Semi-rigid Base Asphalt Pavement Crack Identification Based on FWD Detection Technology

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Abstract: In this study, the fracture damage state was determined comprehensively according to the linear shape of the bending curve and the maximum bending value. The bending curve was drawn through the distance between the detection point and the crack and its bending value. This method detects the bending of both sides of the crack within a certain range, and judges the influence range and damage state of the crack according to the bending curve drawn by the distance of the detection point from the crack and its bending value. It solves the problem of inaccurate observation and judgment of the appearance of crack damage state of the existing semi-rigid base asphalt pavement, and provides scientific, accurate and economic basis for the formulation of pavement maintenance and repair program.

Keywords: Semi-rigid Base; Crack; Damage Degree; Deflection Response

1. Introduction

With the gradual advance of the strategy of transportation power, the durability of highway infrastructure has become a basic problem that needs to be solved urgently. Statistics show that 60% of China's expressways are in use for 10 to 12 years, and 17% need to be repaired after 6 to 8 years of use. The service life of asphalt pavement is difficult to reach the design life of 15 years stipulated in China's regulations, and it is far lower than the international design life of 30 to 40 years, and it is less than the "permanent pavement" standard of 50 years.

The reflection cracks of semi-rigid base asphalt pavement have their own temporal and spatial distribution characteristics compared with other cracking forms, which are as follows: transverse cracks appear in large numbers in 0-5 years after opening to traffic; The fracture width changes periodically with the seasons. The developed reflection cracks have the characteristics of penetrating, generally in the transverse through the road width, in the direction of structural depth to the subgrade. The early occurrence and rapid penetration of reflective cracks make the pavement in a dynamic discontinuous state for a long time, and the reflective crack area becomes the weak part of the pavement, which is one of the main reasons for the long-term performance of semi-rigid base asphalt pavement. At the initial stage, the reflection crack has little impact on pavement performance. However, with the intensification of external factors such as load and water entry, the pavement performance in the reflection crack region gradually deteriorates, and interacts with external factors to gradually cause various forms of secondary diseases, such as subsidence, grouting and secondary cracking, etc., thus seriously reducing the driving comfort and structural integrity of the pavement. Resulting in insufficient durability of the road surface.

A large number of semi-rigid base asphalt pavements built in the early period of our country have entered the maintenance, maintenance and improvement period one after another. However, the method of deflection detection with a certain distance is adopted because the pavement structure evaluation method in the current maintenance specification does not agree on the deflection detection position of the damaged section. Pavement cracking is often serious, but the evaluation index of bending is good, so the actual bearing capacity of pavement structure cannot be accurately evaluated. The traditional method uses the crack appearance observation to determine the crack damage state [1-3].

At present, there are two viewpoints to consider the mechanical behavior characteristics of reflective crack field of semi-rigid base asphalt pavement.

First, it is considered that due to the large width of actual pavement cracks, the interlocking effect of cracks can be ignored, but it is necessary to study the influence of structural separation caused by reflection cracks on the pavement stress. Waheed adopts three-dimensional finite element analysis and believes that when the joint width is larger than 0.25mm, the friction coefficient between the crack contact surfaces is not effective, and the crack gap of 0.2mm is the critical value to determine whether there is contact behavior between the crack surfaces [4]. Due to the large width of reflection crack, the load transfer capacity of the crack itself is not considered in the finite element analysis considering the influence of reflection crack on pavement structure. Lin C, Deng Y, Ma L et al. adopted a similar reflective crack simulation method to identify transverse crack types (low-temperature cracks and reflective cracks) based on FWD curved sink basin [5-7].

Second, it is considered that the interlocking effect of pavement material crack field cannot be ignored, and the load transfer capacity of pavement structure reflection crack is affected by many factors. De Bondt et al. measured the horizontal and vertical displacement of the transverse joint of the semi-rigid base asphalt pavement of the A50 expressway in the Netherlands for a long time and found that the crack displacement was highly dependent on the base temperature. The measured results show that the reflective cracks have different load transfer capacities depending on the width of the cracks and the size of the loads. Based on the measured FWD bending basin data, Pu and B analyzed the variation of load transfer capacity of cracks mainly from the horizontal and vertical stiffness of cracks. When the seam width is small (summer), the load transfer capacity of the crack is mainly contributed by the horizontal stiffness; when the seam width is large (winter), the load transfer capacity of the crack is mainly contributed by the vertical friction stiffness [8]. Maria Esther Castillo et al. took semi-rigid base asphalt pavement of Spanish expressways as the research object, selected 8 sections located in hot summer climate with little rain, and focused on the Load Transfer coefficient LT (Load Transfer %) of reflecting crack edges. The daily and annual changes of the Relative Deflection RD (μm/μm) and the Maximum Deflection MD (μm) at the edge and middle of the fracture were observed. The results prove that it is necessary to study the load transfer capacity of reflective fracture region, that is, LT and RD are more effective indexes to evaluate the structural properties of reflective fracture region than MD. For MD, there is a temperature inversion point. When the pavement temperature rises beyond the inversion point, the softening effect of the asphalt mixture on the surface is greater than the contribution of the crack locking ability, and the bending will decrease; otherwise, the bending will increase [9].

