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Influence of Base Layer Thickness on Flexible Pavement under Moving Load

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Abstract

In the past, elastic pavement layer characteristics were used in semi-experimental methods to design and analyze flexible pavements. Due to the complicated interactions among different layers of flexible pavement, traditional analysis and design techniques have been replaced by quick and effective techniques, such as the Finite Element Method (FEM), which is more suitable in continuum situations. This study uses three dimensional (3D) finite element application for predicting mechanical behavior and pavement performance under moving load. An axisymmetric model is developed in which element type and meshing strategies are taken by successive trial and error to achieve desired accuracy. The stress and deformation behavior are examined by varying the thickness of base layer (100mm, 200mm, 300mm) of flexible pavement. The results are discussed in details and final outcomes are concluded.

Keywords: *flexible pavement; finite element method; moving load, deformation behavior.*

1 Introduction

Transportation is regarded as one of the most important infrastructure components influencing economic and production activities. Among different modes of transportation, only road network provides the facilities to move people and commodities door to door.

Flexible pavement road is the most popular type of road pavement in the world due to its many benefits. Under loads, flexible pavement road is susceptible to distortion. A details analysis of the stress-deformation behavior of the flexible pavement is necessary to reduce or prevent pavement failure and create an appropriate design and maintenance plan for the track. The road layers are regarded as homogeneous, linear elastic, and isotropic in causal approaches used in the analysis of multilayer pavement technique under moving load. Among other techniques, the stress-deformation response of the pavement layers can be confidently examined using a three-dimensional (3D) finite element method (FEM) (Zaghloul and White, 1993). FEM is one of the best methods for simulating how various structural engineering difficulties would respond under moving load. It is now the most widely used method in numerical simulations, both in academia and industry (Laziz et al., 2014).
Over the past three decades, due to significant improvements in computer programs and FE methods, 3D structural studies are now more reasonably priced. Studies on the behavior of flexible pavement layers for various track characteristics are available in the literature (e.g., Park, 2008; Rahman et al., 2010; Alkaissi and Al-Badran, 2018; Mahadi & Mohammad, 2021). The majority of research took into account effect of contact stress, tire type, the shape of the tire imprint region. However, the main focus of this paper is on how variations in base layer thickness affect the flexible pavement's stress-deformation response.

2 Methodology

The investigation was conducted using advanced three-dimensional (3D) finite element (FE) modeling, one of many numerical solutions. ABAQUS software was used to create the 3D FE model of the flexible pavement because it can replicate more practical scenarios than two-dimensional modeling can. Various thickness of base layer for the flexible pavement were considered in the investigation.

2.1 FE Modelling of the Flexible Pavement

The surface, binder, base course, subbase, and subgrade were modeled using 3D FE material and all were thought of as closed systems made up of several layers. In the current study, a conventional pavement section with bituminous layers surface, binder, base, subbase and subgrade was taken into consideration to examine the impact of base layer thickness on the performance of flexible pavement layers. The thicknesses of surface, binder, subbase and subgrade were chosen as 40, 75, 200, and 2500 mm respectively, where the base layer thickness was selected as 200 mm. The materials properties of the flexible pavement are given in Table 1.

The pavement geometry are 5000 mm both along the vertical direction (Y axix) and moving loading direction (X axes) and 3000 mm along the transverse direction (Z axis). The 3D axis symmetry property was used and one-fourth of the model were created for saving computational time and effort.

Table 1. Material properties for road layers.

Layer	**Modulus of elasticity, E (MPa)**	**Poisson's ratio**	**Thickness (mm)**
Surface	2689	0.35	40
Binder	22206	0.35	75
Base	1655	0.35	200
Subbase	110	0.40	200
Subgrade	35	0.499	2500

3 Stress and Deformation Response

The analytical findings demonstrate that the pavement has a certain stress and deformation behavior under moving loads. The analysis was carried out using the nominal model parameters listed in Table 1. Figure 1 depicts the stress and deformation pattern in the 3D axis symmetrical nominal model.

