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Rutting and Fatigue Analysis of Flexible Pavement with or without Geosynthetic

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Abstract: The performance of flexible pavement vehicle varying its depth with vertical wheel load to analysis its distresses. The objective of this project is to determine the performance is of flexible pavement like rutting and fatigue on varying depth of subgrade with and without of reinforcement material subjected to vehicle wheel load. In this research the next step is to find out the laterite soil properties and applying the standard wheel load and single axle wheel load on varying thickness of subgrade. The analysis of both the soil which is used in subgrade murum and laterite is carried out with and without geosynthetic material to obtain minimum depth of subgrade which reduce the material cost moreover construction cost. The model number two is found to be more suitable as compared with other models when compared with the different results in terms of the total deformation, elastic strain and normal stress in the case of murum without geosynthetic material case.
Keywords: Rutting, Fatigue, pavement, FEM, ANSYS

I. INTRODUCTION

Flexible pavement widely used in road construction. While the designing of pavement wheel load, sub grade, climate and pavement materials are the factors which affect the pavement should have considered. Flexible pavement built up in several layers. There are 4 layers in flexible pavement i) sub grade ii) sub base iii) base iv) surface.

Flexible pavement is consisting of a bituminous surface course over base course and sub-base course. The surface course may consist of one or more bituminous or Hot Mix Asphalt layers. These pavements have negligible flexure strength and hence undergo deformation under the action of load.

Reinforced road structure with the suitable stiffness, have been introduced to improve and optimize the performance of traditional road building materials. The performance of reinforced road structure relies heavily on the condition of surrounding material and on the traffic load and therefore each design requires specific analysis and calculation.

The use of reinforced – geosynthetic and geogrid has had an important influence on road pavement design with real cost savings. The effect of geogrid reinforcement depends on numerous and complex factors, such as pavement structure, the characteristics of the geogrid material use and location of the geogrid in the pavement structure. Effectiveness of reinforcement in pavement was investigate throughout laboratory testing and finite-element analysis (FEM).The laboratory testing involved routine material characterization, resilient modulus testing and pavement prototype sections. Result from the previous research study showed that reinforcement material used to reduce the tensile stresses and compressive stresses in flexible pavement system.

II. LITERATURE REVIEW

Dr. Zainab Ahmad Alkaissi , et al (2018) studied that In Baghadad city because of the poor quality control while constructing the granular unbounded pavement layer. there is severe ruffing damage. So far the analysis of flexible pavement 3-D dimensional finite element model is studied in ABAQUS computer program. The ruffing analysis of this research is due to the road condition in Baghdad city because of poor quality condition.

Te-wen Tv Young Wang, et al 2017 studied that controlled low strength material (CLSM) which is recycling sustainable material used in the road pavement analysis the crack resulting from shrinkage due to temperature or moisture usually exist in the flexible pavement in highways and runways of airport.

Jose Nevel, Helena lima et al (2016) studied that analysis of subgrade reinforcement with geosynthetic in road pavement design. This analysis considered different pavement material structure of traffic conditions & subgrade soil quality on the basis of the analyzed the terms rutting & fatigue. Selection of different condition was based on the Portuguese pavement design manual.

M S Ranadive, Anand B Tapase (2016) studied that Calculation the horizontal tensile strain at the bottom of the bituminous layer (BL) Which cause fatigue distress and the vertical compressive strain at the top sub grade that means counting rutting distress from

IRC 37.2012 they estimate the pavement life for various hypothetical condition of rutting and fatigue critical criteria. They varies the depth of bituminous layers sub base layer and also varies modulus and elasticity keeping the poison's ratio constant for while applying the center load of single axel wheel load 40.80KN caused 575 kpa uniform pressure over a circular area of 150 mm radius.

Ankit Gupta(2014):In this research paper the study of sensitivity of these variable in reducing the vertical surface deflections the critical tensile strain at the bottom of the bitumen layer of critical compression strain on the top of subgrade using FEM.

In this study they varied the hot mix Asphalt modulus, the base modulus, sub-base modulus and the subgrade modulus and traffic is expressed in terms of repetitions of single axle load 18-kip applied to the pavements on two set of dual tire is approximately by two circular plates with a radius of 100 mm and spaced at 350 mm center to center.

Emmanuel Ekwulo et al 2009 studied that the layer elastic analysis of the different pavement particularly flexible pavement and which is design with the help of CBR method that consists of of the evaluation of fatigue strain as well as deformation characteristics of rutting.

K. P. George 2000 The different properties related to elastic have been determined for the different materials. The thickness requirement in terms of structural characteristics of the payment has been carried out with the help of design charts for the traffic intensity of 3000 vehicles per day.

Ahmed Ebrahim et al 2012 studied that the flexible pavement which is to be designed based on axle load limits as well as climatic conditions. This study also accompanied with the the different effect of increasing axle load, variation in the elastic modulus of the payment, overall life of the pavement.

Carpenter Samuel H. 2006 The study has been carried out on the BISAR software as well as the Egyptian environmental & materials related to the pavement conditions so that the estimation of the tensile strains which are occurred in the case of the Asphalt concrete layer. The strain corresponding to the compression which is above the surface of the subgrade.

Ker Hsiang-Wei 2007 The results indicated that the strains related to the tensile and compressive have been increased with the axle loads while it decreased as the asphalt layer modulus was increased and thereby trucks which are violated have been unloaded.

