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Mechanical Response Analysis of Asphalt Pavement Structure

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ABSTRACT
Generally, the Chinese designed life of the high- grade asphalt concrete pavement is required 15 years, however, the designed life of the road in surface is often lower than the designed life, and even premature failure. Especially in heavy traffic conditions, the early damage of some high grade-asphalt pavement in China is serious. According to some investigations, we founded the main reason of the long-life asphalt pavement is to determine the function of each structure layer. According to the stress of pavement structure layer, so as to select the structure layer materials. Based on the viewpoint of mechanics, asphalt pavement damage mode is divided into three categories, such as top-down crack, fatigue cracking and rutting. Therefore, this paper uses ANSYS finite element software as calculation tool, the combination of road vehicle load and the primary influence on asphalt pavement structure mechanics response characteristics were analyzed.
In this paper, the method of analysis is control variable: that means under different vehicle axle load, only change surface layer modulus and observe the pavement structure mechanical response trends to compare the effect. By using the same method, the response of the pavement base course parameters to the pavement mechanical structure is analyzed.
Keywords: Asphalt Pavement; Force Response; Finite Element Method

I. Mechanical model hypothesis of Asphalt Pavement

1.1 Wheel load model

In this thesis, the finite element software ANSYS is used to analyze the load and the surface structure of the asphalt pavement. For vehicle load, the contact surface of the tire and the pavement is shown in figure 1, although its contour is approximate to the ellipse, but because of its long axis and short axis, the wheel load is simplified to equivalent circular uniform load.[1]

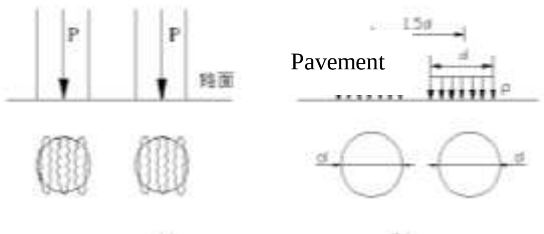

Figure1. Wheel load calculation diagram

When transfer the load under the condition of the fixed environment and wheel load, the thickness of the pavement structure determines the stress response of pavement structure.The relationship between pavement structure form and stress and strain state in pavement. Although there may be many levels in the actual pavement, the pavement structure can be simplified by the pavement structure layer and the material characteristics.[2]

Based on the above assumption, the finite element model of asphalt pavement can be established to analyze the mechanical response of pavement structure.

1.2 Material structure model

The three-dimensional finite element model, such as figure 2, is established to analyze the mechanical response of pavement.

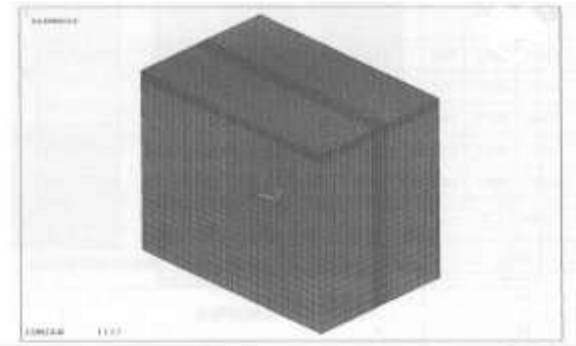

Figure 2. Three dimensional finite element model of asphalt pavement structure

In fact, the row direction and pavement surface depth compare with width direction, which tends to be infinite.

When the method is used to solve the problem, it is impossible to divide the element in the infinite domain.

Through the past experience, the concrete model is as follows:

X: Along the width direction value is appropriate 4 meters. It can be considered that the driving load has little effect on the boundary of the driving load;

Y: Along lane direction value is 8 meters

Z: Along the depth direction, the structural layer according to the actual thickness of the subgrade, the value is 6 meters

Assuming that there is no displacement of the width direction on the left and right sides of the model and no lane direction displacement on the bottom surface.[3]We can consider the layers as complete contact.

In order to distinguish the load area and the non load area, the load area is refined in the grid. The unit size of the load area is adopted $0.05\times0.1m^2$, and the unit size of the non load area is adopted $0.1\times0.1m^2$ .In the depth direction, the average value of the subgrade is $0.02m^2$.In order to make the soil pavement structure layer transit to the subgrade more uniform, the subgrade should use the gradient grid. Therefore, the average coordinate value of Z axis is $0.2m^2$.

Parametric model of composite pavement material is shown in figure 3.The pavement material parameters corresponding to the above structural layer can be founded in table 1.

Structure layer Ⅰ E_1, H_1, μ_1
Structure layer Ⅱ E_2, H_2, μ_2
Structure layer Ⅲ E_3, H_3, μ_3
Subgrade E_0, H_0, μ_0

Figure 3. Combined pavement material parameters

Table 1. Combined pavement material parameters

H_1(m)	E_1(MPa)				μ_1
0.16	800	1200	1600	2000	0.35
0.24	800	1200	1600	2000	0.35
0.26	800	1200	1600	2000	0.35
H_2(m)	E_2(MPa)				μ_1
0.12	400				0.35
H_3(m)	E_3(MPa)				μ_1
0.16	1500				0.35
H_0(m)	E_0(MPa)				μ_1
6	40				0.4

II. Mechanical response analysis of pavement structure

The external factors of structural damage of the pavement is mainly because of vehicle load. According the aim to extend the service life of asphalt pavement,the influence of vehicle load on the life of the asphalt pavement is mainly reflected in the formation of pavement rut. Rutting is designed as a driveway pavement wheel tracks the formation of permanent deformation in subsidence accumulation of the wheel under repeated loading.[4] Rut can seriously affect the service quality and service life of asphalt pavement.

