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Study of Flexible Pavement Layer Reinforced Geogrid with FEA

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Abstract: In civil engineering, geosynthetic is broadly used as reinforced material in various field. The practice of using geosynthetics is extensively used in the road surface construction. Many have been accompanied to study the behaviour of soil reinforced with different types of geosynthetics and while constructing roads on a weak subgrade geogrid can be used as a reinforcement which will improve the performance of these roads by reducing permanent deformation. The finite element analysis is a finest appropriate tool for solving problems related to nonlinear nature of materials. This study illustrates the working of geosynthetics in flexible pavement through finite element analysis with MIDAS GTS NX software. In sub-grade layer, sub-base layer, base layer Mohr-Coulomb theory used and elastic behaviour in surface course and geosynthetics to act out the intraction condition. The hexahedral element of 8-node is used for strata of pavements. The vehicle loading and thickness of of each layer was used according to codal provisions of Indian Road Congress (IRC : 37-2012). In this study, model which is symmetrical about an axis using MIDAS GTS NX for investing the effect the axial stiffness of geosynthetics in the pavement. The FEA results shows the decline in vertical deformation when geosynthetics were added between the layers.
Keywords: Finite element analysis, geosynthetics, flexible pavement, deformation, axial stiffness.

I. INTRODUCTION

Depending on the composition, pavement is classified as either flexible or rigid or composite. Flexible pavement consists of layers of different granular materials. Majority of roads in india are constructed of flexible pavements. It is a load bearing structure which transfers the load stresses from a grain to grain contact and make a smooth riding surface without causing uneasiness for the passengers. The practice of reinforced geosynthetics has had an significant impact on road pavement design with real cost savings (barksdale and brown, 1989; zornberg, 2011; zornberg and gupta, 2010). The conclusion of geosynthetic reinforcement depends on numerous and multifaceted factors, such as the pavement structure, the features of the geosynthetic materials used and the location of the geosynthetics in the pavement structure. Several authors have established the mechanisms of geosynthetic reinforcement in pavements under different conditions (erickson and drescher, 2001; mounes et al., 2011; zornberg et al., 2012). Some studies have executed finite element modeling in order to demonstrate the benefits of using geosynthetics (kim and lee, 2013; saad et al., 2006; perkins, 2011). The durability of flexible pavement is depending on the various parameters such as layers thickness, quality of pavement materials, traffic behaviour and environment conditions. However, it is observed that using of emperical equations and approach in the design methods for estimation of design thickness of pavement doesn't show to be economical. Modelling of flexible pavement is based on elastic model. Finite element analysis is a tool for analyzing and modelling of several types of structures. This practice provides a methodology to solve the complex problems related to the different boundary condition and different materials properties. Many studies have done on the geosynthetics reinforced pavement to assess the stresses and deformation. Several researchers have done studies the effect of geogrids-reinforced pavement over the structural performance of road through laboratory, field and finite element analysis. In past study the effect of geosynthetic reinforcement in improving the structural performance of the flexible pavement. [mandal & ahirwar] studied the performance evalution of flexible pavements using finite element method and analyzed the main parameters for geosynthetics at different depth. Role of geosynthetics is reducing the vertical deformation & stresses generated in the pavement. Axissymmetric model is used in the plaxis-2d for examining the effect of axial stiffness of geosynthetics in pavement at dissimilar thickness of base layer. [josé neves, helena lima and margarida gonçalves] conducted a numerical study to demonstrate the suggestions of subgrade reinforcement with geosynthetics in road pavement design. A parametric analysis was carried out with the finite element program adina using two-dimensional modeling. This analysis considered different pavement materials and structures, traffic conditions and subgrade soil quality.the main conclusions in the paper are reduction of strain and displacement was observed. In this study, a finite element analysis of pavement section with geogrid is carried out by using midas gts nx software and analysis the effect of th vertical displacement in pavement due to load while reinforcing geogrid between different layers of flexibile pavement.

II. MATERIALS AND METHODS

A. Finite Element Analysis

A 3-dimensional linear finite element tool was used to modelling a flexible pavement section. MIDAS GTS NX is a simulation program developed for the evaluation of soil-structure interaction based on the finite element method. GTS NX helps engineers to perform step-by-step analysis of excavation, banking, structure placement, loading and other factors that directly affect design and construction.

The program supports various conditions (soil characteristics, water level etc.) and analytical methodologies to simulate real phenomena.

A model of pavement section contains surface course, base course, sub-base course, and subgrade course. The flexibile pavement model as a multilayer structure to static loading according to codal provisions of IRC: 37-2012. The pavement prototype is using GTS NX software for analyzing the base layer thickness with and without geosynthetics. The thickness of pavement layer was elected as per IRC: 37-2012 and design traffic intensity considered 150 MSA. The total thickness of pavement was vatied from 1080 to 1230 mm. A uniform loading of 575 KN/m^2 was applied which is equivalent to a single wheel load of 4080 kg.

