Experimental Study on Interlayer Mechanical Properties of Semi-Rigid Base Asphalt Pavement Using Interlayer Treatment Method

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Abstract: In order to improve the interlaminar mechanical properties of semi-rigid layer and asphalt layer in asphalt pavement, the method of the base surface treated pits was studied and their properties at different temperatures were explored. The experimental results show that at 20 °C, compared with the base surface untreated, the interlayer shear strength of the base surface treated 9 pits of φ20 mm was increased by 27.95%, and the tensile strength was increased by 57.51%. Within a certain range, increasing the diameters of the pits can improve the bonding effect between the layers. In the temperature range of 0 °C-40 °C, the interlayer bonding effect of the base surface treated 9 pits of φ20 mm and spread oil is been better than the other three interlayer treatment methods in the experiment. These results show that the base surface treated the pits can form mortise structure, which can improve the mechanical properties between layers and weaken the negative effect of high temperature on the adhesion between layers.

Keywords. Semi-rigid base asphalt pavement, interlayer treatment, shear strength, tensile strength, temperature.

1. Introduction
In recent years, asphalt pavement occupies a considerable proportion in the pavement structure, accounting for as much as 90% [1-4]. Due to the different characteristics of semi-rigid materials and asphalt materials, it is difficult to ensure complete continuity between the base surface layers. If the layers are not treated properly, slippage and cracking are very easy to occur [5]. King and May performed a force simulation on the asphalt pavement of graded crushed stone base under the contact between different layers. The analysis showed that when the bond strength between layers decreased by 10%, the fatigue life of the pavement will be reduced by 50% [6]. Adopting a suitable interlayer treatment method has a good effect on enhancing the bonding force between pavement layers. Chen et al. concluded that SBS modified asphalt as an adhesive layer material met the shear requirements and improved the adhesion between layers [7]. Laith Tashman et al. added the asphalt pavement under different conditions and found that the interlayer bonding effect was better after milling the original pavement or sprinkling the layer oil [8]. Hui Bing et al. used three control parameters of groove depth, groove width and groove spacing to conduct shear and pull-out tests to study the influence of different groove parameter combinations on the bond strength between rigid-flexible composite specimens [9]. Xie Jun et al. studied the influence of different interface treatment methods and found that the shear
strength and bonding strength of the interface were significantly better than the smooth treatment after the interface was processed by artificial roughening and stone inserting [10].

This paper aims to increase the cohesive force between the base layer and the surface layer of the semi-rigid base asphalt pavement. Starting from the surface treatment of the base layer, mortise structure is formed between the base layer and the surface layer to explore whether the pit treatment can effectively and stably improve the ability of the pavement to resist inter-layer damage.

2. Experiment Method

2.1. Test Material Ratio

The base mixture was selected and sieved according to the aggregate gradation of the suspended compact structure mixture in the "Highway Asphalt Pavement Design Specification" (JTG D50-2006). The ratio of cement stabilized macadam aggregate was (0~5 mm: 5~10 mm) (10~20 mm) =37%: 35%: 28%. The main parameters of ordinary Portland cement used are shown in table 1, the strength grade was 32.5R, and the content was 5%. The gradation of the surface asphalt mixture was designed in accordance with the AC-20 recommended gradation in the "Highway Asphalt Pavement Design Code" (JTG D50-2006). The ratio of the fourth-grade aggregate was (0~2.36 mm): (2.36~4.75 mm): (4.75~9.5 mm): (9.5~19 mm) =33%: 25%: 13%: 29%, 90# asphalt was used, and the asphalt usage was 5%, and the permeable layer oil of HTC-08 type was selected.