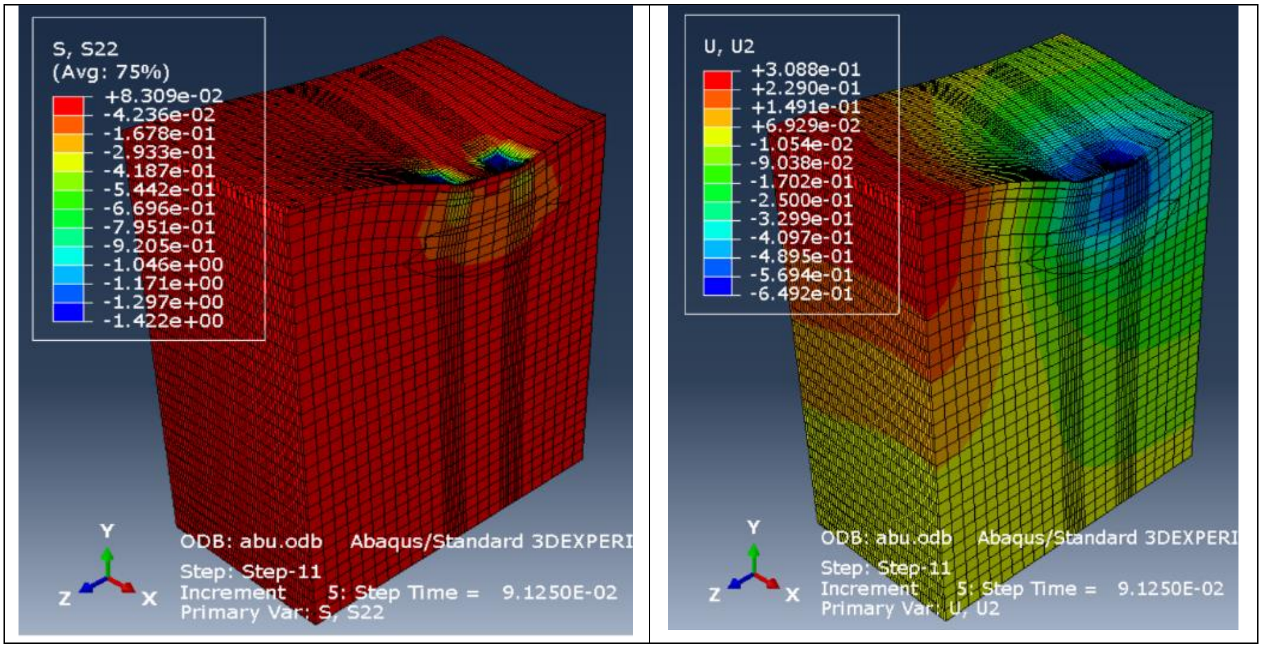

Figure 1. Stress and deformation behavior of flexible pavement.

4 Parametric Study

It is impractical to expect the nominal model attributes and loading circumstances to remain constant throughout time. To observe the substantial changes in stress-deformation response under moving load various properties were used. Vertical stress and deformation are investigated in this study for various base layer thicknesses 100 mm, 200mm and 300 mm for Cases 1, 2, and 3 respectively. The other properties of the model were remain the same as nominal model. as indicated in Table 2.

Table 2. Layer thickness.

Layer	Layer name	Thickness (mm)		
		Case 1	Case 2	Case 3
1	Surface	40	40	40
2	Binder	75	75	75
3	Base course	100	200	300
4	Subbase	200	200	200
5	Subgrade	2500	2500	2500

4.1 Impact of Base Layer Thickness for Vertical Stress

The base layer thickness has a significant impact on the flexible pavement's ability to respond to stress under moving load. The effects of various base layer thickness values on the flexible pavement's stress response under moving load are shown in Figure 2. Figure 3 represent a comparison of stresses for various base layer thickness. It is evident that as vertical depth increases, vertical stress diminishes.

