Study on High Temperature Stability of Hot Mix Asphalt Mixture with Low Volume RAP

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Abstract: In this paper, the mix design of hot mix asphalt mixed with low content of RAP by Marshall design method, asphalt mixture is divided into AC-10 and AC-13 two types. From the point of view of the feasibility of incorporating RAP in a hot mix asphalt mixture, the high temperature stability of hot mix asphalt mixture with 15%, 20% and 25% RAP content was studied. It is well known that the asphalt mixture is an extremely complex road material; simply look at the experimental or theoretical analysis, can not draw an accurate conclusion. So, in this paper, through the combination of rutting test results and finite element method, the effects of different content of RAP on the high temperature stability of hot mix asphalt mixture were studied.

Keywords: low content of RAP; hot mix asphalt mixing; finite element; high temperature stability

Introduction

As is well known, asphalt mixture when the typical viscoelastic material, mainly asphalt from the role of cementing material. When the road surface in the high temperature or load, from the cementation of the asphalt will become soft, while the occurrence of flow and deformation, and it is because of the accumulation of this flow and deformation, resulting in rutting, so the asphalt mixture must have good high-temperature anti-rutting. In this paper, we will be in the hot mix asphalt mixture with a certain amount of RAP, the role of road performance is one of the main parameters, we need to verify the relevant aspects and his feasibility study.[1-5] The modulus of the asphalt mixture is inversely proportional to the temperature rise and is deformed as a function of temperature. When there is deformation of more than 2cm, it will produce water drift phenomenon, leading to a car accident. Therefore, the detection of high temperature stability is also extremely necessary. According to "Highway Engineering Asphalt and Asphalt Mixture Test Code" (JTG E20-2011), usually based on the dynamic stability of DS as the evaluation of high temperature stability of asphalt mixture evaluation criteria, this time we mainly carry out 60℃ rut test to obtain the high-temperature stability index.[6-8]

1 High Temperature Stability Analysis of Asphalt Mixtures with Different Content of RAP

1.1 High Temperature Stability Analysis Based on Experiment

According to "Highway Engineering Asphalt and Bituminous Mixture Test Rules" (JTG E20-2011), the asphalt mixture rutting test is suitable for the
determination of asphalt mixture high-temperature anti-rutting ability, for asphalt mixture mix design high temperature stability test. Therefore, from the experimental point of view, through the rut test we measure the high temperature stability of asphalt mixture standards. After the Marshall test and the relevant road performance tests, the optimum asphalt ratio of each group of asphalt mixtures was obtained, and the rutting pieces were made according to the gradation proportion in Table 7. Because compared to the normal rutting test, because in the mixture to add a certain amount of RAP in the course of the experiment is worth noting the following points:

a. In the mixing before the aggregate to the heating work, the same is true for the RAP, but the heating temperature can not be too high, usually set at 120 ℃. Because the temperature is too high, accelerated the asphalt aging in RAP, is not conducive to the experimental results analysis.

b. In the hot mix asphalt mixing process, the best to achieve the temperature of each aggregate homogeneity, and will lead to the formation of the specimen when the internal contraction of uneven voids and cracks. According to the specification, the mixing temperature is set at 170 ℃ and the heating temperature of RAP is 120 ℃. Therefore, in order to achieve such a temperature, it is necessary to set the new aggregate of the heating temperature to be high, set at 185 ℃. Although there is some damage to the new aggregates, the heating temperature of the new aggregates is higher than that of the asphalt in RAP.\[9\textsuperscript{-11}\]

Due to the presence of RAP in the aging of asphalt, but through the above description shows that, through regeneration and reconcile, the aging of asphalt is to achieve the required road performance. Therefore, the real mixture of asphalt ratio is added by the new asphalt and the aging of asphalt. This is also a common phenomenon in our experiments. For the same type of hot mix asphalt, such as AC-13, the hot mix asphalt mixture with RAP has a higher oil-to-aggregate ratio, even when all the new aggregates are the same as the rate of oil-stone mixture without RAP.