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III.METHODOLOGY

A three-dimensional modeling used for flexible pavement. Hexahydral element (8 nodes) are used for this analysis. In this study, 8 noded hexahydral structural solid element use for modeling of the pavemnt section. Boundary conditions of the model were taken as sides are constraint so that stress distribution would be minimum. Four layered pavement prototype with rectangular area 10mx5m considered & tyre pressure applied at the middle of the pavement on a small assumed square area, which is equivalent to 8 times the tyre radius (15cm) of the surface contact area. Vertical displacement allowed. Unreinforced and 3 different types of reinforced models used for the d\study the effect of reinforcement on the pavement section. Reinforced models are:-

A. Geosynthetics between subgrade and sub-base course.
B. Geosynthetics between sub-base and base course.
C. Geosynthetics between subgrade, sub-base and base course.

Table 1 : Flexibile Pavement Properties

Material course	Surface course	Base course	Sub-base course	Sub-grade course
Types of model	linear elastic	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Thickness(mm)	100	100-250	380	500
Dry unit weight (kN/m^2)	22.4	22.2	15.6	14.50
Saturated unit weight (kN/m^2)	-	23.5	16.2	16.10
Cohesion(kN/m^2)	-	1	1	120
Angle of internal friction(Φ^o)	-	43	40	5
Elastic Modulus (MPa)	1000	20	42	10.6
Poisson's ratio(μ)	0.35	0.35	0.35	0.40

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Table 2 : Geosynthetics Properties

Types Of Materials	Axial Stiffness	Elastic Modulus
Geogrid	1000kN/m	535100 kN/m^2

IV.RESULTS

In this study, finite element analysis is determine the effects of geosynthetics in pavement base layers of different thickness and different layers. The outcomes of the analysis shows the benefical effects of the axial stiffness of geogrids in the base course at different thickness of base course layer on vertical deformation as shown in figures.

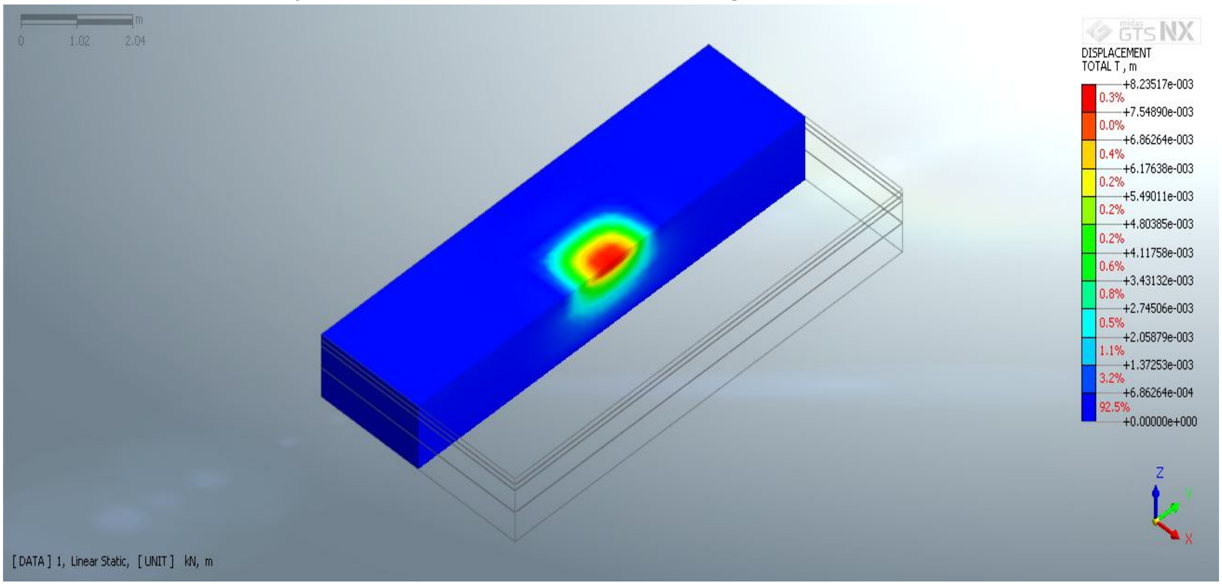

Fig 1(a):Total displacements for unreinforced pavement of base layer 100mm.