Mohd Khattak et al 2020 studied that the actual performances of the pavement particularly flexible pavement. The relationship with the different properties related to the on field mechanistic properties and the volumetric properties. The data which is required for this investigation in terms of the performance database which is for the long run performance of the pavement. Almost 116 sections related to the flexible pavement for this study have been analyzed as well as the discussions were carried out in the United States. The results found that the temperature is the major concern for the back calculation of the elastic modulus of the hot mix asphalt layer in the pavement.

Abdolla Shaeste 2017, In this paper, we first compare the methods of road surface analysis, namely the finite element method (FE) with ABAQUS software and the theory of multilayer systems with KENLAYER software. Second, the PIs identified in the analysis of the road surface are used to study the effect of isotropic properties of the material on the reaction of the road surface on transport loads.

E. Tutumluer, 2003, studied. The methods used to cover the road surface must be completely proportional to the design of the road surface. Flexible paving consists of a base and base materials that are anisotropic, including hot mix asphalt (HMA).

Wang and Hoyos, 2004 investigated that asphalt mix consists of aggregates, bitumen and aggregates. Because aggregates have anisotropic behavior, asphalt concrete also exhibits anisotropic behavior. Bitumen is a homogeneous adhesive material that reduces the anisotropic behavior of the asphalt mix.

Wagoner and Braham (2008) studied the anisotropic behavior of the asphalt mix at low temperatures; After testing to determine the complex modulus, creep and tensile strength, they concluded that asphalt concrete exhibits anisotropic behavior at low temperatures, although the tensile strength of the material does not depend on the orientation particles.

According to Underwood et al. (2005), Heidari conducted several tests in this area, showing that the anisotropic properties of asphalt concrete are reduced at high temperatures. The results of numerous studies of the anisotropic properties of asphalt concrete have shown that asphalt concrete exhibits anisotropic behavior.

Al-Qadi and others. (2002) In this study, ABAQUS commercial software version 6.11 for 3D FE was used to model the pavement. He measured the reactions of the pavement to the new generation tires with a wide base on the Virginia Smart Road test site. The measured stresses and strains were used to study the effect of various parameters used on the reaction of the road surface.

S. Immanuel 2006 According to modern research, the influence of anisotropic properties of pavement materials on the critical reaction of pavement structures to transport loads has not been clearly determined. The disadvantage of most of the studies cited in this study is that their findings were contradictory because the anisotropic effect of soil and asphalt layers was not considered simultaneously.

The research has done mostly on the sub-base, base layer and temperature effect on wearing course. To minimize the distresses, the strength of soil material has increased by treating the pavement layer soil or by stabilization the distresses means rutting & fatigue can be reduced with respect to the wheel load.

III. METHODOLOGY

Geogrids act as a tensile element at the bottom of a base or within a base course to:

1) Improve the service life &/or
2) Obtain equivalent performance with a reduced structural section.

Geogrid of grid structure of bi-axial & f minimum average tensile strength longitudinal direction of 20 kN/m& 40 kN/m will in subgrade.

A. Laboratory Test

Test on material

1) Optimum moisture content & maximum dry density test.
2) Tri-axial test
3) CBR

B. Optimum Moisture content & Maximum dry Density test (OMC and MDD)

A test is standardized by IS2720 part (VII & VIII) and used to determine maximum dry density. The maximum dry density of murum and laterite soil is calculated. Water content for murum varies from 5%, 7%, 9%, 11%, 13%, 16% & 19%.

C. Tri-axial Test

For the modulus of elasticity of murum this test is conducted. According to IS2720 part –XI unconsolidated undrainedtri-axial test.

D. CBR Test

IS2720-16(part16) used for the CBR. The CBR value of a soil can be considered to be an index which in some fashion is related to its strength. The CBR test will carry on a unreinforced murum and laterite soil. After that the reinforcement i.e. geogrid is used in pavement subgrade murum& laterite soil. Calculate the rutting and fatigue.

E. Codal Provision

The computed strain are incorporated in the fatigue and rutting criteria recommended in Indian Road Congress (IRC 37-2015) to estimate the pavement life for various hypothetical conditions. As per IRC ESAL with single wheel carrying of 40 KN and standard axle load of 80 KNload is applied on the single lane.

Table 1: Properties of Layer 1 (Bituminous Surface).

Property	Value
Young's Modulus (E)	229.8 MPA
Poisson’s Ratio	0.35
Density	2400 kg/m^3

Table 2:Properties of Layer 2 (Sub base Layer).

Property	Value
Young's Modulus (E)	114.9 MPA
Poisson’s Ratio	0.30
Density	2300 kg/m^3

Table 3: Properties of Layer 3 (Sub Grade Layer).

Property	Value
Young's Modulus (E)	70 MPA
Poisson’s Ratio	0.13
Density	1870 kg/m^3

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Table : Thickness of all models

	model-1	model-2	model-3	model-4	model-5
subgrade Thickness (mm)	500	600	700	800	1000
subbase Thickness (mm)	600	600	600	600	600
bituminous Thickness (mm)	100	100	100	100	100

IV. RESULTS

To perform structural analysis of Existing Excavator Bucket, following steps are to be performed.

1) *Step 1:* Open ANSYS Workbench 14.5 Software and select structural analysis option from analysis setting menu.
2) *Step 2:* Set material Properties in engineering data module for flexible pavement.
3) *Step 3:* Import .igs format file of existing flexible pavement into design modeler module.
4) *Step 4:* Apply material property to imported pavement geometry.
5) *Step 5:* Perform Meshing operation in model module. This process is also called as discretization process.
6) *Step 6:* Apply Boundary Conditions on flexible pavement.
7) *Step 7:* Select required result type from solution menu.
8) *Step 8:* Solve the analysis.
9) *Step 9:* Save required Results.