Table 1. Performance indicators of cement.

| Setting time/min | Bending Strength/MPa | Compressive strength/MPa | Water requirement of normal consistency/% |
|------------------|----------------------|--------------------------|------------------------------------------|
| Initial set      | Final set            | 3d                       | 28d                                      | 80 |
| 45               | 600                  | 3.5                      | 5.5                                      | 16 |
|                  | 28d                  | 16                       | 32.5                                     | 28 |

2.2. Sample Preparation

Composite cylindrical samples of "semi-rigid base with different diameter pit treatment method and asphalt layer" were used as the test object. The semi-rigid base and asphalt surface were formed by static pressure, and the press used was constant stress pressure using testing machine (model YAW-1000). First, cement stabilized macadam was prepared. Aggregate, water, and cement according to the specified ratio were mixed evenly, then they were poured into a mold with an inner diameter of 150 mm and a height of 230 mm. Finally, they were loaded and compacted gradually until the density reached 98%, and the untreated cement stabilized macadam can be obtained. Second, cement stabilized macadam with the pits was prepared. When pit molds of different diameters were placed on the bottom plate, cement stabilized macadam base with the pits could be obtained according to the steps of preparing cement stabilized macadam samples untreated. Nine pits of φ20 mm uniformly were distributed on the surface of the cement stabilized macadam base. Third, the asphalt pavement samples with untreated and treated the pits were prepared. The base after different treatments was turned over, and the asphalt mixture with temperature of 160 °C would be filled into the mold, and the semi-rigid base asphalt pavement samples were obtained by tamping, loading and health preservation, and the process are shown in figure 1. The JHY-A multi-functional pavement material shear instrument and the combined pull-out instrument of press and reaction frame were used to conduct shear and pull-out tests at 20 °C.
3. Experimental Study on Treatment of Pits
In order to find the optimal pit diameter corresponding to pit treatment within a certain range, three kinds of the pits with the diameter of 10 mm, 15 mm and 20 mm were selected. Nine pits were designed and treated evenly on the surface of cement stabilized macadam base and finally semi-rigid base asphalt pavement were obtained. Six composite samples were prepared for the pits of each diameter. The average values of shear strength and tensile strength after shear and pull failure are shown in figure 2.

When the surface of the base has never been treated, and treated evenly 9 pits of φ10 mm, 9 pits of φ15 mm, and then to 9 pits of φ20 mm, the interlayer shear strength and tensile strength of the samples are continuously increasing. The average shear strength of the samples with 9 pits of φ10 mm increased by 13.97% and the average tensile strength increased by 14.91% compared with the untreated samples. The average shear strength of the samples with 9 pits of φ15 mm increased by 3.89% and the average tensile strength increased by 21.07% compared with the samples with 9 pits of φ10 mm. The average shear strength of the samples with 9 pits of φ20 mm increased by 8.05% and the average tensile strength increased by 13.21% compared with the samples with 9 pits of φ15 mm. Additional, compared with the base untreated, the average interlayer shear strength of the samples with 9 pits of φ20 mm increased from 0.1510 MPa to 0.1932 MPa, increasing by 27.95%, and the average interlayer tensile strength increased from 0.0892 MPa to 0.1405 MPa, increasing by 57.51%.

When the surface of the base was not treated, the interface between the separated base and the asphalt surface layer was relatively smooth. After the pits were treated, the pits on the surface of the base and the asphalt mixture in the pits form a mortise structure. The original single and weak interlayer contact condition was transformed into a combined contact condition of material bonding and structural embedding, which improved the interlayer bonding quality and the pavement's shear resistance. With the increase of the diameter of the pits, the more asphalt mixture was squeezed in the pits, and the stronger the interlayer shear failure resistance and the interlayer tensile strength were formed.
4. The Effect of Temperature on the Treatment Effect between Layers

The above study showed that the combined treatment method of 9 pits of 20 mm and spraying permeable layer was more favorable for interlayer connection. Therefore, when the effect of temperature on the treatment effect between layers was studied, the surfaces of the base were treated 9 pits of 20 mm in temperature gradients of 0 °C, 10 °C, 20 °C and 40 °C. Table 2 shows the average value of shear strength and average tensile strength under each test condition, where A represents the average value of shear strength and B represents the average value of pulling force.