It is found that the deflection value of the cracked pavement is equivalent to that of the normal pavement when the deflection detection is carried out at the crack location in engineering. The bending value of some cracks is larger than that of normal pavement, even reaching more than 3 times. This significant response of bending and subsidence provides a clear direction for the determination of fracture damage degree, and further provides data guidance for the implementation of fracture classification and treatment plan [10, 11].

For the pavement where the bending at the crack location is basically the same as the bending at the uncracked location, only the filling treatment is needed. For cracks with large damage degree, the bending at the crack is different from that in the surrounding area, so it is necessary to mill and resurface. The cost difference of different pavement crack treatment methods is more than 10 times. The current method of determining the crack damage state of semi-rigid base asphalt pavement affects the scientific and economic development of pavement maintenance and repair plan. Based on this, this study tested the buckling response at the crack and the position with equal spacing before and after the crack, so as to clarify the buckling response characteristic values of different fracture forms [12, 13].

2. Fracture Damage Degree Test Method

Based on Equidistance Bending Response

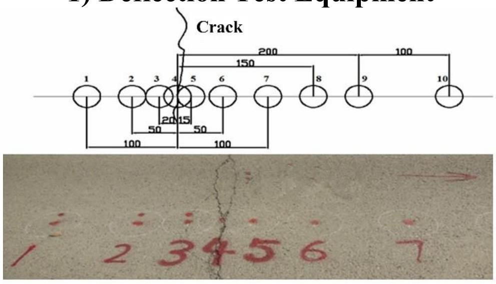
In order to grasp the influence of different types of cracks on the bending index, FWD bending detection was carried out at and around the cracks, as shown in Figure 1. The specific steps are as follows:

(1) Mark points are drawn on the crack and both sides. The first point is the crack mark 4#; Draw the second and third points on both sides 25cm away from the crack, and mark them as 3# and 5# respectively; Draw the fourth and fifth points on both sides 50cm away from the crack, and mark them as 2# and 6# respectively; Draw the sixth and seventh points on both sides of the crack 100cm away, and mark them as 1# and 7# respectively; Marks are 8#, 9#, and 10# at 1.5m, 2m, and 3m away from the crack.

(2) Use the drop hammer bending detector to test the bending value of the response position according to the number from small to large (or from large to small).

(3) Draw the "distance-subsidence" curve, and determine the fracture damage state comprehensively according to the linear shape of the curve and the maximum subsidence value.

1) Deflection Test Equipment



2) The Position of Deflection Test Point is arranged

Figure 1. Schematic Diagram of Crack Deflection Detection Position

3. Study on Bending Response of Typical Semi-rigid Base Asphalt Pavement

Reflection cracks of asphalt pavement with semi-rigid base have existed for a long time in China. Under the complex environment and load coupling, the load transfer capacity of reflective cracks gradually decreases, and secondary diseases develop in the fracture region. Due to the unclear understanding of the internal operating mechanism of the disease mode, the effect of relevant technical measures is not good, resulting in insufficient durability of the pavement. Based on this, the project carried out research on crack refinement identification algorithm and detection and evaluation method based on deflection characteristics, and combined with engineering practice, developed fast and effective detection equipment. This project can provide a new judgment method for the evaluation of the internal state of the semi-rigid base asphalt pavement crack zone, and provide a new technical means for the protection decision of the semi-rigid base asphalt pavement.

3.1 Variation of FWD Test Response with Road Thickness

In the design of pavement structure, the thickness of the structural layer has a significant impact on the bending. In this paper, the pavement bending after being in service for 5 years, the bending after milling the surface layer and the lowest surface bending were tested to study the change rule of the bending response with the pavement thickness. The test results are shown in Figure 2.

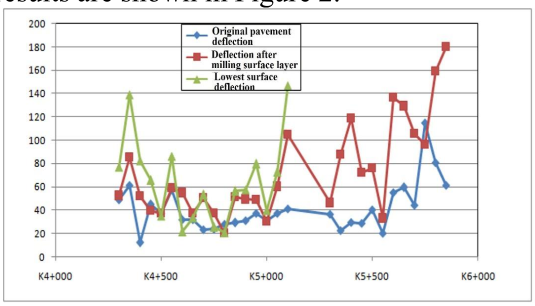


Figure 2. Curve of FWD Test Response with Road Thickness

From Figure 2, it can be seen that after layer milling, the change in base deflection ultimately reflects the change in surface deflection. The thicker the structural layer is laid (especially after the asphalt layer is laid), the smoother the deflection change, and the smaller the deflection value.