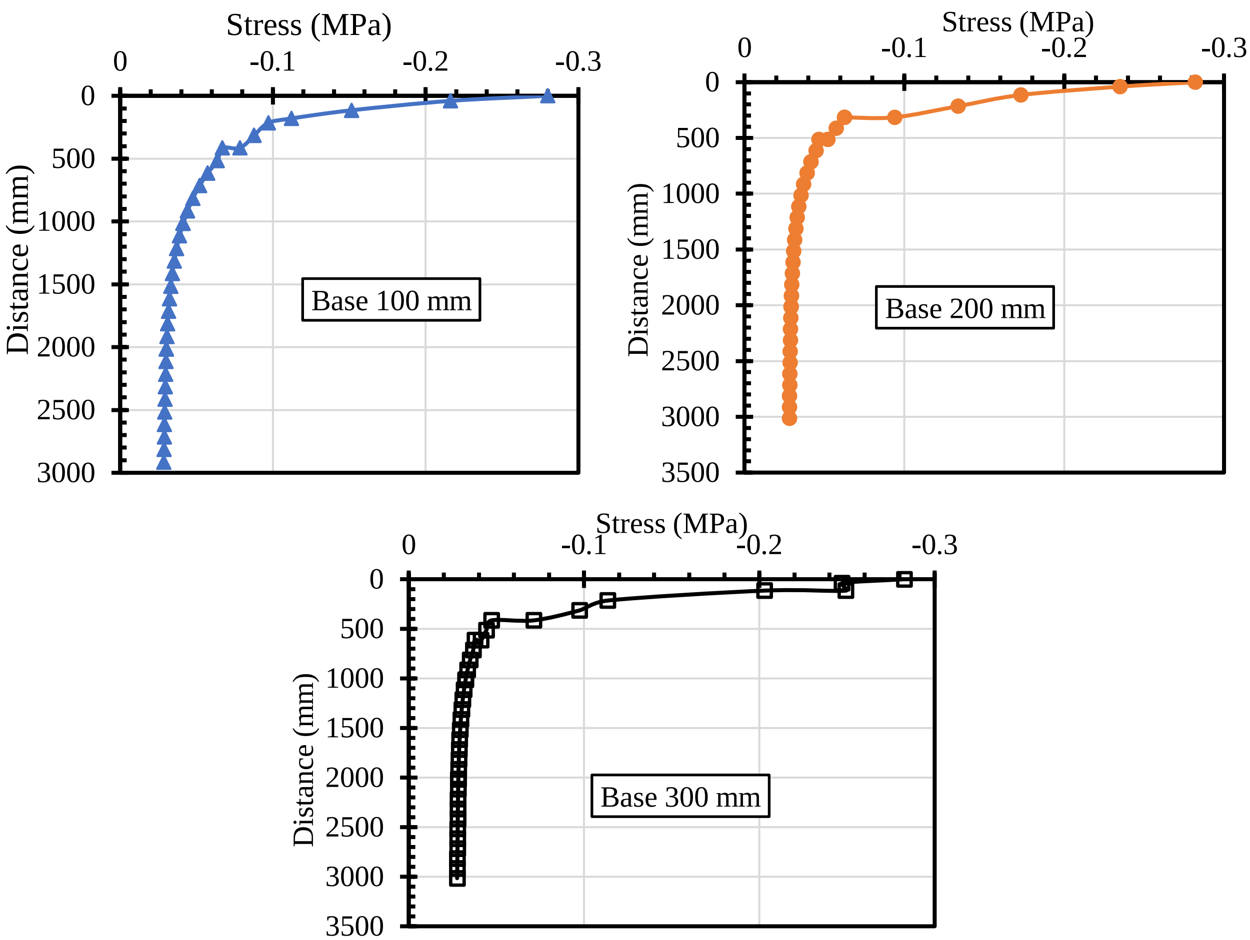

Figure 2. Impact of base layer thickness for vertical stress.