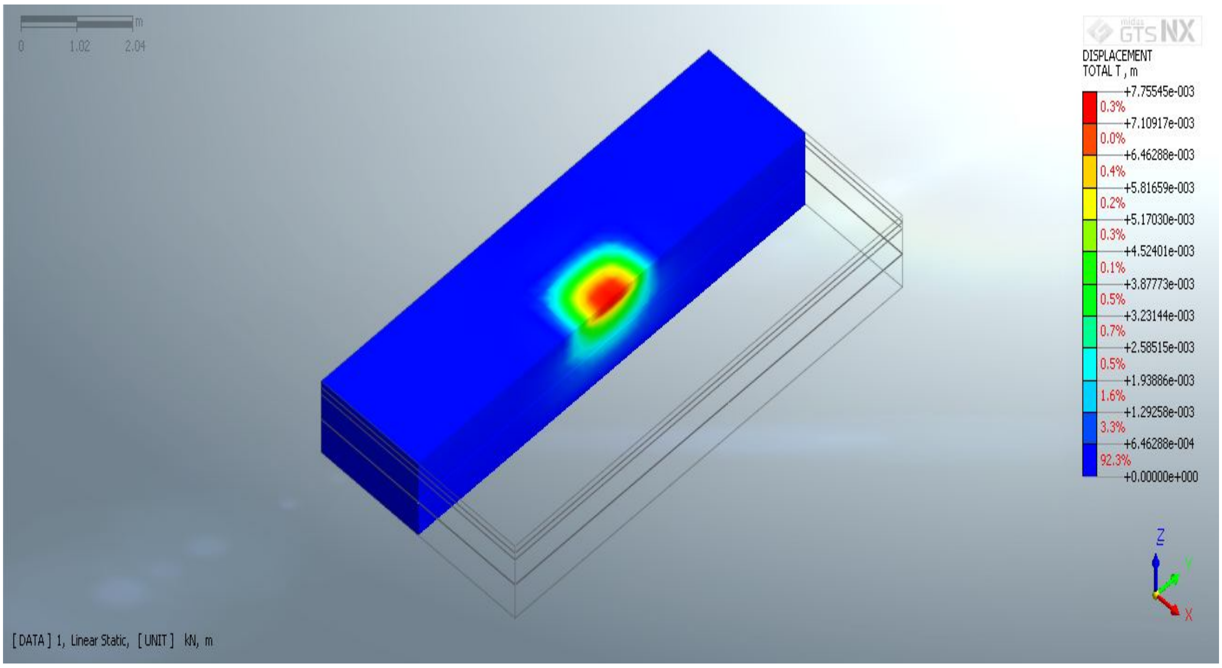

Fig 1(b):Total displacements for reinforced pavement of base layer 100mm (geogrid between subgrade & sub-base)

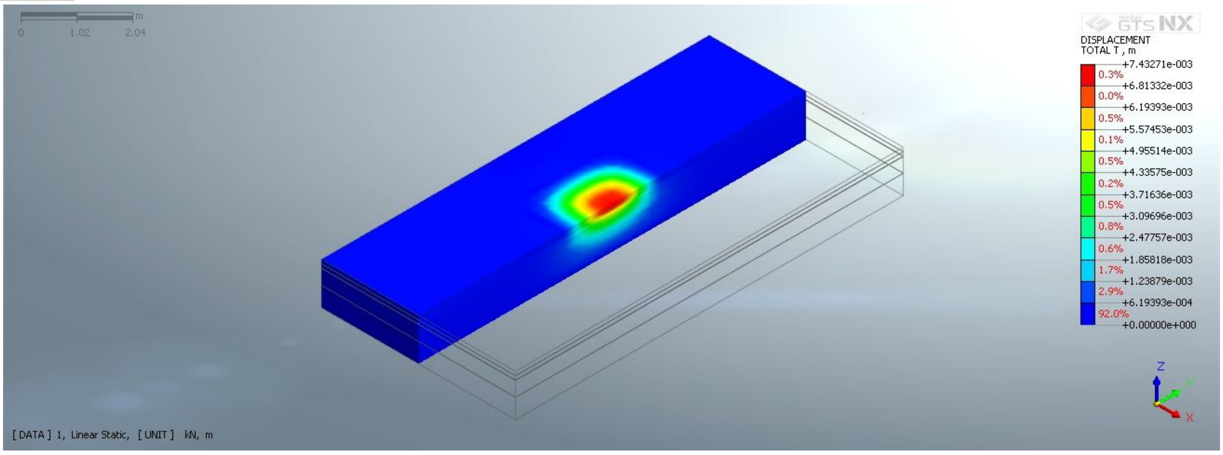

Fig 1(c):Total displacements for reinforced pavement of base layer 100mm (geogrid between sub-base & base)

