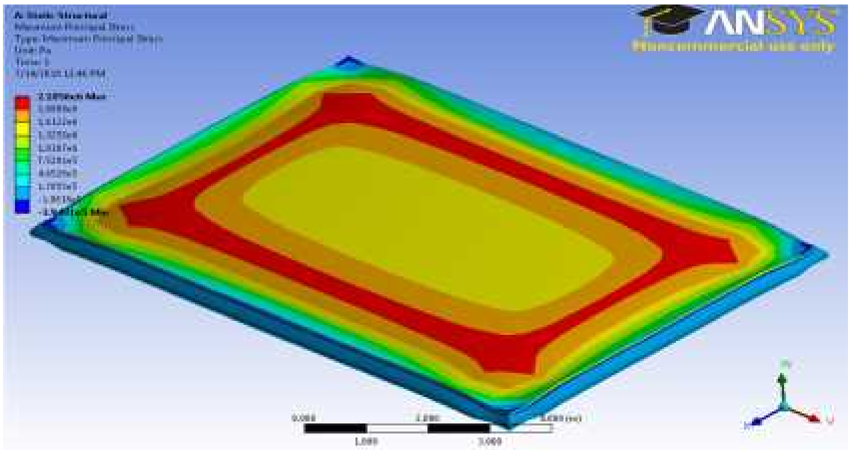

Fig.3. Maximum Principal Stresses in Pavement without Reinforcement

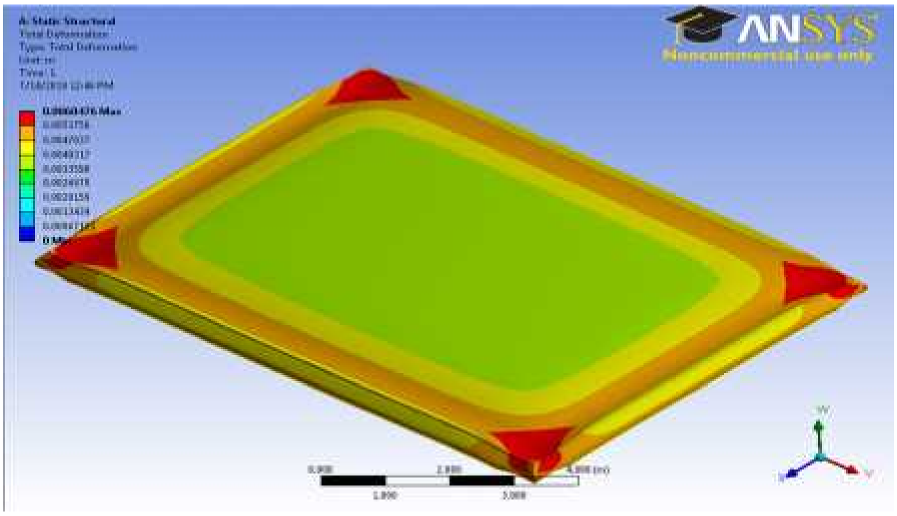

Fig.4. Total Deformation of Pavement without Reinforcement

Flexible Pavement with Geocell Between Sub Base and Subgrade. Geocells are placed above the subgrade level to provide better working platform and good subgrade to carry the pressure from the base course layer. The pavement is designed as per IRC 37 -2012 and the geocell is introduced between sub base and subgrade course. From the analysis it is found that the principal Stress and total deformation are observed to be 4.433 MPa and 0.00460 mm shown in Fig.5 and Fig. 6.

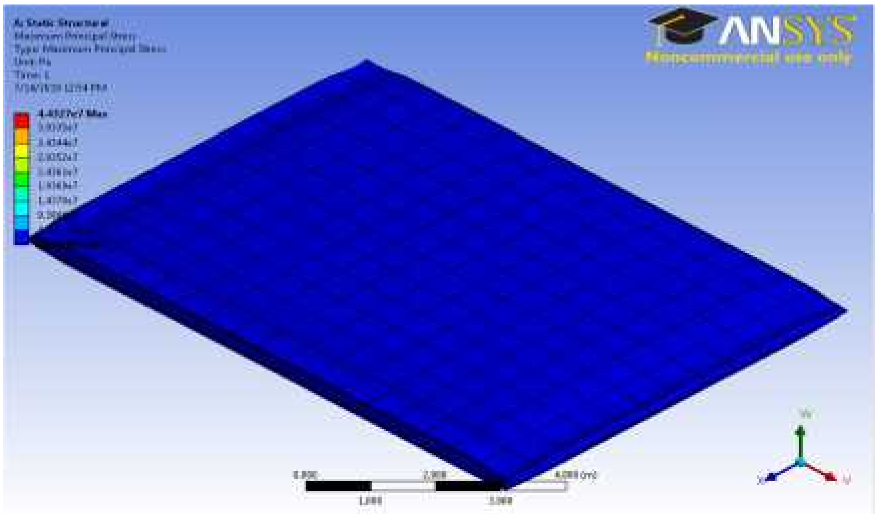

Fig.5. Maximum Principal Stresses in Pavement with Geocell Between Sub Base and Subgrade