Table 2. Shear strength / tensile strength under different condition (MPa).

| Temperature | Untreated Spray priming oil 9 pits of Φ20mm 9 pits of Φ20mm and spray priming oil |
|-------------|---------------------------------------------------|
|             | A | B | A | B | A | B | A | B |
| 0°C         | 0.3492 | 0.2391 | 0.4693 | 0.3779 | 0.4204 | 0.3074 | 0.5387 | 0.4387 |
| 10°C        | 0.2392 | 0.1592 | 0.3396 | 0.2696 | 0.2909 | 0.2209 | 0.3929 | 0.3229 |
| 20°C        | 0.1510 | 0.0892 | 0.2124 | 0.1643 | 0.1932 | 0.1405 | 0.2629 | 0.1977 |
| 40°C        | 0.0238 | 0.0472 | 0.0373 | 0.0590 | 0.0449 | 0.0736 | 0.0800 | 0.0887 |

The change curve of shear strength of different interlayer treatment methods at 0°C, 10°C, 20°C and 40°C is shown in figure 3(a). It can be seen that the shear strength after four different interlaminar treatments decreases with the increase of temperature. When the temperature rises from 0°C to 40°C, the interlayer shear strength of the base surface untreated was reduced by 93.18%, and the interlayer shear strength of the base surface sprayed with permeable oil was reduced by 92.05%, and the interlayer shear strength of the base surface treated 9 pits of Φ20 mm was reduced by 89.32%, and the interlayer shear strength of the base surface treated 9 pits of Φ20 mm was reduced by 85.15%. It can be seen that high temperature have a very serious negative impact on the interlaminar shear resistance of the pavement. Simultaneously, with the increase of temperature, the interlayer shear strength of the base surface treated 9 pits of Φ20 mm is getting closer and closer to the interlayer shear strength of the method of spreading oil. When the temperature reaches 40°C, the interlayer shear strength of the base surface treated 9 pits of Φ20 mm is 20.38% higher than that of spreading oil. It shows that the base surface treated the pits can not only improve the interlayer shear strength of the pavement, but also effectively reduce the negative impact of the rising temperature on that to a certain extent. The method combined the base surface treated 9 pits of Φ20 mm and spread oil was superiority over the other three methods in the range of 0°C-40°C.

Figure 3. The shear strength/tensile strength change curve.

The tensile strength change curve of different interlayer treatment methods at 0°C, 10°C, 20°C, and
40°C is shown in figure 3(b). It can be seen that the tensile strength between layers decreases with increasing temperature. When the temperature rises from 0°C to 40°C, the interlayer tensile strength of the base surface untreated was reduced by 80.26%, the interlayer tensile strength of the base surface sprayed permeable layer oil was reduced by 84.39%, and that of the base surface treated 9 pits of φ20mm was reduced by 76.06%, and that of the base surface treated 9 pits of φ20mm and sprayed layer oil was reduced by 79.78%. It can be seen that the influence of high temperature on the tensile strength between layers was very serious. When the temperature reaches 40°C, the interlayer tensile strength of the base surface treated 9 pits of φ20mm is 24.75% higher than that spread the oil, showing better high temperature stability. The tensile strength of the base surface treated 9 pits of φ20mm and spread oil layer in the range of 0°C-40°C is significantly higher than that of other three methods, which also shows the combining pit structure and material bonding is an effective interlayer treatment method.

5. Conclusion
In this paper, the method of the base surface treated pits and their properties at different temperatures were studied. The conclusions are as follows:

(1) Within a certain range, with the increase of the diameter of the pit, the shear resistance and the tensile strength between layers is increased gradually. Compared with the base untreated, the average interlay shear strength of the samples with 9 pits of φ20mm increased by 27.95%, and the average interlay tensile strength increased by 57.51%. The results show that, After the pits were treated, the pits on the surface of the base and the asphalt mixture in the pits form a mortise structure, and the stronger the interlayer shear failure resistance and the interlayer tensile strength were formed.

(2) In the temperature range of 0°C~40°C, the interlayer bonding effect of the method of the base surface treated 9 pits of φ20mm and sprayed oil layer is better than that of the other three interlayer treatment methods. These show that a reasonable change of the interlayer contact structure (from smooth plane contact to a tenon structure), coupled with better material bonding, can significantly improve the weak interlayer connection.

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