Mechanical analysis of asphalt stabilized permeable base to inhibit reflective cracking

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Abstract: Asphalt stabilized drainage base has good drainage performance, can effectively rule out the water in pavement structure, reduce the occurrence of water damage, and maintain good pavement performance. Based on the mechanical analysis of the affect of asphalt stabilized permeable base on the inhibition of reflection crack, using the finite element software to simulate the stress characteristics of the asphalt and to do the mechanical analysis of asphalt pavement cracks at the grass-roots level to the pavement after stretching process, by comparing the pavement crack tip stress intensity factor of original pavement structure and set up the ATPB layer, respectively, to study the effect of asphalt stabilized permeable base on inhibition of reflection cracking.

1 Preface
Pavement cracking is one of the main diseases in the process of the use of asphalt pavement, its distribution is relatively common, just crack types and severity are differences between different areas. According to the main reason for the cracking of asphalt pavement, we can divide into two major categories of load type crack and non load type crack. Load type fracture is mainly produced by traffic loads of fatigue cracking, mostly for shear crack; Rather than the non load type fracture is mainly caused by factors such as the temperature crack, main show is open type, and its causes and mechanism of different fracture types are also different.

As the deepening understanding of the cracking of asphalt pavement structure damage, and the further development of research on damage theory in the field of mechanics, the research of cracking of asphalt pavement structure also experienced from empirical summary to theoretical analysis combined with mechanics. With the application of fracture mechanics and fatigue fracture mechanics in engineering, the structure cracking theory of asphalt pavement is constantly update and deepened, and the anti-cracking design method gradually tend to be more reasonable and complete. In this paper, on the basis of fracture mechanics, analyzed the cracking mechanism of asphalt pavement in our country.

2 Design parameters of pavement structure
(1) the original pavement structure
According to the related project, the original structure scheme and design parameters are shown in table 1.
Table 1 The scheme of original pavement structure

| Structural hierarchy | Material type                        | Modulus of elasticity (E) (MP) | Poisson's ratio (µ) | Thickness h (cm) |
|----------------------|--------------------------------------|--------------------------------|---------------------|-----------------|
| The above layer      | AC13 fine grained type asphalt concrete | 1400                           | 0.25                | 4               |
| The middle layer     | AC20 grain type of asphalt concrete   | 1200                           | 0.25                | 6               |
| The following layer  | AC25 coarse type of asphalt concrete  | 1000                           | 0.25                | 8               |
| Above base           | Cement stabilized macadam            | 1500                           | 0.15                | 25              |
| Bottom base          | Cement stabilized macadam            | 1500                           | 0.15                | 25              |
| The subgrade         | soil                                 | 80                             | 0.35                | 600             |

Note: The layer structure design parameters selection specification range of intermediate value

(2) Set ATPB structure
Set 8 cm permeable asphalt stabilized macadam base (ATPB - 25) in the original pavement structure, and appropriately reduce the thickness of the grass-roots level, as shown in table 2.

Table 2 installed ATPB structure scheme

| Structural hierarchy | Material type                        | Modulus of elasticity (E) (MP) | Poisson's ratio (µ) | Thickness h (cm) |
|----------------------|--------------------------------------|--------------------------------|---------------------|-----------------|
| The surface layer    | AC13 fine grained type asphalt concrete | 1400                           | 0.25                | 4               |
| The middle layer     | AC20 grain type of asphalt concrete   | 1200                           | 0.25                | 6               |
| The following layer  | AC25 coarse type of asphalt concrete  | 1000                           | 0.25                | 8               |
| Above base           | ATPB - 25                            | 600                            | 0.25                | 8               |
| Middle base          | Cement stabilized macadam            | 1500                           | 0.15                | 25              |
| Bottom base          | Cement stabilized macadam            | 1500                           | 0.15                | 18              |
| The subgrade         | soil                                 | 80                             | 0.35                | 600             |

Note: The layer structure design parameters selection specification range of intermediate value

3 Finite element model
Pavement structure mechanics properties is complicated due to the existence of crack, so the elastic layered system program have been unable to effectively calculate. The finite element method is one of the most effective method for analyzing the pavement structure mechanical properties.

Considering different depth of crack extension in asphalt layer, using the finite element method to analyze the stress field and displacement field of crack tip, the pavement structure of fracture finite element calculation model is set up, as shown in figure 1, figure 2.
Due to the crack horizontally throughout the semi-rigid base, road tire relative to the location of the crack can be divided into two situations: one is called partial load, which effect on the side of crack; the other is called symmetrical load, which effect on the crack, therefore when modeling separately considered.

Assume that cracks have transverse throughout the semi-rigid base, the width of seam is 0.1mm, the length of pre-existing crack of mixture is set to 1cm and crack development process is in the stage of initiation and crack.