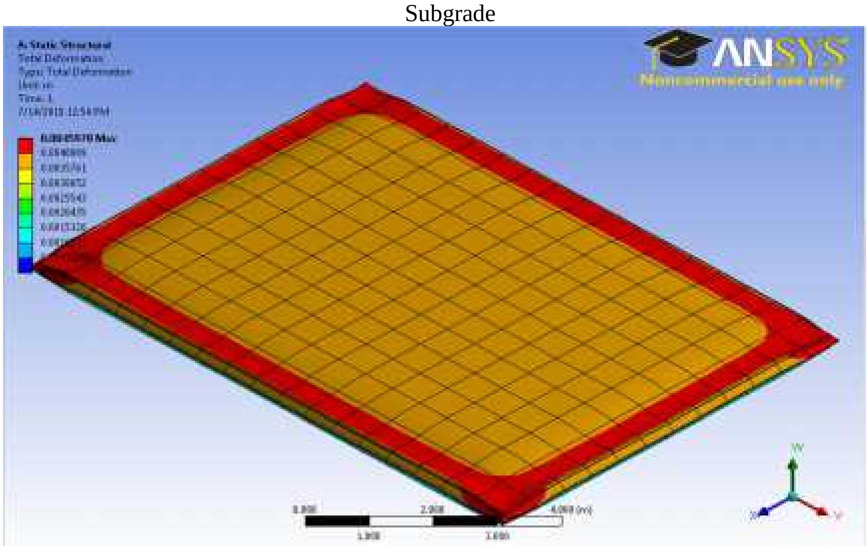

Fig.6. Total Deformation of Pavement with Geocell Between Sub Base and Subgrade

Flexible Pavement with Geogrid Between Wearing Course and Base Course.

Geogrid is placed above the base course and below wearing course to bear the tensile stresses. The pavement is designed as per IRC 37 -2012 and the geogrid is introduced between base and wearing course. From the analysis it is found that the principal Stress and total deformation are observed to be 2.154 MPa and 0.00602 mm shown in Fig.7 and Fig. 8.

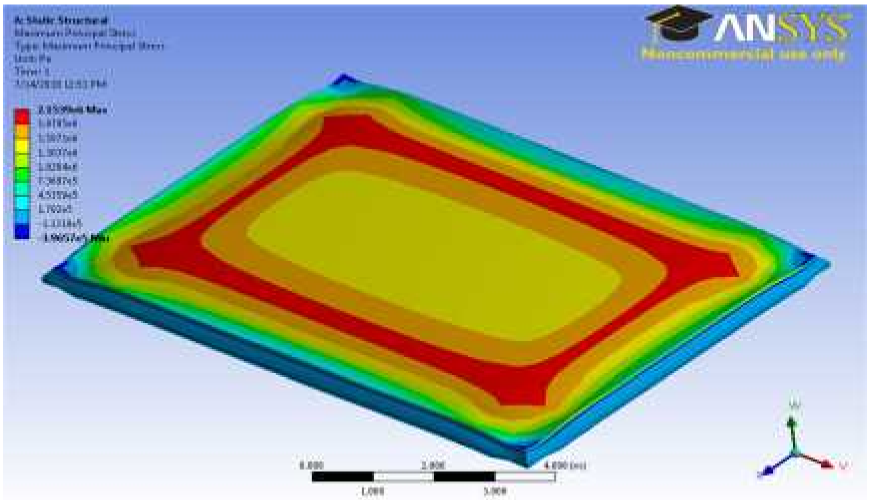

Fig.7. Maximum Principal Stresses in Pavement with Geogrid Between Wearing Course and Base Course.