In the rutting experiments of AC-10 and AC-13, the following rutting results were obtained for different RAP contents, as shown in Table 1:

<table>
<thead>
<tr>
<th>RAP content</th>
<th>Hot mix asphalt mixture with different gradation</th>
<th>AC-10</th>
<th>AC-13</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td></td>
<td>2937</td>
<td>3367</td>
</tr>
<tr>
<td>15%</td>
<td></td>
<td>3218</td>
<td>3621</td>
</tr>
<tr>
<td>20%</td>
<td></td>
<td>3597</td>
<td>3889</td>
</tr>
</tbody>
</table>
As shown in Figure 1, where shows the x-axis direction of the mix type of mix, in this experiment, only 10 and 13 two parameters, refers to the AC-10 and AC-13 fold Y axis refers to the RAP content, this test, there are 10%, 15% and 20% of the three parameters; z axis refers to the dynamic stability DS (mm / times), the overall dynamic stability of AC-10 is lower than that of AC-13. For the same type of hot mix asphalt mixture, the more the dynamic stability of the mixture is higher.

In summary, the hot mix asphalt mixture with RAP will increase the dynamic stability of the mixture, which improves the high temperature stability of asphalt mixture, and when the RAP content increases, the mixture of high temperature stability is better. This is because the RAP contains a large amount of aged asphalt, according to the aging mechanism, we can see that the soft content of small molecules that reduce the amount of macromolecules that hard content increased, in other words, RAP in the aging of asphalt added to the new asphalt, the viscosity of the asphalt mixture increases. In this case, as the content of RAP increases, the optimum bitumen content of the asphalt mixture decreases, and the temperature sensitivity of the asphalt to the hot recycled asphalt mixture Anti-deformation ability, thereby enhancing the ability of high temperature. From a macroscopic point of view, as the RAP content increases, the asphalt mixture becomes brittle, the overall strength increases, in the range of strength, the asphalt mixture deformation capacity decreases, which also increases the high temperature stability of the mixture.

2 High Temperature Stability Analysis of Finite Element
2.1 Model establishment

We used an asphalt pavement with a 5-ply structure (Table 9) with a total pavement thickness of 69 cm. (10.65cm), the center distance is 3δ (31.95cm), and the width of the model is 3m, and the width of the model is 6m.
### Table 2. Pavement material properties.

<table>
<thead>
<tr>
<th>Structural layer</th>
<th>Material name</th>
<th>thickness (cm)</th>
<th>Elastic Modulus $E$ (Mpa)</th>
<th>Poisson's ratio $\mu$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface layer</td>
<td>AC-13</td>
<td>4</td>
<td>1400/1600/1800</td>
<td>0.35</td>
</tr>
<tr>
<td>The middle layer</td>
<td>AC-10</td>
<td>6</td>
<td>1200</td>
<td>0.3</td>
</tr>
<tr>
<td>The lower layer</td>
<td>ATB</td>
<td>24</td>
<td>1000</td>
<td>0.3</td>
</tr>
<tr>
<td>On the base</td>
<td>GM</td>
<td>15</td>
<td>500</td>
<td>0.35</td>
</tr>
<tr>
<td>Under the base</td>
<td>CTB</td>
<td>20</td>
<td>1500</td>
<td>0.25</td>
</tr>
<tr>
<td>Soil foundation</td>
<td>SG</td>
<td>—</td>
<td>40</td>
<td>0.4</td>
</tr>
</tbody>
</table>

The definition of the parameters as shown in Table 2 is performed for each layer of the above model. According to the above analysis, our team's surface layer of AC-13 model changes, of which 1400Mpa corresponds to 10% RAP, 1600Mpa corresponds to 15% RAP, 1800Mpa corresponds to 20% RAP.

### 2.2 Model analysis

In order to study the different rutting requirements of our experiment, we carry out the corresponding intercepting of the corresponding force cloud, as shown in Fig. 2.
However, due to the relative displacement of the rutting problem, the 3D model is selected as the front view, and for the three different models of RAP, we intercept the corresponding three stress cloud images, as shown in Fig.3.