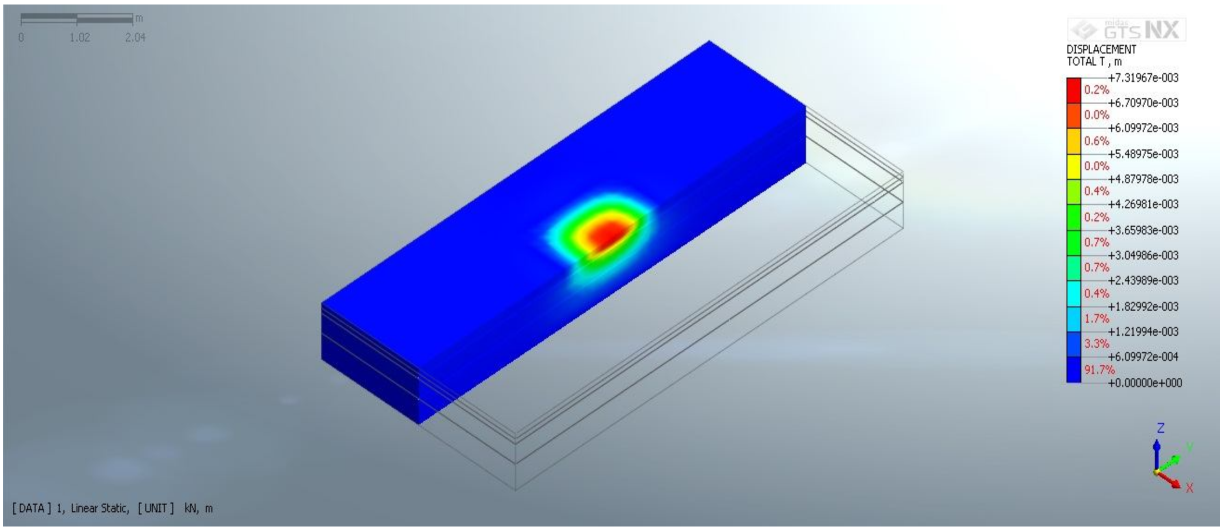

Fig 1(d):Total displacements for reinforced pavement of base layer 100mm (geogrid between subgrade, sub-base & base)

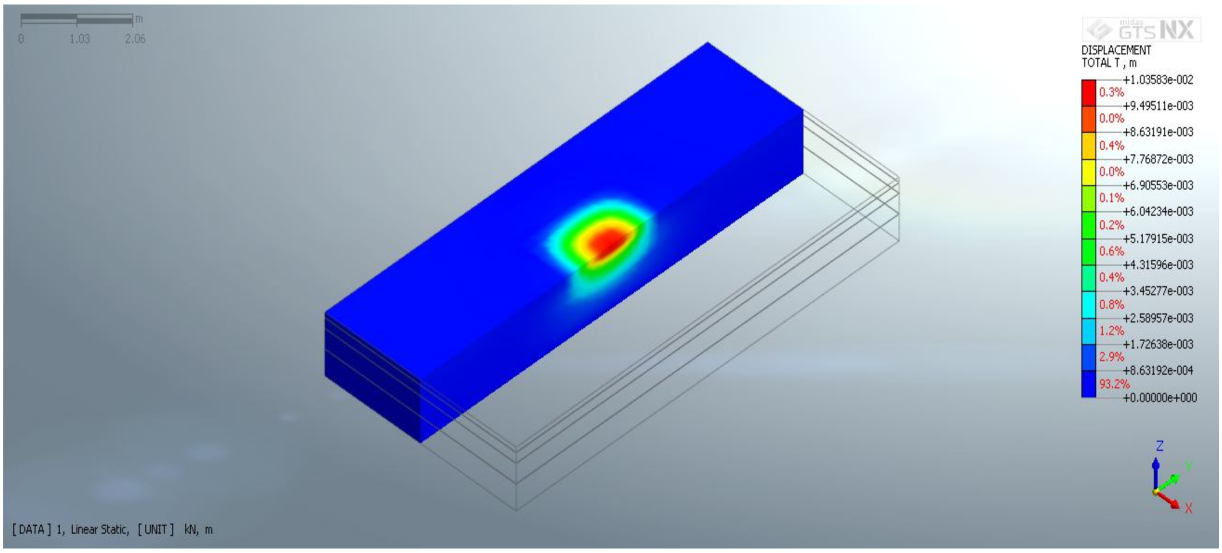

Fig 2(a):Total displacements for unreinforced pavement of base layer 200mm.