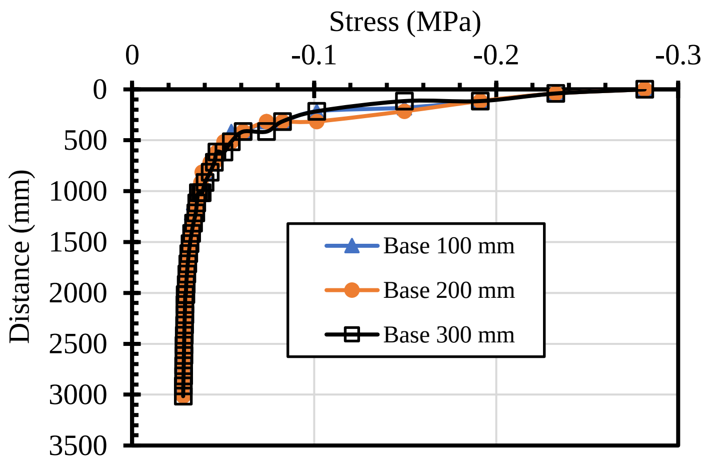

Figure 3. Impact of various base layer thickness for stress.

4.2 Impact of Base Layer Thickness for Vertical Deformation

Base layer thickness plays an important role in the vertical deformation of the flexible pavement under moving load. Figure 4 presents the impacts of different values of base layer thickness on the deformation response in the flexible pavement under moving load condition. A comparison of vertical deformation for various base layer thickness has shown in Figure 5. It can be seen that the deformation decreases with the increase of base layer thickness.