As shown in the figure, we find that with the increasing content of RAP, the curvature of the upper side of the interface is more gentle, which means that as the RAP content increases, the rut depth will be smaller, Performance will be better. The experimental results of the dynamic stability in the test are also verified. At the same time, we can see from the color of the cloud that with the increasing of RAP content, the area of large stress in the cloud image decreases (reddish) and the area of safety force increases (bluish blue). When only the surface layer of the road surface is changed, the maximum layer bottom stress of each road surface layer is correspondingly reduced. In summary, with the increase of RAP content is conducive to the long-term use of the road and the overall pavement structure safety.

In order to better reflect the stress situation, we are for the surface layer, the base layer and soil-based bottom stress analysis, and for three different RAP content of the structure are drawn force diagram, as shown in Figure 4.
Figure 4. 10%, 15%, 20% of the RAP content of different layers of road surface stress curve.

As shown in the figure, the stress of different layers, with the depth of the changes in the layer, the force tends to be flat, indicating that with the depth of the constant changes in the road vehicle load has been a certain dispersion. And for the stress on the bottom surface of the same surface layer, we can clearly see that with the increasing content of RAP, the trough of tensile stress from one into two, from two to one, but also It is observed that the lateral length of the bottom is increasing, meaning that the more uniform the tensile stress distribution of the surface layers increases with the increase of the RAP content, the longer the service life of the road surface. As can be seen from Table 10, both the maximum tensile stress and the maximum compressive stress decrease as the RAP content increases, and we can also see this with reference to the stress cloud diagram of Fig. 4.
Table 3. The bottom of the surface layer of different RAP content of the extreme stress.

<table>
<thead>
<tr>
<th>RAP content (%)</th>
<th>Maximum stress (kN)</th>
<th>Minimum stress (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>-2.01</td>
<td>-11.30</td>
</tr>
<tr>
<td>15</td>
<td>-1.34</td>
<td>-10.87</td>
</tr>
<tr>
<td>20</td>
<td>1.23</td>
<td>-10.43</td>
</tr>
</tbody>
</table>

With ABAQUS finite element analysis, with the increase of RAP content, both for the rut effect, or the road force point of view, have a great improvement. However, this paper is based on the project test, RAP is relatively simple, not from the perspective of diversification to study. And from the research content, but for high temperature stability of this one, for low temperature, water stability and fatigue performance without a specific study. As mentioned earlier, the addition of RAP hot-plate asphalt mixture to low-temperature, water-stability and anti-fatigue is not entirely new, but from a comprehensive standpoint, we are able to guarantee low temperature, water stability, Fatigue properties based on the RAP content of the study of the role of the road is still very meaningful.

Conclusions

1. In the study of RAP moisture content, we found that it is necessary to carry out large-scale drying work in the relevant hot mix asphalt mixture with RAP to ensure the late mixing of the mixture. Drying time can be controlled at 60h or so.
2. Our recycled RAP material, whether in the aging of asphalt or in their own contained in the coarse aggregate, can meet the performance indicators of hot asphalt.
3. In the low content RAP experiment, we found that when the RAP content is higher, the dynamic stability of the rut is higher, which means that the high temperature stability is superior. The dynamic stability of AC-13 was better than that of AC-10 under the same RAP content. This means that the AC-1313 is superior to AC-1010 in high temperature stability.
4. Experiments show that, with the RAP content increases, the modulus of the specimen will also increase.
5. Combined with ABAQUS three-dimensional cloud diagram, we can see that with the increase of the modulus of the surface layer, it can be intuitively seen that the curve of the road surface is smooth, indicating that the smaller the deformation, indirectly verify the RAP and High temperature performance.
6. It can be seen that the stress change shows a steady trend with the increase of the modulus of the surface layer, depending on the modulus of the surface layer and the bottom stress map of the different layers. It can be seen that with the increase of the modulus, the maximum value of the stress at the bottom decreases. This reflects that under the condition of meeting other road performance, increasing the proportion of RAP can improve the service life of the road better.
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References