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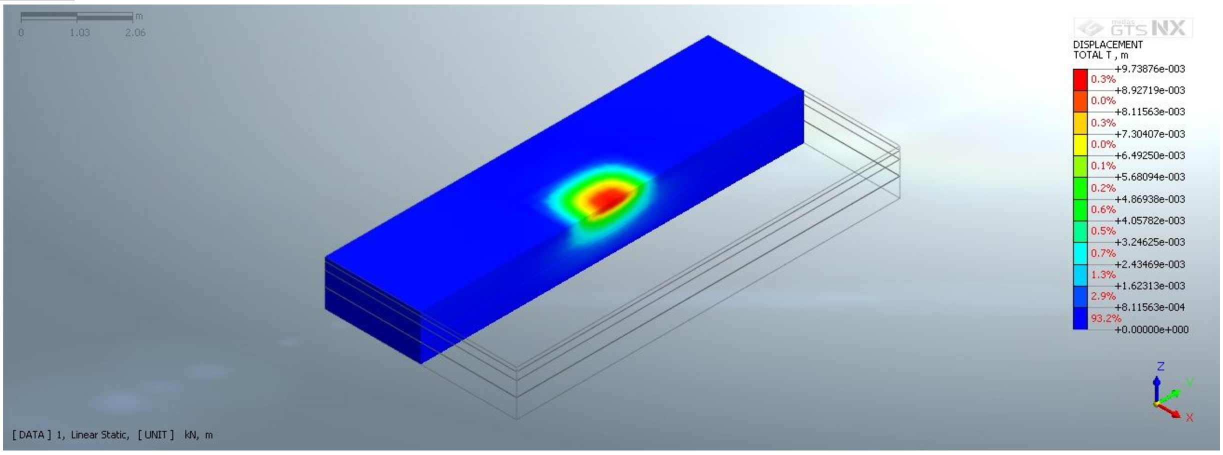

Fig 2(b):Total displacements for reinforced pavement of base layer 200mm (geogrid between subgrade & sub-base)

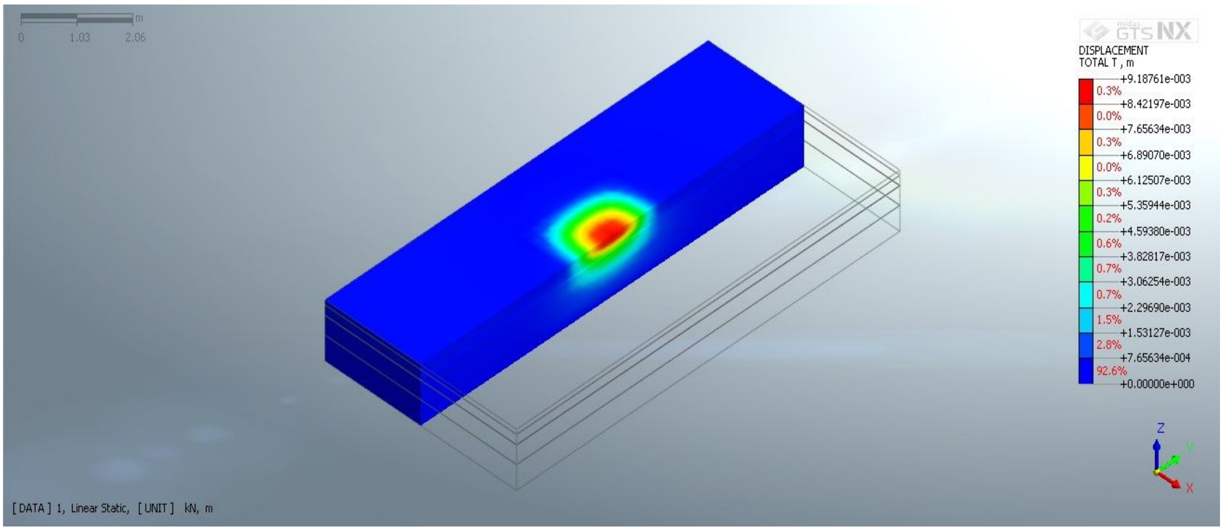

Fig 2(c):Total displacements for reinforced pavement of base layer 200mm (geogrid between sub-base & base)

