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STRUCTURAL ANALYSIS OF FLEXIBLE PAVEMENT USING FEA

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Abstract : The flexible pavements encompass different layers made of different materials and provide strength to the pavement along with flexing. The objective of current research is to investigate the effect of different layer thicknesses on strength of flexible pavement using techniques of Finite Element Analysis. The modeling and structural analysis is conducted using the ANSYS simulation package. The normal stress, shear stress, and deformation plots are generated for the pavement. From the FEA simulation, the critical regions of high stresses and deformation-induced on the flexible pavement are identified. The optimization results have shown that shear stress induced on flexible pavement reduces with an increase in subgrade layer thickness. The shear stress also reduces with an increase in base layer thickness as well.

***Index Terms* - Pavement, strength, optimization.**

I. INTRODUCTION

Depending on the amount of external traffic and the surrounding environment, the pavement may react in a variety of ways. Asphalt mixture, aggregate, and subgrade soil compositions vary greatly from place to region, and this is mostly due to traffic and environmental differences. It is essential to evaluate pavement distresses such as cracking and rutting, as well as the structural qualities of the pavement, to make judgments about its design, construction, upkeep, and rehabilitation in the future. Utilizing performance models, mathematical expressions that relate condition data to explanatory variables like material properties and pavement design characteristics, and traffic loading along with environmental factors, environmental conditions, and the history of maintenance activities, condition forecasts can be generated.

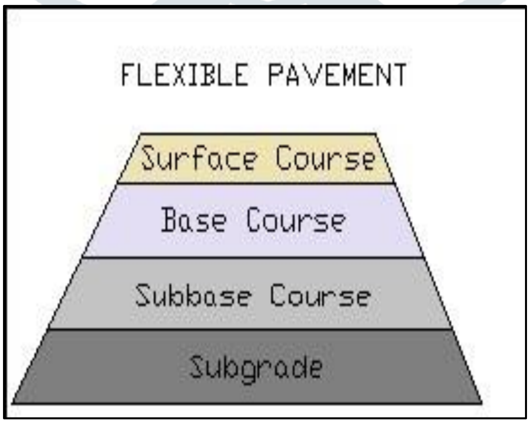

Figure 1: Flexible pavement design

Subgrade soil strength and CBR value may be affected by a wide range of variables, including load, soil qualities, and environmental and climatic conditions. In a big metropolis, flexible pavement is essential to maintain road safety and saves time, and avoids design problems that can arise. Therefore, the goal of this research is to compare and contrast several flexible pavement design software programs. The thickness of the different pavement layers is being designed using computer programs.

II. LITERATURE REVIEW

Garoosiha et al. (2019) [1] MLPNNs with different designs and training processes were studied for their ability to forecast concrete shrinkage MLPNNs' non-linear depiction of material performance versus composition may assist a broad variety of paving materials. It's prone to overfitting small experimental datasets using MLPNN.

Dinegdae and Birgisson, (2018) [2]. Autonomous vehicles have an immediate impact on lane selection and lane layout in truck traffic. AV trucks have a different lane selection and placement system than non-autonomous vehicles driven by humans. The effect of AVs on pavements will be different than it is today because of this. Cars and big goods are likely to be funneled into one restricted wheel path because of the ability of AVs-based systems to lane center, resulting in congestion.

Liu et al., (2019) [3] Infrastructure such as roads and pavements must be protected. As a consequence, the impact of autonomous vehicles (AVs) on public roads must be evaluated. This is true for both the design and construction of new pavements as well as the upkeep and rehabilitation of already existing pavements. There must be a focus on protecting and maintaining existing pavement structures, as well as developing new sustainable methods and materials for future road projects.

Das et. al. [4] have investigated different types of failures occurring in the bituminous pavement. The approach used for the analysis is mechanistic-empirical. The research is conducted using both analytical and numerical simulation techniques.

Tarefder et. al (2010) [5] have researched flexible pavement design and the variability affecting its strength. The reliability of pavement is evaluated based on subgrade strength, mean, median, variation coefficient, and density distribution. When compared to a probabilistic process, the study results demonstrate that AASHTO has greater dependability values.

Fang et al., 2019 [6] have investigated the development of high-quality pavement and the factors affecting the deterioration of the pavement. The factors affecting the deterioration of pavement are water seepage, porous mixing, and the gap in gradation besides the chemical properties and physical properties of aggregates.

Ma et al. [7] have investigated the problem of bitumen by mixing crumb rubber and plastics. The research findings have shown that the rutting resistance of bitumen is improved by plastic and the compatibility of the blend is improved by rubber.

Martin et al. [8] Recycled greenhouse plastic (LDPE) has been used as an additive in our modified BM. Two modifications were made to this process because the "plastic-bitumen interaction time in the dry process is short; first, they treated plastic to make it compatible with agents such as recycled mineral lubricating oil, bitumen grade 15/25 and 500, and secondly, after making BM from the dry process, 1 hour was given to the mix in an oven at 165°C. It was previously impossible to simultaneously enhance the bitumen-plastic interface and minimize the mixing time" using these methods. [8].