In this thesis，taking the unstable rut as a example to analyze the same vehicle load under different pavement structure.

2.1 Mechanical response analysis

For selected pavement structure combination H_1 is value as 0.16m、0.24m、0.26m, mapping analysis of the τ_{max} which deep drawing wheel center along the road.

Results of our analysis between τ_{max} and H_1 are summarized in figure 4.Results of our analysis in the H_1 and E_1 how to affect τ_{max} can be found in table 2.

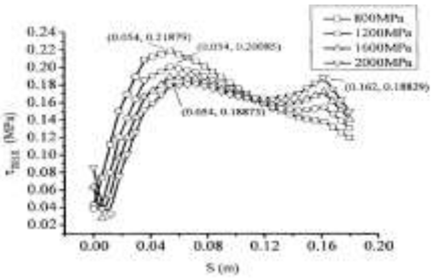

Figure 4 (a). the law of wheel center τ_{max} under depth variation (H_1=0.16m)

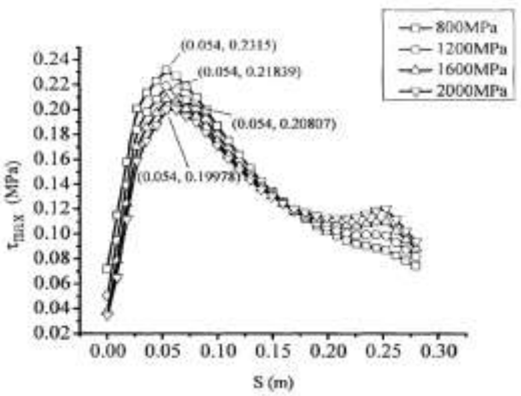

Figure 4 (b). the law of wheel center τ_{max} under depth variation (H_1=0.24m)

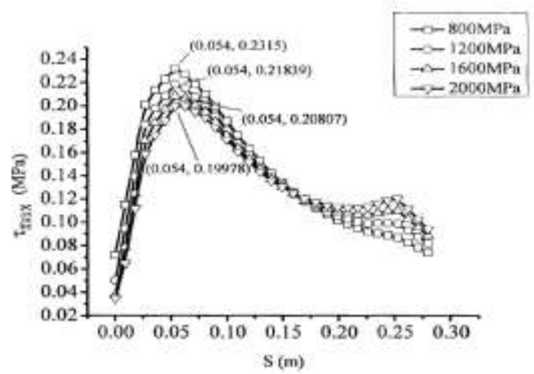

Figure 4 (c). the law of wheel center τ_{max} under depth variation (H_1=0.26m)

Table 2(a). Effects of E_l value and its position on the formulation of road wheel center τ_{max}

H_1(m)	E_1(MPa)	Maximum Coordinate value of τ_{max} (m)	Maximum value of τ_{max}(MPa)
0.16	800	0.053	0.217
	1200	0.054	0.195
	1600	0.055	0.189
	2000	0.164	0.178
0.24	800	0.047	0.225
	1200	0.052	0.214
	1600	0.056	0.201
	2000	0.056	0.199

(Continued Table 2(a))

H_1(m)	E_1(MPa)	Maximum Coordinate value of τ_{max} (m)	maximum value of τ_{max} (MPa)
0.26	800	0.053	0.022
	1200	0.054	0.021
	1600	0.054	0.021
	2000	0.053	0.020

Table 2(b). Effects of H_l value and its position on the formulation of road wheel center τ_{max}

E_1(m)	H_1(MPa)	Maximum Coordinate value of τ_{max} (m)	Maximum value of τ_{max}(MPa)
800	0.16	0.053	0.217
	0.24	0.047	0.225
	0.26	0.053	0.022
1200	0.16	0.054	0.195
	0.24	0.052	0.214
	0.26	0.054	0.021
1600	0.16	0.055	0.189
	0.24	0.056	0.201
	0.26	0.054	0.021
2000	0.16	0.164	0.178
	0.24	0.056	0.199
	0.26	0.053	0.020

2.2 Data analysis

From the figure 4 and table 2, we can draw the

following conclusions:
(1).When the value of E_1 is 800, wheel center τ_{max} along the road depth direction to the maximum and gradually reduced;
When the value of E_1 is more than 1200, wheel center τ_{max} along the road depth direction change is similar to the value as 800.However,the bottom of the structure is slightly larger than the surface of the road.
(b).When the H_1 is constant, the maximum value of E_1 is decreased.
Thus, in comparison of H_1 and E_1, the mechanical response of the E_1 to the deep change of the wheel core is relatively larger.
(c).When the H_1 is large, the maximum value is close to the road surface, which is about 1/5 of the structural layer thickness, the maximum position of E_1 is seemed as a slight influence.
(d).For the formulation of pavement, the smaller value of H_1 and E_1 is,the more difficult to occur rut.

III. Conclusions

This paper has many deficiencies; especially the following problems still need to wait for the solution:

(a). For pavement structure, it is a kind of special structure, which is representative and extensive should waiting for proved. In addition, this paper mainly discusses the influence of E_1 and H_1 on the pavement structure, but it is not discussed the other structural layer from the thickness and modulus, which is to be further studied.

(b). It is not consider about the effect of temperature on pavement mechanical response.

(c). For vehicle load, there are still a lot of factors that affect the pavement. In this paper we only consider the influence of gravity loads on the pavement.

Because the analysis is based on single parameter of pavement structure mechanics response change.If the multiple parameters of pavement mechanical response degree have to analysis, this method will meet some limitations and biases. This conclusion can be used as the reference basis for the design of asphalt pavement structure, which has a certain reference value.

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