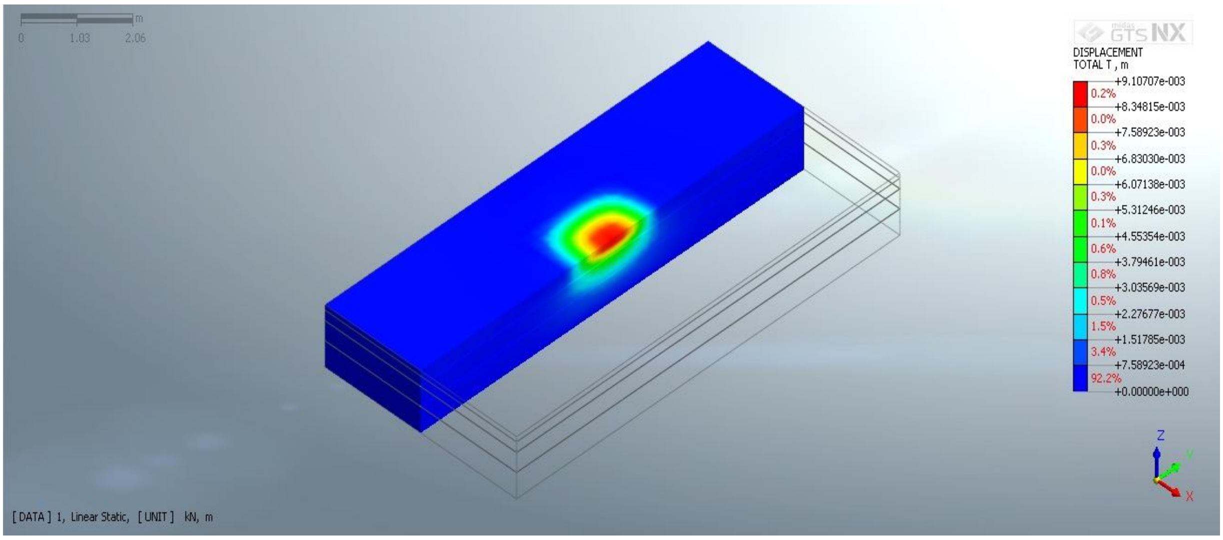

Fig 2(d):Total displacements for reinforced pavement of base layer 200mm (geogrid between subgrade, sub-base & base)

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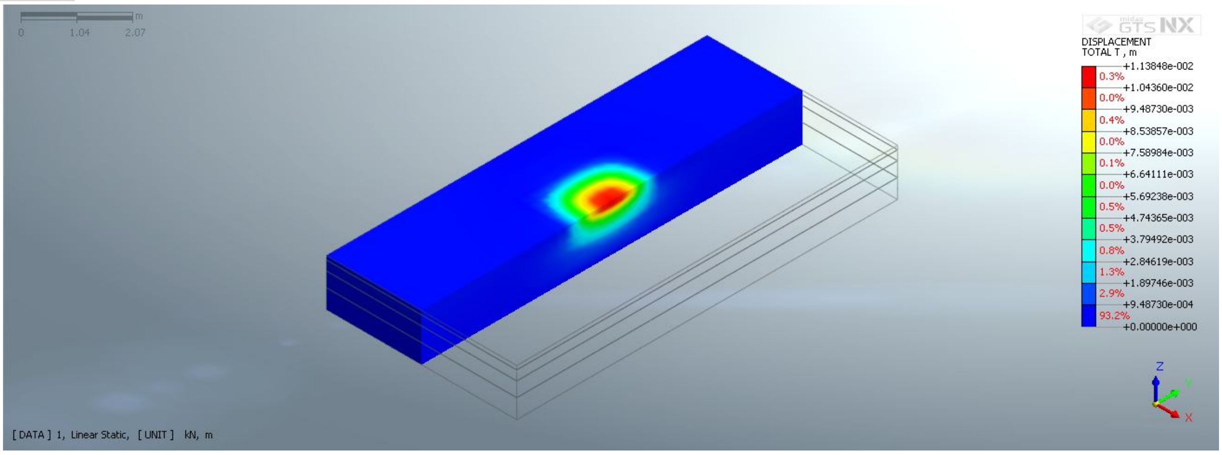

Fig 3(a):Total displacements for unreinforced pavement of base layer 250mm.

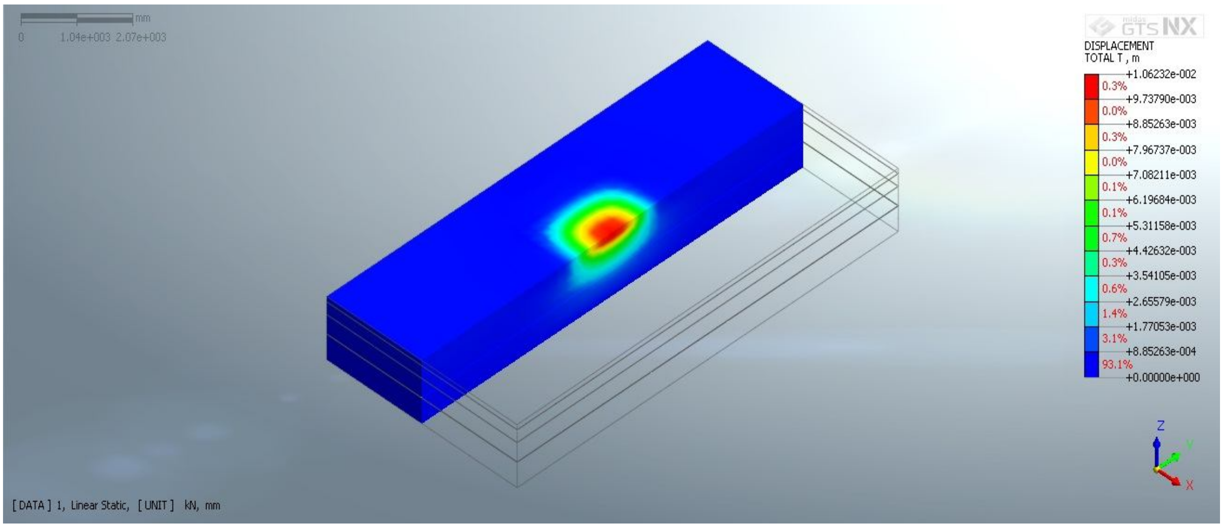

Fig 3(b):Total displacements for reinforced pavement of base layer 250mm (geogrid between subgrade & sub-base)

