Calculation and Analysis of Shear Stress Asphalt Mixture Based on X-ray CT Technology and Finite Element Method

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ABSTRACT
In order to calculate and analyze shear stress of asphalt mixture based on three-dimensional microscale, three dimensional numerical model consistent with the actual spatial distribution of mixture was established by using core images of nano-CT scanning and Simpleware image processing software combined with finite element method, aggregate, mortar and void were given corresponding material parameters considering the change of temperature, and the maximum shear stress value were calculated. The results show that the shear stress distribution is not uniform within the three-dimensional numerical samples, most of the shear stress borne by the aggregate; the maximum shear stress value increases with the increase of temperature, which indicates that shear failure occurs more easily under high temperature conditions, and the rationality of the calculation results was verified by the macro-shear strength determination of mixture.

Keywords Road engineering, asphalt mixture, three-dimensional numerical model, maximum shear stress

INTRODUCTION
Pavement is treated as continuous homogeneous system in road design theory at home and abroad, but it is difficult to simulate the stress, deformation and failure process of road material with non continuity characteristics by using the method of continuum mechanics[1-3]. Therefore, some scholars have begun to study the non uniformity of road materials. The CT scanning equipment used in this paper can distinguish the fine aggregate and asphalt mortar (asphalt and
mineral powder), and overcome the inaccuracy caused by the calculation that the mortar and fine aggregate are generally treated as asphalt sand glue. Under the combined action of horizontal load and vertical load, great shear stress occurs on the asphalt pavement[4-5]. When the shear strength of the mixture is insufficient, it is easy to produce the shear failure such as rutting, passing, and supporting[6]. Therefore, nano-CT scanning equipment was used to scan the prepared core samples, then Simpleware software was adopted for image processing of CT image and constructing the mesh model, which was imported into ABAQUS software for shear stress calculating.

1 EXPERIMENT

(1) materials
The gradation of AC-13 asphalt mixture used in this paper is as shown in Table 1. The binder is SK-90# asphalt, aggregate and mineral powder are limestone, and the optimum asphalt aggregate ratio of asphalt mixture is 4.82%[7].

<table>
<thead>
<tr>
<th>Sieve size/mm</th>
<th>16</th>
<th>13.2</th>
<th>9.5</th>
<th>4.75</th>
<th>2.36</th>
<th>1.18</th>
<th>0.6</th>
<th>0.3</th>
<th>0.15</th>
<th>0.075</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passing rate/%</td>
<td>100</td>
<td>93</td>
<td>70</td>
<td>43</td>
<td>30</td>
<td>21</td>
<td>16</td>
<td>11</td>
<td>9</td>
<td>5</td>
</tr>
</tbody>
</table>

(2) specimen making
The specimen maximum size requirements of Nano-CT scanning equipment is stringent[8-9], in order to improve the clarity of the scanned image, standard Marshall specimen was molded firstly, then cylinder core sample (20mm×20mm) was formed by drilling and cutting Marshall specimen for CT scanning test.

The VersaXRM-410 nano CT equipment of University of California Irvine School was used for tomography of asphalt mixture, asphalt mixture internal structure was shown in figure 1.
2 THE THREE-DIMENSIONAL NUMERICAL MODULE RECONSTRUCTION AND
FINITE ELEMENT ANALYSIS OF ASPHALT MIXTURE

(1) The CT images were imported into Simpleware image processing software, in order to
achieve image resolution adjustment, the images were resampled and cropped\cite{10}. Otsu method
was used to distinguish the three components of asphalt mixture. As shown in Figure 2, purple,
green and white areas represent the aggregate, mortar and void, it can be seen from the figure, in
the mixture of three components were distinguished very well.

(2) The core sample is cut by Crop function. At the same time, in order to improve the
accuracy of the calculation results, the cube of 2mm×2mm×2mm were intercepted at different
parts of the core sample and 10 cubes were formed.

(3) The mesh results of each cube were output to form the INP file, and then the INP file is
imported into the ABAQUS software for calculation. In order to study the uneven distribution of
internal stress in asphalt mixture, different material parameters were given to aggregate unit,
asphalt mortar unit and void, in which aggregate modulus is 50000MPa and Poisson's ratio is
0.25.

(4) Uniform displacement load was imposed on the surface in the simulation, the boundary
condition of under surface was \( U_2 = UR_1 = UR_3 = 0 \)\cite{11}.

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3 CALCULATION OF MAXIMUM SHEAR STRESS

3D numerical model reconstruction and finite element calculation of 10 cubes were carried out in accordance with the aforementioned steps, Figure 3 is the three-dimensional graphic model and the maximum shear stress calculation results of a cube, the maximum shear stress value represented by red, green, blue and yellow area decreased gradually.

Figure 3. 3D image and maximum shear stress cloud chart results of Cubic.

Figure 3 shows that the greater shear stress was mainly distributed on the aggregate and the junction part of aggregate and motor, so aggregate plays a major role in the mixture resistance to shear deformation. And studies have shown that the angularity and orientation characteristics of aggregate were important factors of mixture shear performance. Therefore, aggregate structure optimization is very effective way for improving the shear performance of asphalt pavement.

CONCLUSION

The shear stress distribution of internal three-dimensional numerical sample is inhomogeneous, the greater shear stress is mainly distributed on the aggregate and the junction part of aggregate and motor, so aggregate plays a major role in the mixture resistance to shear deformation.

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REFERENCE