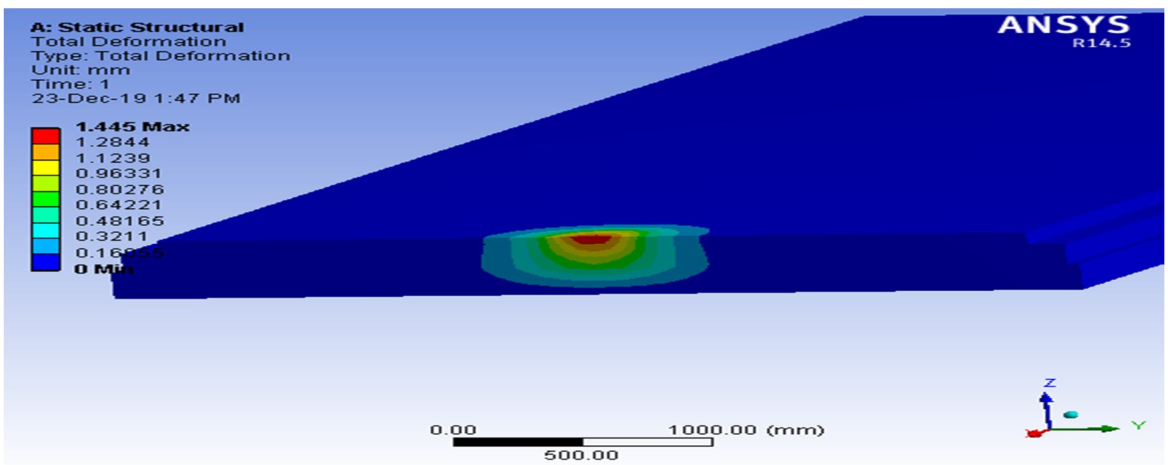

Fig. 1: Total Deformation in all direction

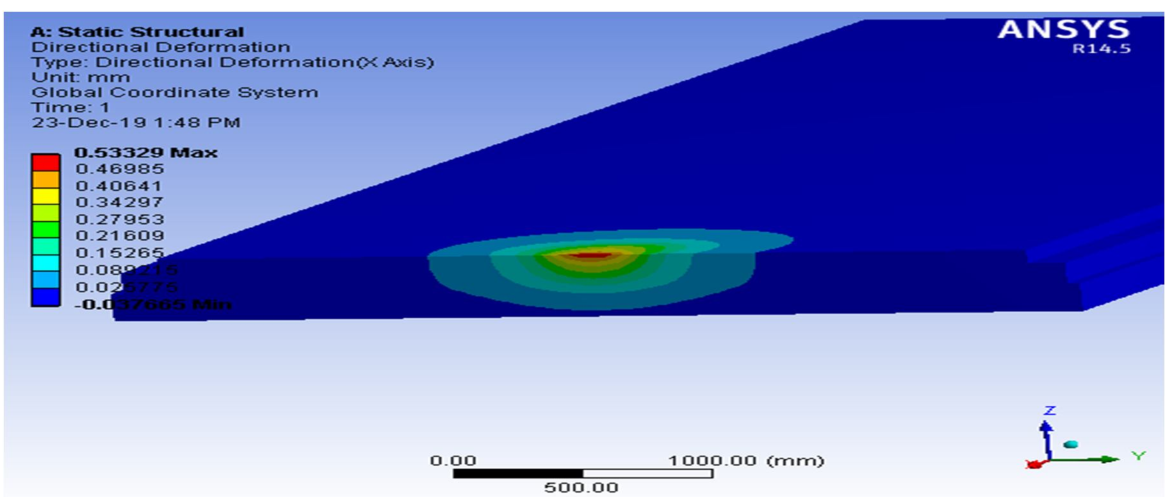

Fig. 2: Directional Deformation in X direction

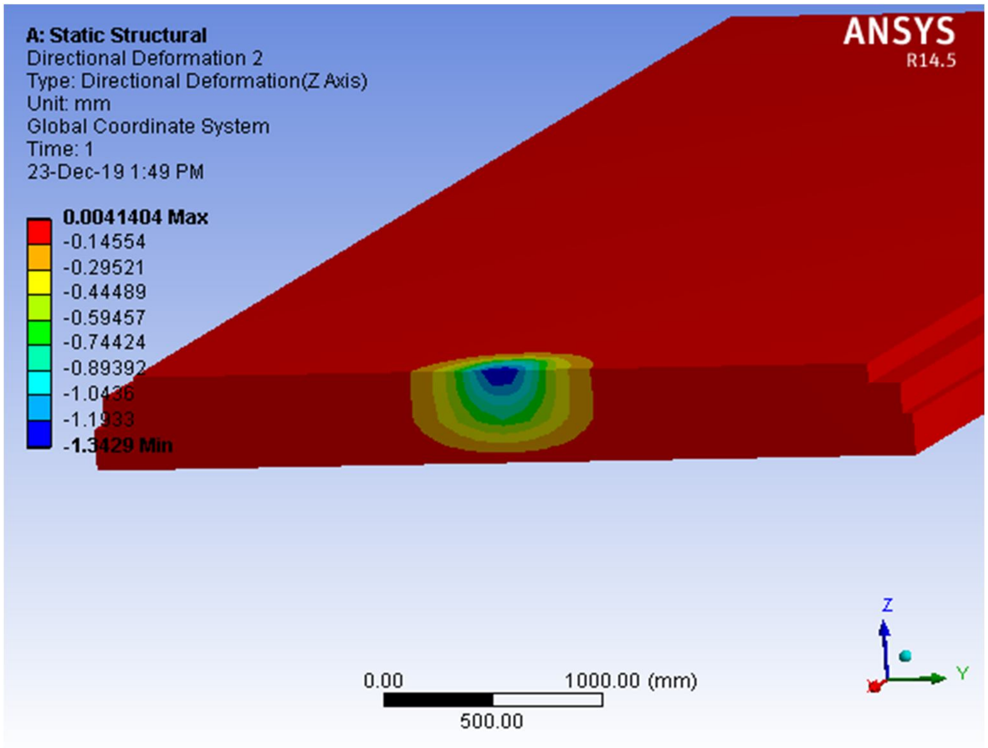

Fig. 3: Directional Deformation in Z direction

Table 5: Parametric evaluation of all models

	model1	model2	model3	model4	model5
total deformation (m)	0.0013207	0.0011648	0.0015083	0.0016032	0.0018021
maximum principal stress (Pa)	48988	31266	49247	46208	47174
maximum shear elastic strain (m/m)	0.0022147	0.0018306	0.0021749	0.0021574	0.0021529
directional deformation (m)	0.0002379	0.00023647	0.00025219	0.00025363	0.00025483
Middle principal elastic strain (m/m)	0.00030821	0.00025196	0.00030807	0.00030515	0.00029492
Elastic strain intensity (m/m)	0.0022147	0.0018306	0.0021749	0.0021574	0.0021529
stress intensity (Pa)	1.37E+05	1.31E+05	1.35E+05	1.34E+05	1.33E+05
Equivalent total strain (m/m)	0.0019744	0.0015756	0.0019432	0.001938	0.0019334
Normal stress (Pa)	29697	18799	28157	27828	27011
Shear Stress (Pa)	34785	21000	34756	38690	38399
Maximum shear stress (Pa)	68597	65400	67364	66822	66684
Strain Energy (J)	1.3268	1.2682	1.2496	1.3795	1.3202