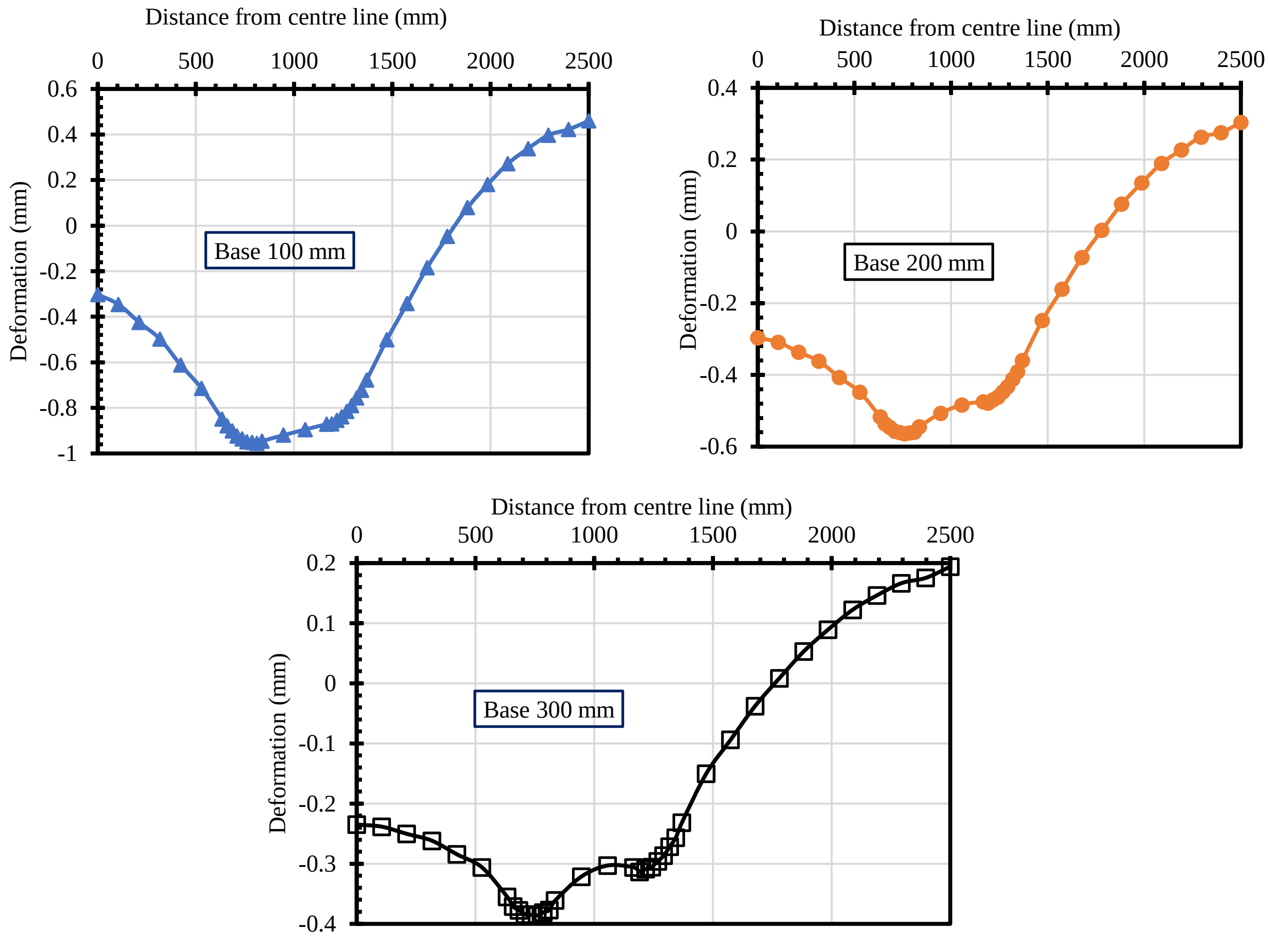

Figure 4. Impact of base layer thickness for vertical displacement.

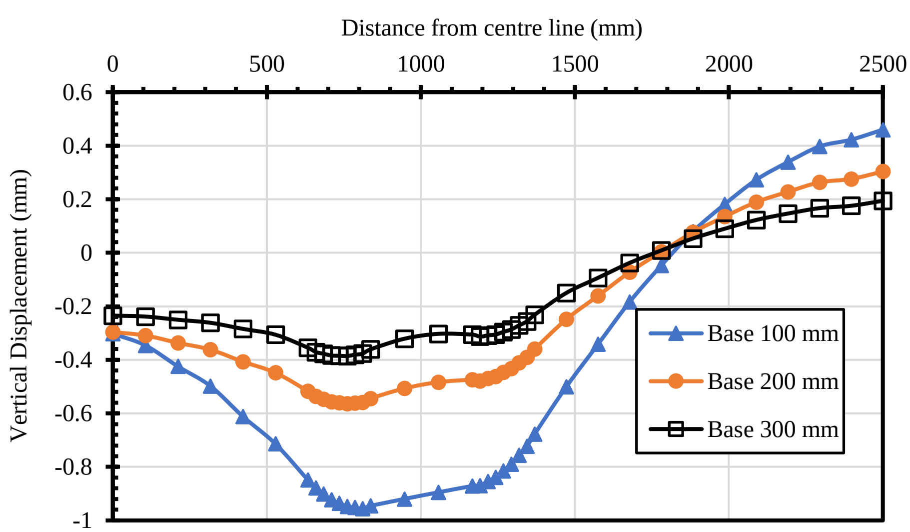

Figure 5. Impact of base layer thickness for vertical displacement.

4.3 Variation of Stress

The different base layer thickness plays an important role on the other layers of pavement. Stress developed on the upper layers increase but below the base layer it can be seen that the developed decreases with the increase of base layer thickness. The variation of stress for the different layers have been shown in Table 3.

Table 3. Variation of stress.

	Case 1	**Case 2**	**Case 3**	**Case 1 to 3**
Top of Binder	216.2	234.9	247.2	14.33%
Top of Base	218.4	237.1	249.3	14.14%
Top of Subbase	162.13	133.72	113.51	-29.98%
Top of Subgrade	78.4	57.4	47.3	-39.66%

5 Conclusions

In this paper, the stress and deformation behavior of flexible pavement under moving load was investigated using 3D finite element model. Various thickness of base layer for the flexible pavement were considered in the investigation. It was found that the base layer has the most significant impact on the deflection and stress response of the flexible pavement. The deflection of the pavement surface and the stresses below the base layer decrease significantly with the increase of base layer thickness. On the other hand, the stress developed above the base layer increases with the increase of base layer thickness.

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