Fadzil et al. [9] have investigated the application of plastics for flexible pavement construction. Plastics may save building costs by a large amount. The conventional dry heating process didn't yield good results. The addition of plastics with aggregates resulted in higher strength.

P. Dharani et al. [10] have investigated the use of different types of waste materials for pavement. Different types of materials i.e. plastics, bakelite, and other waste from industries like fly ash can be used for pavement design.

III. OBJECTIVE

The Finite Element Analysis (FEA) is being used to study the influence of varied layer thicknesses on the strength of the flexible pavement. The modeling and structural analysis is conducted using the ANSYS simulation package. The normal stress, shear stress and deformation plots are generated for the pavement.

IV. METHODOLOGY

To determine the stresses and deformations on the pavement, an FEA structural analysis is performed. Pre-processing, solution, and post-processing are all parts of the FEA analysis process. Before the post-processing, CAD modeling and meshing are required, as well as the application of loads and boundaries.

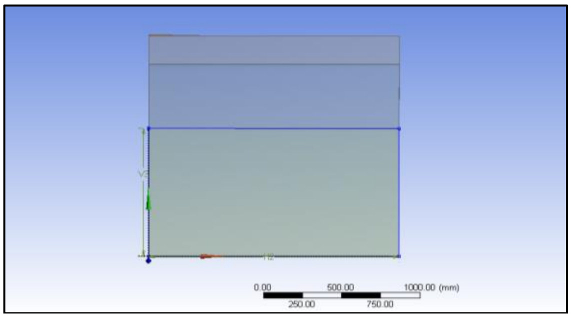

Figure 2: Sketch and modeling of sub grade layer

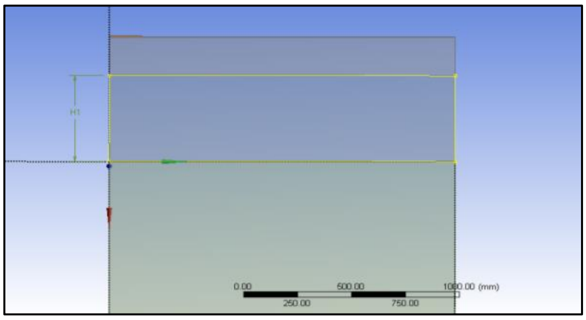

Figure 3: Sketch and modeling of the base layer

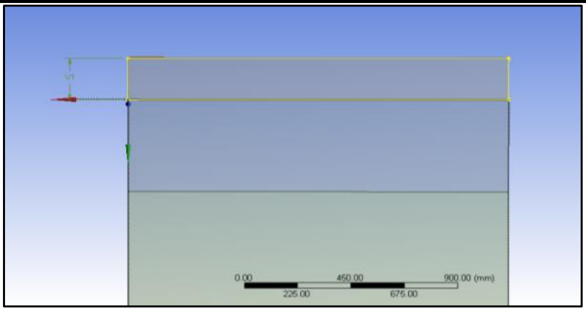

Figure 4: Sketch and modeling of BL

Different layers of pavement are modeled in the ANSYS design modeler. The subgrade layer has a dimension of 900mm, the base layer has a dimension of 450mm and BL has a dimension of 200mm.

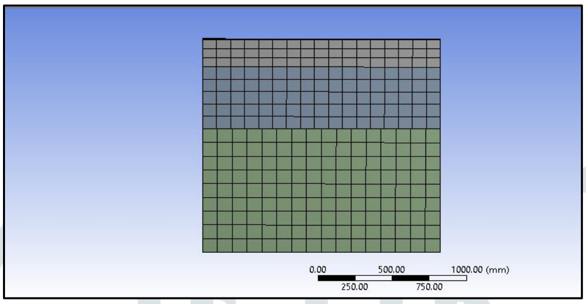

Figure 5: Meshed model of pavement

The model of pavement is discretized using hexahedral element type. The hexahedral element comprises 8 nodes with 3DOF/node. The model is discretized with fine relevance setting and adaptive shape function. After meshing the structural loads and boundary conditions are applied to the structure. This boundary condition involves applying fixed support at the bottom and downward force on the top left end. The loading conditions are applied as per the IRC:37-2012 code.

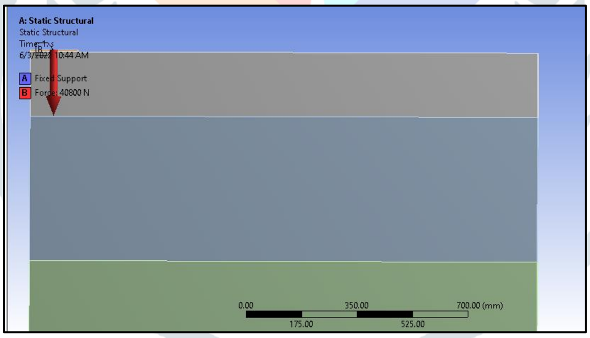

Figure 6: Structural loads and boundary conditions

The simulation is done after the pavement has been subjected to structural stresses and boundary conditions. The process involves the formulation of matrices associated with each element. They are combined into a single global matrix. Interpolation is done for all element edge lengths based on the nodal computations.

