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Analysis of Load Stress for Asphalt Pavement of Lean Concrete Base

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Abstract

The study revealed that whether it is early distresses in asphalt pavement or not depends largely on working performance of base. In the field of asphalt pavement, it is widely accepted that lean concrete base, compared with the general semi-rigid base, has better working performance, such as high strength and good eroding resistance. Problem of early distresses in asphalt pavement, which caused by more traffic loadings, can be settled effectively when lean concrete is used in asphalt pavement. Traffic loading is important parameter used in the analysis of the new pavement design. However, few studies have done extensive and intensive research on the load stress for asphalt pavement of lean concrete base. Because of that, it is necessary to study the load stress for the asphalt pavement. In the paper, first of all, three–dimension finite element model of the asphalt pavement is created for the aim of doing mechanical analysis for the asphalt pavement. And then, the two main objectives of this study are investigated. One is analysis for load stress of lean concrete base, and the other is analysis for load stress of asphalt surface. The results show that load stress of lean concrete base decreases, decrease and increase with increase of base’s thickness, surface’s thickness and ratio of base’s modulus to foundation’s modulus respectively. So far as the asphalt surface is concerned, maximum shearing stress, which is caused by load, is evident in asphalt surface which is located in transverse contraction joint of lean concrete base of asphalt pavement. Maximum shearing stress decrease, decrease, decrease and increase respectively with increase of the surface’s modulus, the surface’s thickness, base’s thickness and ratio of base’s modulus to foundation’s modulus.

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Keywords: asphalt pavement; lean concrete base; asphalt surface; transverse contraction joint; load stress; shearing stress

1. Introduction
Nowadays it is a fact that asphalt pavements have been applied frequently and widely to highway in China. However, early distresses in asphalt pavements remain a challenge to pavement engineers in recent years. Because of that, researchers have been doing their best to find the solution to the problem. In a fact, one of the most important reasons that results in early distress in asphalt pavement is more traffic loadings. The study revealed that whether it is early distresses in asphalt pavement or not depends largely on working performance of base. Reference [1,2,3] have shown that lean concrete base, compared with the general semi-rigid base, has better working performance, such as high strength and good eroding resistance. Therefore, the problem of early distresses in asphalt pavements is solved effectively when lean concrete base is used in asphalt pavement.

Road researchers have been taking the intensive and extensive study on load stress for asphalt pavement. In China, based on numerical method, Reference [2] took use of finite element method to study load stress for asphalt pavement with porous concrete base. Reference [3] took use of finite element method to study load stress for composite pavement which includes roller compacted concrete and asphalt concrete. More importantly, diagrams for calculation of shearing stress are put forward when various factors are considered in detail. Based on theory of fracture mechanics, Reference [4] took use of finite element method to make systematic study on the stress of asphalt pavement which includes old cement concrete pavement and asphalt overlay. Lean concrete base, concrete surface and load difference are taken into consideration in Reference [5,6], meanwhile, finite element model which can calculate the stress of concrete pavement, was created, furthermore, the validity and accuracy of the model is proved in the process of applying it to practice. In Reference [7], stress for asphalt pavement with lean concrete base was studied intensively, and calculating model for the stress was put forward. However, the stress state of asphalt surface, which is located in transverse contraction joint of lean concrete base, was not considered in the previous studies. Especially, traffic loading is important parameter used in the analysis of the new pavement design. Therefore, in order to put forward theoretical basis for pavement design method, it is necessary to study the load stress for asphalt pavement with lean concrete base.

2. load stress for lean concrete base

2.1 Finite Element Model

Both lean concrete base and asphalt surface are regarded as elastic layer of finite thickness. Because foundation is regarded as an elastic half space, the larger size of model is taken use of simulating foundation. At the same time, the elastic modulus of the foundation is equivalent value of the sub-base course and the sub-grade.