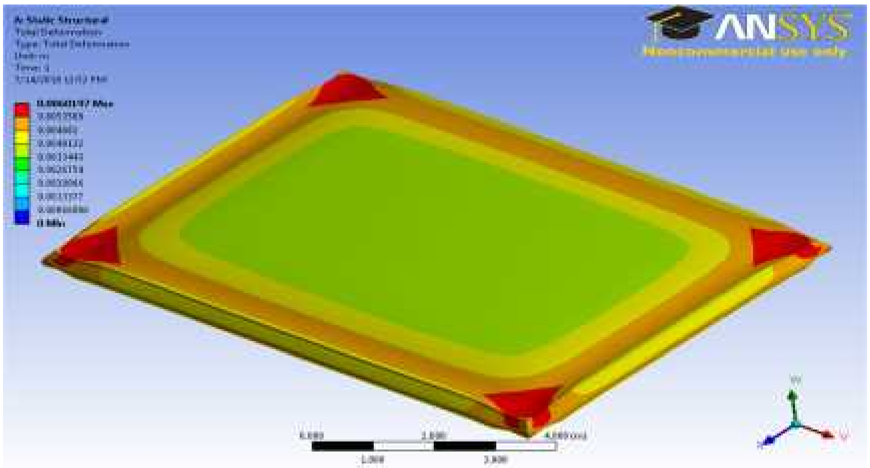

Fig.8. Total Deformation of Pavement with Geocell with Geogrid Between Wearing Course and Base Course.

Flexible Pavement with Geogrid Between Wearing Course - Base Course and Geocell at Sub Base – Subgrade.

In this model Geogrid is placed between Wearing course and Base course and Geocell at the interface of Sub base – Subgrade. The pavement is designed as per IRC 37 -2012 and the geocell and geogrid are introduced. The ANSYS msodel of the pavement are shown in Fig.9 and Fig. 10. From the analysis it is found that the principal stress and total deformation are observed to be 4.426 Mpa and 0.00458 mm as shown in Fig. 11and Fig. 12.

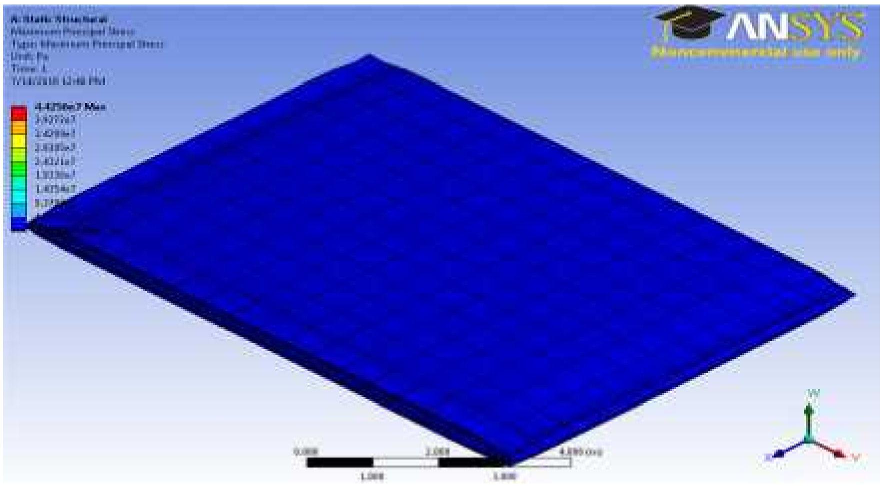

Fig.9. Maximum Principal Stresses in Pavement with Geogrid Between Wearing Course - Base Course and Geocell Between Sub Base – Subgrade.

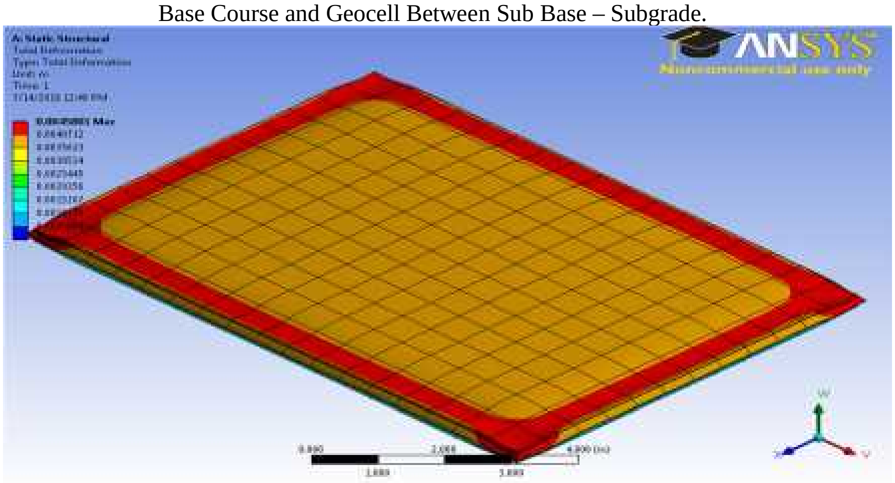

Fig.10. Total Deformation of Pavement with Geogrid Between Wearing Coat - Base Course and Geocell Between Sub Base – Subgrade.