V. RESULTS AND DISCUSSION

Deformation, normal stress, and stress intensity are determined by the FEA structural analysis.

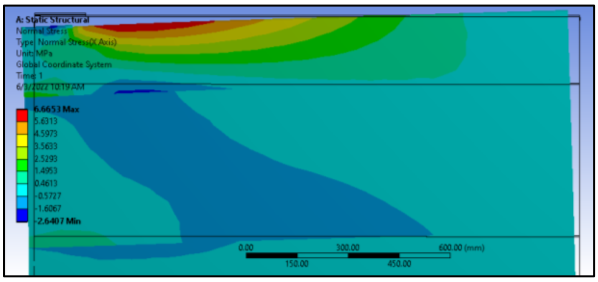

Figure 7: Normal stress (longitudinal direction)

Figure 7 depicts the pavement normal stress map created using the aforementioned formula. The highest normal stress is found in the top corner, where the usual stress is around 5.6MPa. The stress decreases along the length of pavement as shown in the green-colored region.

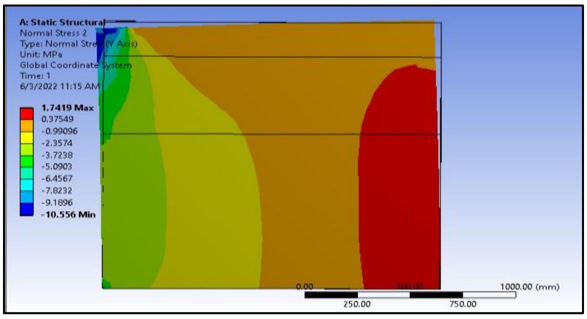

Figure 8: Normal stress (transverse direction)

The normal stress is generated on the pavement as shown in figure 8. The maximum normal stress is observed for the top left corner region with a magnitude of more than 9.1MPa. The pressure is compressive in the region of load application and is tensile on the rear region of pavement.

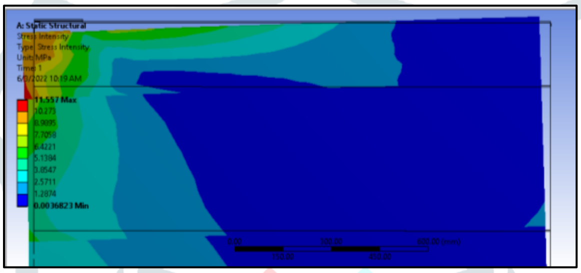

Figure 9: Stress Intensity

Figure 9 shows the stress intensity map created for pavement. The stress intensity is determined to be highest in the area where the stress intensity exceeds 8.98MPa.

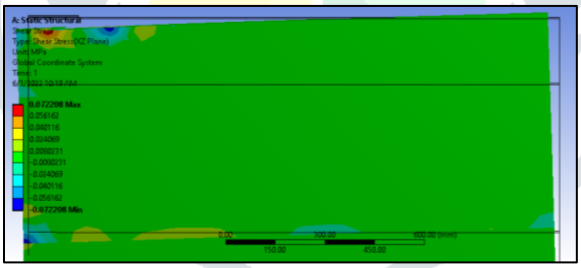

Figure 10: Shear stress

The shear stress plot is generated for pavement and the shear stress generated is more than .0561MPa. The shear stress in most of the region is .00802MPa.

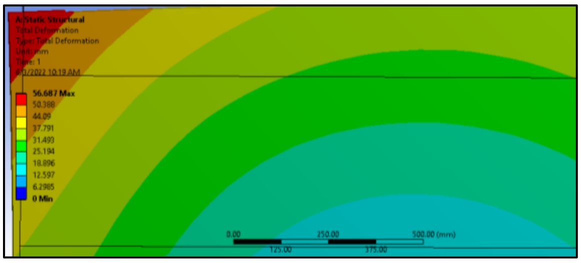

Figure 11: Total deformation

Figure 11 shows the overall deformation plot created for pavement. The maximum deformation is observed for the region of load application which reduces moving towards the bottom of the pavement.

VI. CONCLUSION

The FEA is a viable tool for determining the lateral and longitudinal strength of the flexible pavement. From the FEA simulation, the critical regions of high stresses and deformation-induced on the flexible pavement are identified. The optimization results have shown that shear stress induced on flexible pavement reduces with an increase in subgrade layer thickness. The shear stress also reduces with an increase in base layer thickness as well.

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