Based on characteristics of the asphalt pavement of lean concrete base, three-dimension finite element model is created. Model consists of three parts, such as asphalt surface, lean concrete base and foundation. Plane calculating size of lean concrete base is equal to 5.5 meter multiplied by 6 meter. Plane calculated size of asphalt surface is the same as lean concrete base. Length, width and depth of expanding size for foundation are taken as 5.5 meter, 6 meter and 6 meter respectively. In the process of analyzing the stress for the asphalt pavement, single-axle load (100kN) is used. The location of load is in the middle of the model’s length. The grid refinement of the structure for pavement is done in order to meet requirements of the accuracy. At the same time, the appropriate grid gradient is taken as effective methods to guarantee the accuracy. Finite element model for stress of base is shown in Fig. 1.
2.2 Calculation Parameters

When load stress is calculated, the main mechanical parameters for each layer of pavement structure are shown in Table 1.

Table 1 Parameters of calculation for load stress

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Asphalt surface</th>
<th>Lean concrete base</th>
<th>Foundation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elastic modulus (MPa)</td>
<td>1200</td>
<td>10000-14000</td>
<td>40-100</td>
</tr>
<tr>
<td>Poisson's ratio</td>
<td>0.25</td>
<td>0.15</td>
<td>0.30</td>
</tr>
<tr>
<td>Thickness (cm)</td>
<td>0-16</td>
<td>16-30</td>
<td>600</td>
</tr>
</tbody>
</table>

2.3 Analysis for Calculation Results

So far as the asphalt pavement of lean concrete base is concerned, factors, which have the effect on the stress of base, include thickness of surface (h_a), thickness of base (h_c) and ratio of base’s modulus to foundation’s modulus (E_c/E_s). In the following part, the effect of different factors on stress of base is studied one by one.

1) Thickness of asphalt surface
Calculating results of load stress are shown in Fig. 2 when thickness of base is taken from 16 cm to 30 cm. It can be seen from the Fig. 2 that load stress decreases with the increase of thickness of surface.

2) Thickness of base
Calculating results of load stress are shown in Fig. 3 when ratio of base’s modulus to foundation’s modulus is taken from 80 to 200 and thickness of base is taken from 16 cm to 30 cm. It can be seen from the Fig. 3 that load stress decreases with the increase of thickness of base.

3) Ratio of base’s modulus to foundation’s modulus
Calculating results of load stress are shown in Fig. 4 when ratio of base’s modulus to foundation’s modulus is taken from 80 to 300. It can be seen from the Fig. 4 that load stress increases with the increase of ratio of base’s modulus to foundation’s modulus.

4) Load
Calculating results of load stress are shown in Fig. 5 when load is taken from 100kN to 220kN. It can be seen from the Fig. 5 that load stress increases quickly with the increase of load.

3. Load stress for asphalt surface

3.1 Finite Element Model

Based on characteristics of the asphalt pavement, which is located in transverse contraction joint of
lean concrete base, three-dimension finite element model is created. Model consists of three parts, such as asphalt surface, lean concrete base and foundation. Both lean concrete base and asphalt surface are regarded as the elastic layer of finite thickness. Foundation is regarded as an elastic half space, and the larger size of model is taken use of simulating foundation. At the same time, the elastic modulus of the foundation is equivalent value of the sub-base course and the sub-grade. Suppose transverse contraction joint runs through lean concrete base, and width of transverse contraction joint is 0.5 cm, and transverse contraction joint has no load transfer ability. The boundary conditions of three-dimensional finite element model are two points. One is fixed bottom foundation, and the other is using the free surface to simulate the contraction joints. Plane calculating size of lean concrete base is equal to 4.5 meter multiplied by 5 meter. Plane calculated size of asphalt surface is the same as lean concrete base. Length, width and depth of expanding size for foundation are taken as 5.5 meter, 6 meter and 6 meter respectively. In the process of analyzing the stress for the asphalt pavement, single-axle load (100 kN) is used, as shown in Fig. 6 and Fig. 7.

3.2 Calculation Parameters

The main calculating parameters for each layer of asphalt pavement structure are shown in Table 1.