Table 8. Maximum Deformation in Pavements

MODEL 1	MODEL 2	MODEL 3	MODEL 4
0.00605 m	0.00460 m	0.00602 m	0.00458 m

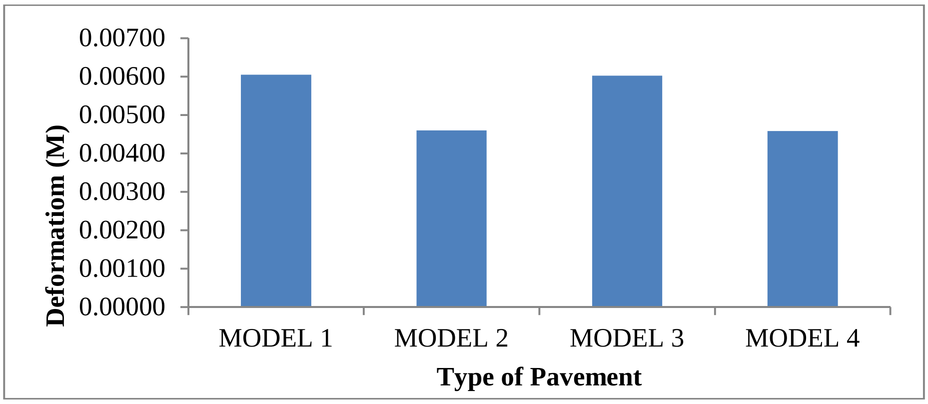

Fig.11. Maximum Deformation Graphs

Table 9. Maximum Principal Stresses in Pavements

MODEL 1	MODEL 2	MODEL 3	MODEL 4
2.186 MPa	4.433 MPa	2.154 MPa	4.426 MPa

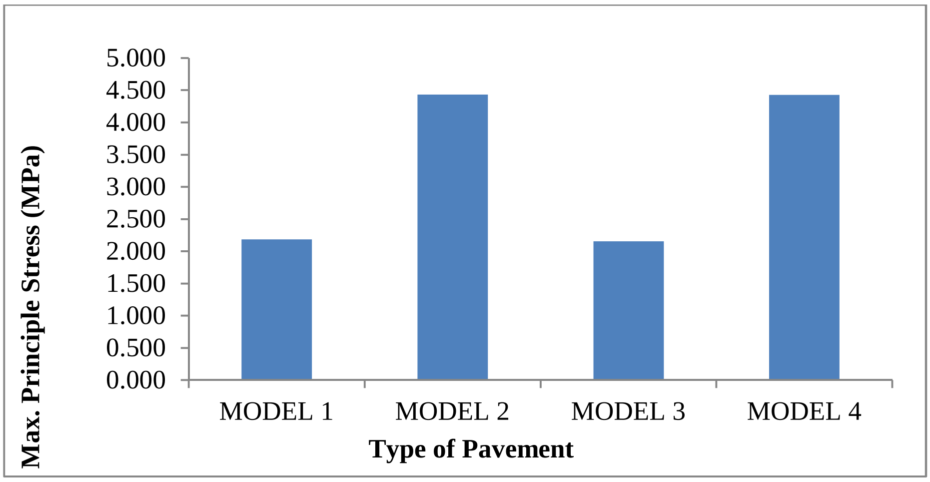

Fig. 12. Maximum Principal Stresses in Pavements.

4. Conclusions

- The geocell confinement increased the stiffness of the base course and reduced the compression of the base course.
- The reduction in deformation is 24.3 % which shows that the combination of geogrid and geocell is effective in transferring the loads without yielding. This shows that the pavement can sustain more number of repetitions.
- The reduction in deformation in geocell reinforce pavement is 24% less when compared to unreinforced pavement.
- The maximum principal stress is observed in Model 2 and it is two times than the conventional pavement.
- The results show that the placing geogrid at the interface of wearing course and base course along with geocell at the interface between subgrade and sub base course is not showing significant improvement. The use of geogrid in the pavement is not effective in improving the performance of pavement. Further more experimental and field studies are to be carried out to validate the analytical results.

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