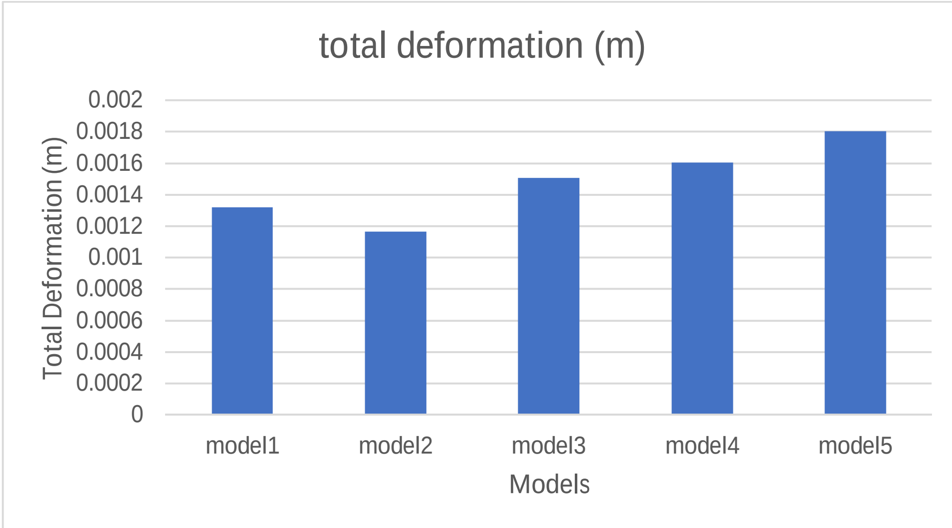

Fig.4: Total deformation of all models

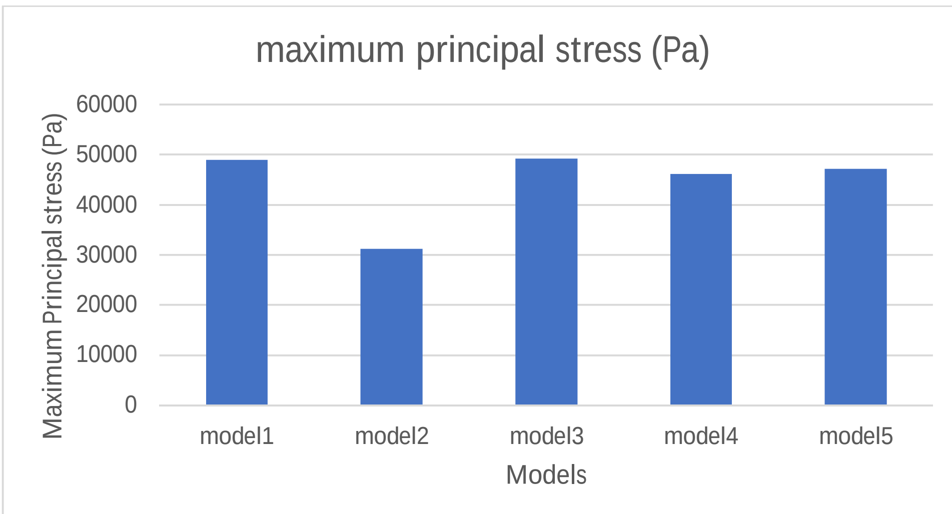

Fig.5: maximum principal stress (Pa) of all models

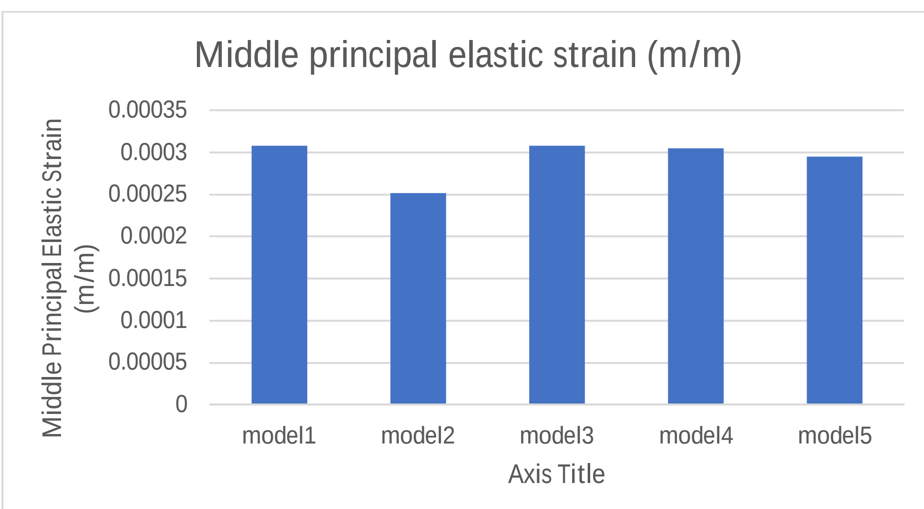

Fig.6: Middle principal elastic strain (m/m) of all models

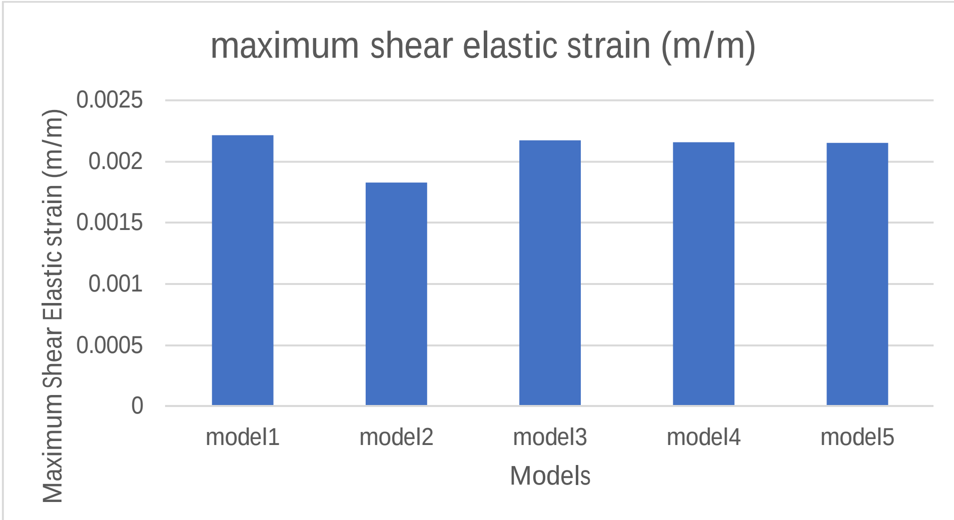