![Figure 6. Calculation plane model](image)

![Figure 7. Calculation diagram](image)

3.3 Analysis for Calculation Results

Calculating results of load stress are shown in Fig. 8 when modulus of asphalt surface is taken from 800 MPa to 2000 MPa. It can be seen from the Fig. 8 that maximum tensile stress (σ) is less than zero when modulus of asphalt surface is taken from 800 MPa to 1600 MPa. Despite it has the tensile stress in asphalt surface, its value is close to zero. It indicates that asphalt surface is in the state of compression. Maximum shearing stress (τ) decreases with the increase of modulus of asphalt.
Calculating results of load stress are shown in Fig. 9 when ratio of base’s modulus to foundation’s modulus is taken from 80 to 300. It can be seen from the Fig. 9 that maximum tensile stress (σ) is less than zero when ratio of base’s modulus to foundation’s modulus is taken from 80 to 300. It is clear that asphalt surface is in the state of compression. Maximum shearing stress (τ) increases with the increase of ratio of base’s modulus to foundation’s modulus.

Calculating results of load stress are shown in Fig. 10 when thickness of asphalt surface is taken from 6cm to 20cm. It can be seen from the Fig. 10 that maximum tensile stress (σ) is less than zero when thickness of asphalt surface is taken from 6cm to 20cm. It shows that asphalt surface is in the state of compression. Maximum shearing stress (τ) decreases with the increase of thickness of asphalt surface.

Calculating results of load stress are shown in Fig. 11 when thickness of base is taken from 16cm to 30cm. It can be seen from the Fig. 11 that maximum tensile stress (σ) is less than zero when thickness of base is taken from 16cm to 30cm. It is clear that asphalt surface is in the state of compression. Maximum shearing stress (τ) decreases with the increase of thickness of base.

All in all, analysis for load stress shows that asphalt surface, which is located in transverse contraction joint of lean concrete base of asphalt pavement, is in the state of compression. Maximum shearing stress, which is caused by load, is evident in asphalt surface which is located in transverse contraction joint of lean concrete base of asphalt pavement.
4. Load stress and pavement design

So far as the asphalt pavement is concerned, no one can deny the fact that traffic loading is an important parameter used in the analysis of the new pavement design. That is to say, stress of asphalt pavement, which is caused by the traffic load, plays a very important role in the design of asphalt pavement. Therefore, it is necessary to study how to make the bridge between the load stress and the asphalt pavement design.

It is generally accepted that asphalt pavement design can be executed as follows: Firstly, the thickness of lean concrete base should be calculated according to load stress, which is obtained from the above results. Secondly, based on load stress, the thickness of the asphalt surface is calculated.

Frankly, it can be seen from the above discussion that the load stress of lean concrete base is in tension, while asphalt surface, which is located in the transverse contraction joint of lean concrete base of asphalt pavement, is in compression. Because of that, the load stress of lean concrete base should be considered mainly and seriously in the design of the thickness of lean concrete base.

In the process of designing the surface, maximum shearing stress for asphalt surface is regarded as the main factor, due to maximum shearing stress, which is caused by load, is evident in asphalt surface which is located in the transverse contraction joint of lean concrete base of asphalt pavement.

5. Conclusion

Based on the characteristics of the asphalt pavement of lean concrete base, a three-dimensional finite element model is created. The model consists of three parts, such as asphalt surface, lean concrete base and foundation.

Analysis of load stress for base shows that load stress of lean concrete base is in tension, and load stress of lean concrete base decreases, decreases and increases with increase of base’s thickness, surface’s thickness and ratio of base’s modulus to foundation’s modulus respectively.

Analysis of load stress for asphalt surface shows that asphalt surface, which is located in the transverse contraction joint of lean concrete base of asphalt pavement, is in compression. Maximum shearing stress, which is caused by load, is evident in asphalt surface which is located in the transverse contraction joint of lean concrete base of asphalt pavement.

So far as the asphalt pavement is concerned, load stress of lean concrete base should be considered mainly and seriously in the design of the thickness of lean concrete base. In the process of designing the surface, maximum shearing stress for asphalt surface is regarded as the main factor, due to maximum shearing stress, which is caused by load, is evident in asphalt surface which is located in the transverse contraction joint of lean concrete base of asphalt pavement.
References