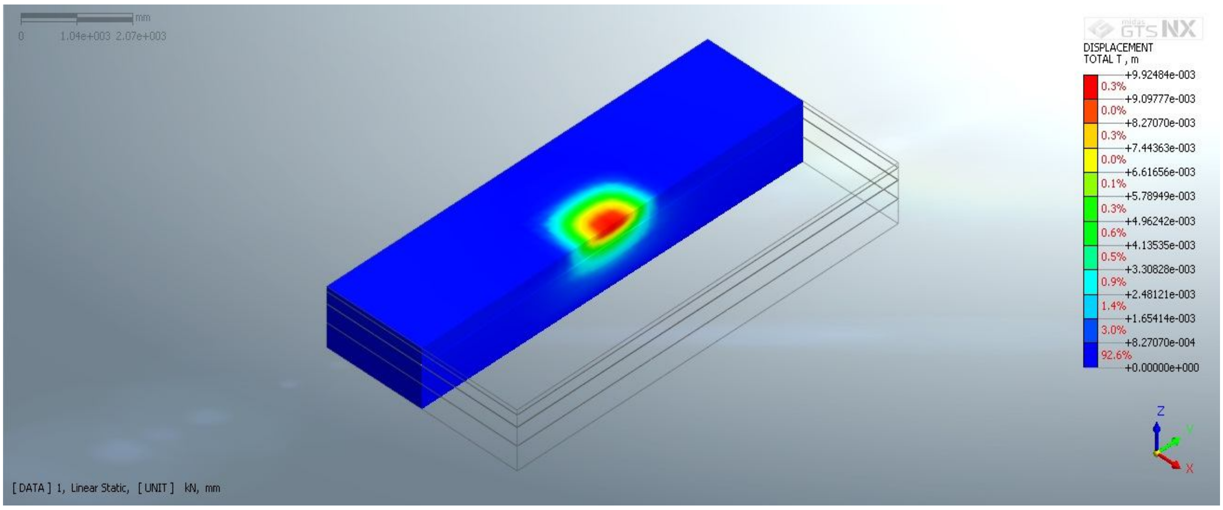

Fig 3(c):Total displacements for reinforced pavement of base layer 250mm (geogrid between sub-base & base)

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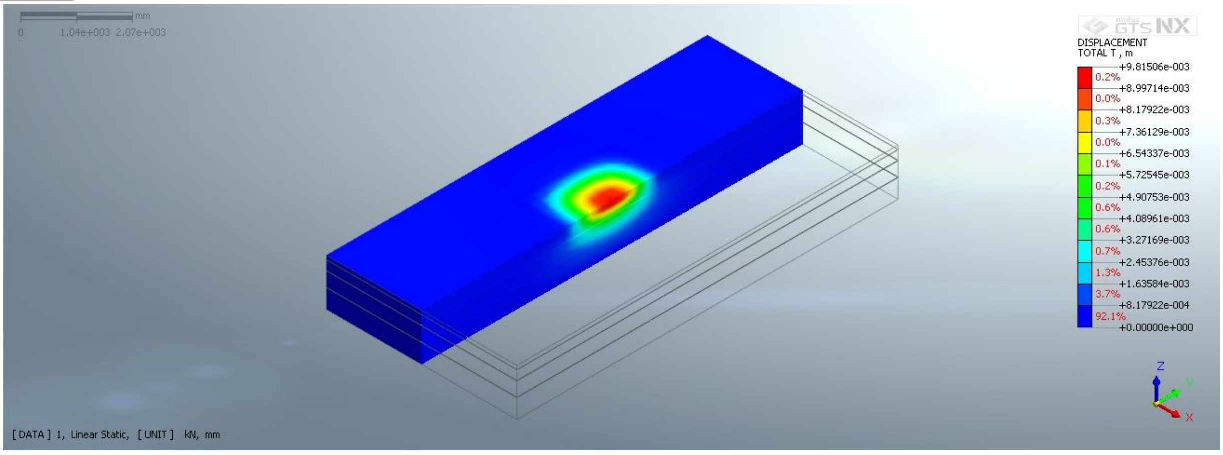