Fig.7: maximum shear elastic strain (m/m) of all models

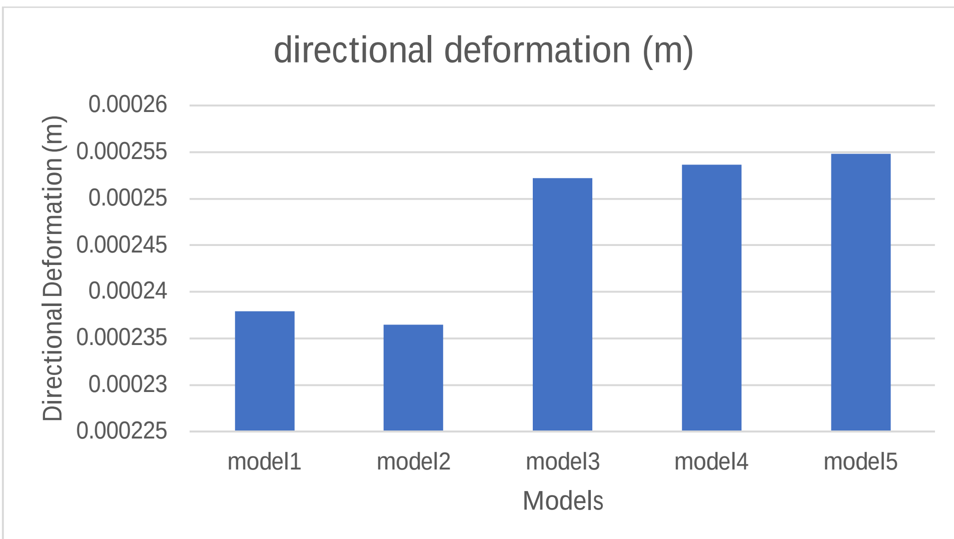

Fig.8: directional deformation (m) of all models

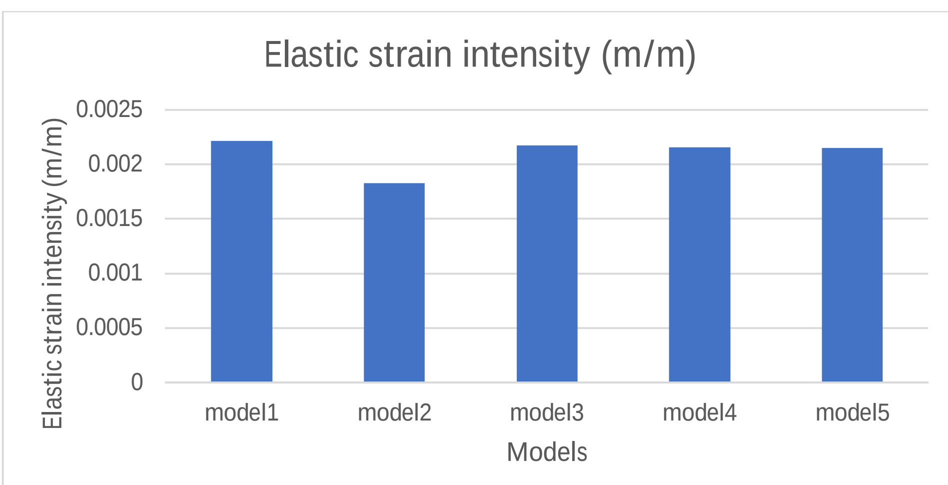

Fig.9: Elastic strain intensity (m/m) of all models

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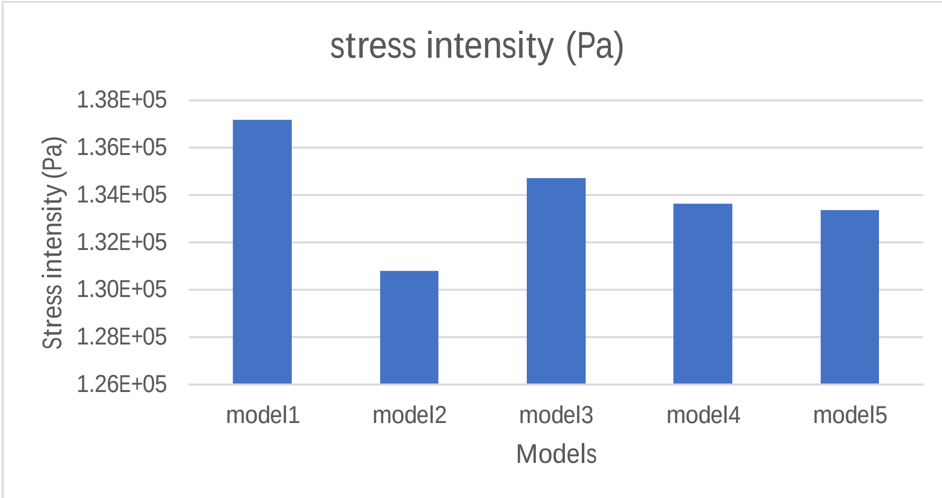