Using ABAQUS finite element software to calculate. Crack tip uses CPS6M six nodes triangular element as singular element, and the CPS6 eight node quadrilateral element is adopted around the grid, the grid as shown in figure 3.

Figure 1 symmetrical load finite element model  Figure 2 antisymmetric loading finite element model

**4 The calculated results of stress intensity factor**

The crack of asphalt pavement is a composite crack of I and II, crack extension must consider the combination of two cracking patterns, the stress intensity factor should be the combination of two kinds of stress intensity factor K I, K II. At present, about the fracture criterion of principles of compound fracture are not unified, in engineering, from the perspective of safety, and refer to the minimum strain energy density factor theory [4], I, II, III mixed crack crack problem using the equivalent intensity factor Ke said.
For I, II compound fracture crack problem, \( K_{III} = 0, K_{I} + K_{II} \).

For cracks in the asphalt layer (including ATPB) extension of different depth, the original test road pavement structure scheme and design change equivalent stress intensity factor of crack tip calculation results as shown in Table 3.

Table 3 pavement structure stress intensity factor, the results (unit: MPa. M^{0.5})

| Test road | The original pavement structure | After setting ATPB pavement structure |
|-----------|----------------------------------|--------------------------------------|
| The load type | Symmetrical load | Partial load | Symmetrical load | Partial load |
| Crack length (mm) | Ke= KI | KI | KII | Ke | Ke= KI | KI | KII | Ke |
| 10 | -0.0672 | -0.07074 | 0.2379 | 0.16716 | 0.0141 | 0.0038 | 0.0993 | 0.1031 |
| 20 | -0.03003 | -0.8054 | 0.2657 | -0.5397 | 0.0003 | -0.0062 | 0.09 | 0.0838 |
| 40 | -0.03167 | -0.1093 | 0.282 | 0.1727 | -0.2087 | 0.0072 | 0.0878 | 0.095 |
| 60 | -0.1088 | -0.1554 | 0.2789 | 0.1235 | 0.0065 | -0.0099 | 0.0549 | 0.045 |
| 70 | -0.1548 | -0.1903 | 0.295 | 0.1047 | 0.0074 | -0.0274 | 0.182 | 0.1546 |
| 80 | -0.1548 | -0.1903 | 0.295 | 0.1047 | 0.0074 | -0.0274 | 0.182 | 0.1546 |
| 90 | -0.1449 | -0.2189 | 0.3414 | 0.1225 | 0.0023 | -0.0854 | 0.232 | 0.1466 |
| 100 | -0.2991 | -0.1479 | 0.3612 | 0.2133 | -0.0317 | -0.1113 | 0.2461 | 0.1348 |
| 120 | -0.4056 | -0.3632 | 0.4064 | 0.0432 | -0.0333 | -0.1644 | 0.2531 | 0.0887 |
| 140 | -0.3456 | -0.3775 | 0.3626 | -0.0149 | -0.1498 | -0.1145 | 0.1452 | 0.0307 |
| 160 | -0.1164 | -0.1323 | 0.1529 | 0.0206 | -0.1566 | -0.1053 | 0.0914 | -0.0139 |
| 180 | -0.1469 | -0.2005 | 0.197 | -0.0035 | -0.1671 | -0.4988 | 0.5711 | 0.0723 |

We can be seen from table 3:

1. Under the faction of symmetrical load, the stress intensity factors KII of original pavement structure and set the ATPB pavement structure are both zero, namely Ke = KI, and after setting drainage asphalt stabilized macadam base, the crack tip stress intensity factor Ke significantly drop when compared to that of the original pavement structure.

2. Under the faction of partial load ,the crack tip stress intensity factor Ke of the original pavement structure and setting the ATPB pavement structure can both use the equation to calculate , namely Ke = K I+ K II. After setting drainage asphalt stabilized macadam base, the crack tip stress intensity
factor Ke is significantly drop when compared to that of the original pavement structure, but when the length of crack is about 80 mm, the stress intensity factor of two type structure are almost equal.

5 Conclusion

1. Using ABAQUS finite element software to establish pavement structure model, to analyze the change rules of the stress intensity factor with the crack length of structure layer with ATPB, and it is concluded that under the same crack length, the crack tip stress intensity factor of the pavement structure with ATPB has significant decline. This suggests that the drainage asphalt stabilized macadam base can effectively reduce the stress concentration of the crack tip, and has the effect on the inhibition of semi-rigid base crack extension to asphalt road surface.

2. In general, the ATPB can significantly diminish the phenomenon of stress concentration in crack tip, and can delay and inhibit the action of the semi-rigid base reflection crack.

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