Fig 3(d):Total displacements for reinforced pavement of base layer 250mm (geogrid between subgrade, sub-base & base)

V. CONCLUSIONS

The finite element analysis results indiaceted that geogrid-reinforced pavement has less deformation as compared to unreinforced flexibile pavement for same thickness of base layer and loading conditions. Total deformation of surface shown in fig 1 to 4 with respect to variation in pavement. The finite elemnt results are discuss in terms of surface deformation. The conclusions of this study are as follows:-

A. Vertical surface deformation in flexible pavement reinforced with geogrid are reduced as compared to unreinforced pavement.
B. Reduction in total surface displacement is 5% (without reinforcement of geogrid and 100mm thick base layer) to 14% (with two geogrid reinforcemnet between subgrade, sub-base & base layer; and 250mm thick base layer).
C. Reduction increase when thickness of base layer increase.
D. Reduction in stress genertaed in the different layers of flexibile pavement.

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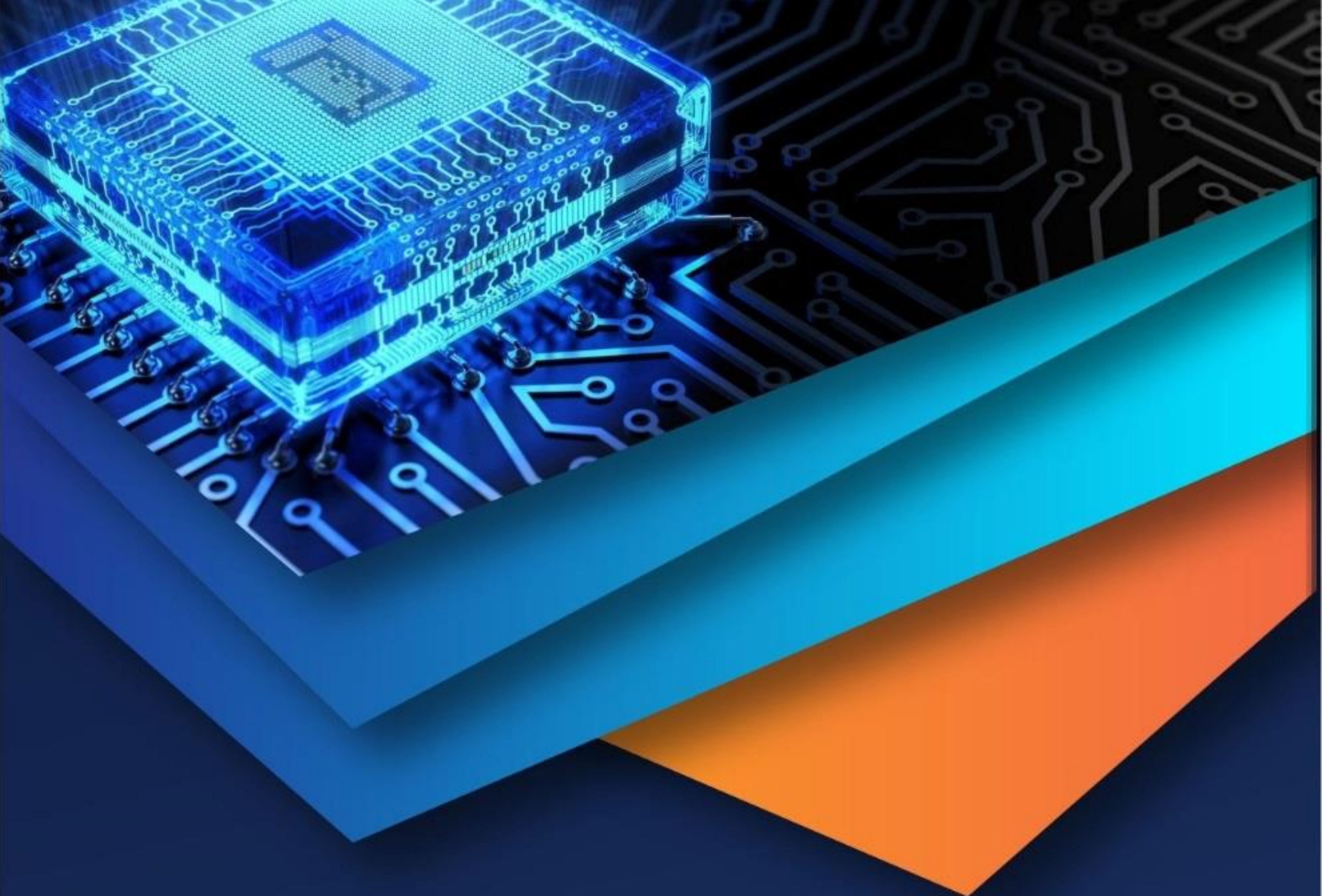

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