Fig.10: stress intensity (Pa) of all models

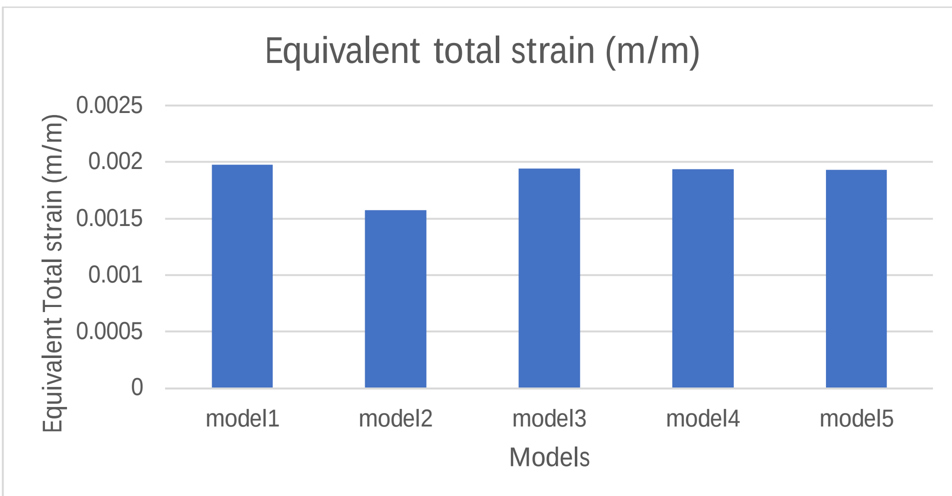

Fig.11: Equivalent total strain (m/m) of all models

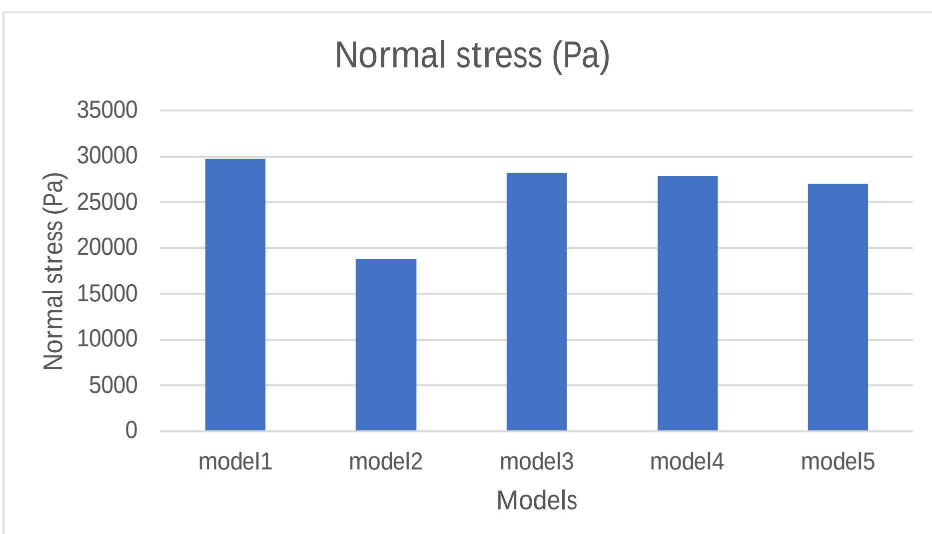

Fig.12: Normal stress (Pa) of all models

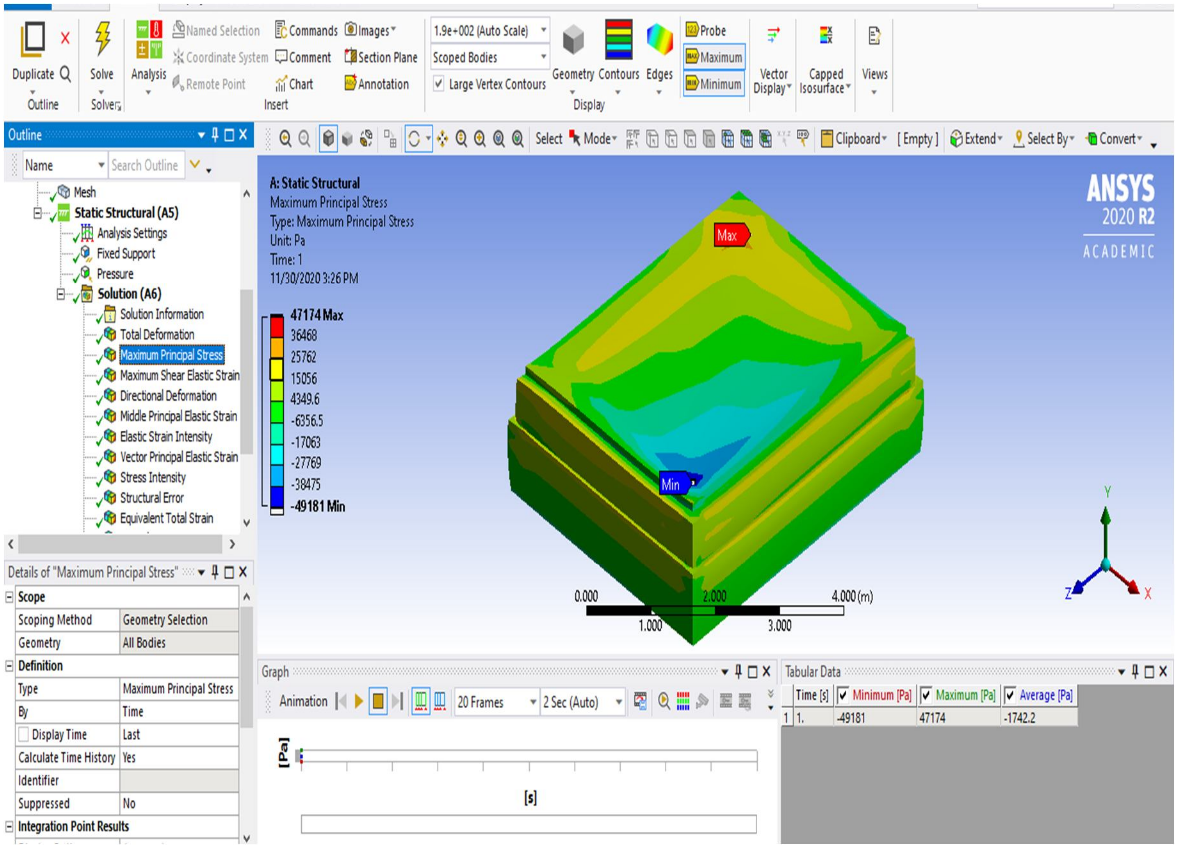

Fig.13: maximum principal stress (Pa) in the model

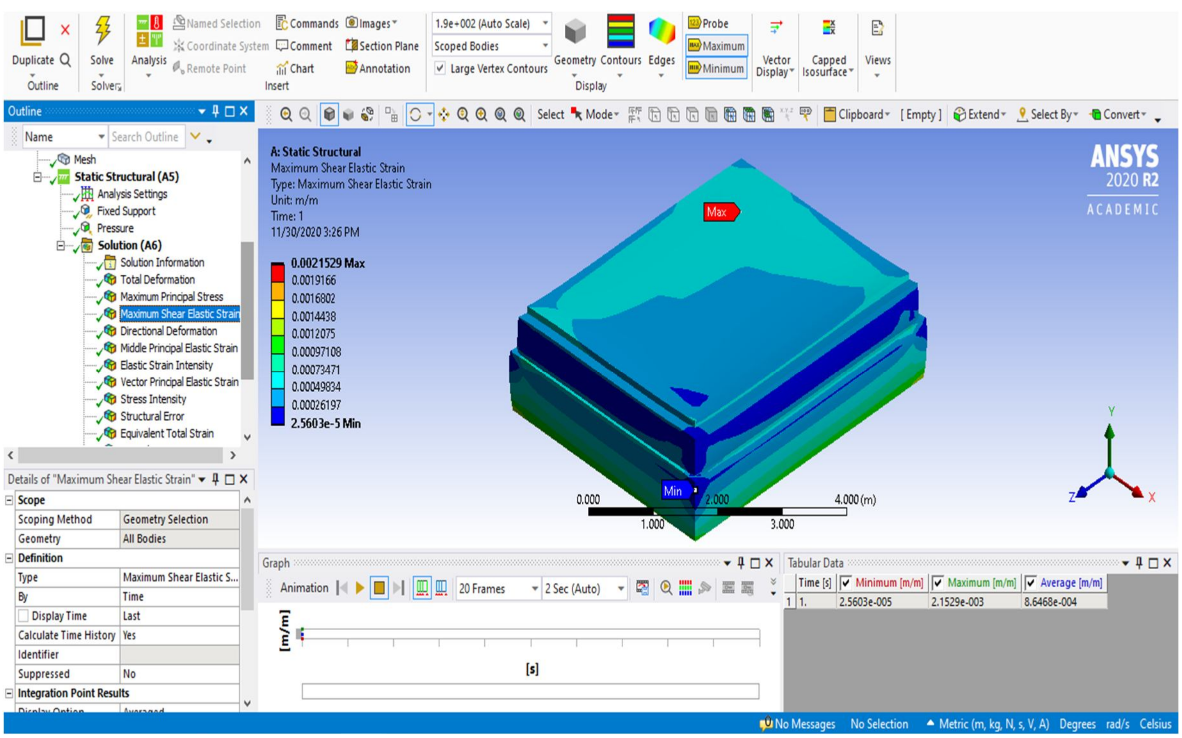

Fig.14:Maximum shear elastic strain (m/m) in the model

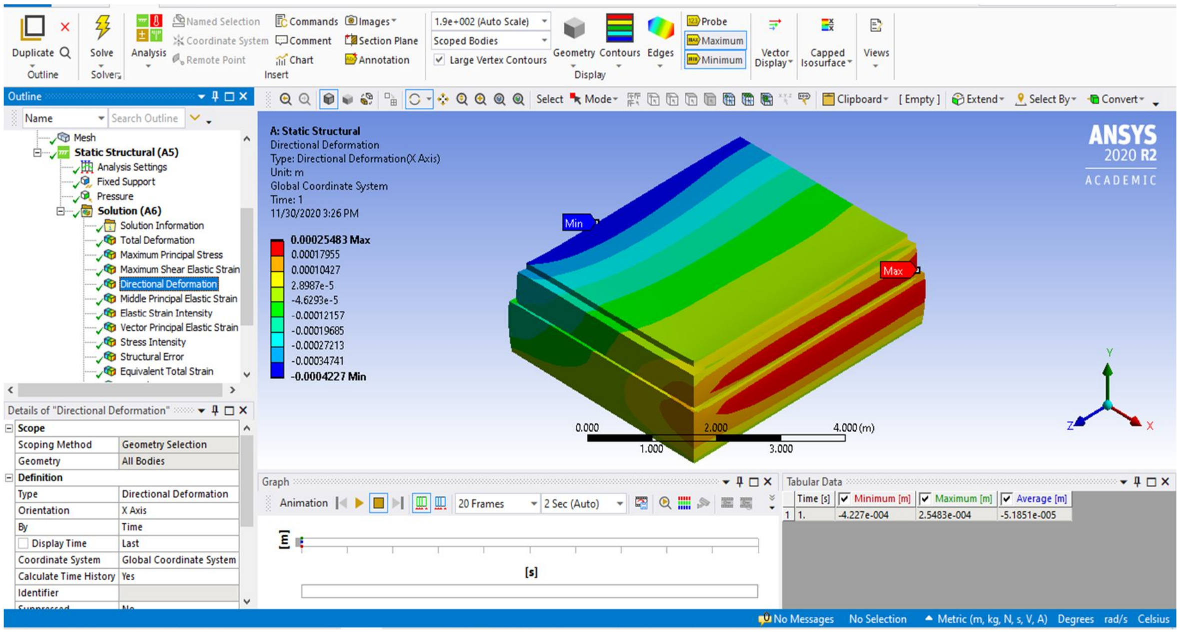

Fig.15: Directional deformation in the model

V. CONCLUSION

In software, model is design to analysis the behavior of flexible pavement. The properties of the bituminous surface and base layers are taken from the research of the Ankit Guptas research paper and values of the properties of the subgrade layer from performance of laboratory test. Fig 2 shows total deformation in all direction that is 1.445mm maximum. The horizontal tensile strain is maximum at the surface layer which is fatigue and the maximum vertical compressive strain at the subgrade layer. This is the maximum rut in the flexible pavement. The material used for subgrade layer is murum having high strength to resist the stresses so the stress and strain deformation are not more than low strength soil like laterite.

Maximum total deformation is found in the model number five, minimum total deformation is found in the model number two. The directional deformation is found maximum in the model number five. Elastic strain intensity is found maximum in the model number one, minimum normal stress is found in the model number two. Maximum shear stress is found to be in the model number one while minimum strain energy is found to be in model number three.

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