3.2 The Influence of Different Test Methods (FWD and PFWD) and Load on Deflection

At present, there are FWD and PFWD test

equipment for drop hammer bending. In order to make clear the influence of the force of test equipment on the bending response, PFWD-200kpa, FWD-700kpa and FWD-800kpa devices are selected in this paper to study the test method and the influence of load on the bending response. The test interval of this section is 5m. The specific results are shown in Figure 3 and Table 1:

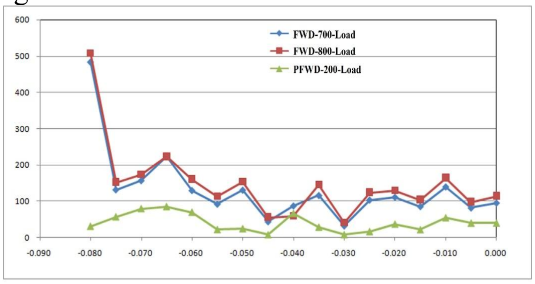


Figure 3. Influence of Test Method and Load on Deflection

Table 1. Bending Changes under Different Loads

Load	Mean deflection(0.01mm)	Deflection variance	Coefficient of variation
FWD-700KPa	132.2	100.2	0.758
FWD-800KPa	148.5	103.4	0.696
PFWD-200KPa	41.1	24.2	0.589

As can be seen from Figure 3 and Table 1, there is little difference between the measured bending values of FWD-707kpa and FWD-848kpa. Due to the small load class, the measured bending values of PFWD are smaller than those of FWD and fluctuate less, but the variation rules of the two are basically the same. The measured bending value of PFWD-200 KPa is one-third of that of FWD-700 KPa, and the variation is basically linear. The variance results show that with the increase of load, the deviation of pavement bending distance will be larger. The coefficient of variation results show that the coefficient of variation of pavement bending is in the range of 0.5~0.8, and the coefficient of variation tends to increase with the increase of bending load. According to the above test results, it can be seen that FWD and PFWD are feasible to judge crack development in pavement based on mechanical response.

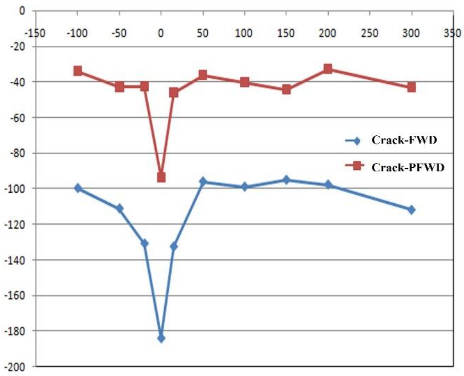
4. Detection of Bending Response of Damaged Semi-rigid Base Asphalt Pavement

The crack is mainly at the transverse joint of the road surface. From the situation of the road surface milling, the transverse joint is mainly caused by the cracking of the semi-rigid base. Common transverse joints of semi-rigid base cracks include single transverse joints and supported transverse joints (or block cracks). In this paper, the bending and subsidence response characteristics are defined by testing the above two types of cracks, as shown in Figure 4 to Figure 6.

4.1 Detection of Bending Response of Asphalt Pavement with Separate Cracks

FWD and hand-held drop hammer bending meter are used to test the pavement bending of individual asphalt cracks, and the bending - distance curve is drawn, as shown in Figure 4:

1) Crack Field Test



2) Distance of Crack and Measuring Points on Both Sides - Bending Curve

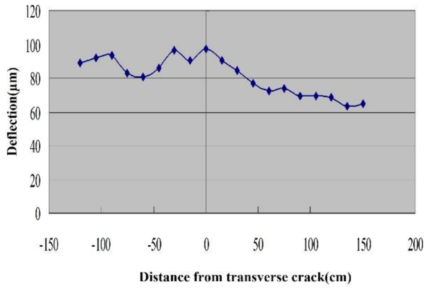
Figure 4. Bending Response of Transverse Crack through Pulp

As shown in Figure 4, FWD has a load of 700KPa and PFWD has a load of 200KPa. At the crack point (point 4#), the bending subsidence is the largest, and the influence range of the transverse joint on the bending subsidence is ±50cm from the joint center.

According to the above analysis of the characteristics of the crack and the bending at both ends, the response law of the crack and the bending at both ends to different loads

(FWD or PFWD) is consistent, and the bending value of the crack increases with the increase of the load. When the loading value is larger, the odd Angle peak is more likely to be generated at the crack position when the crack is shallower.

1) Crack Field Test

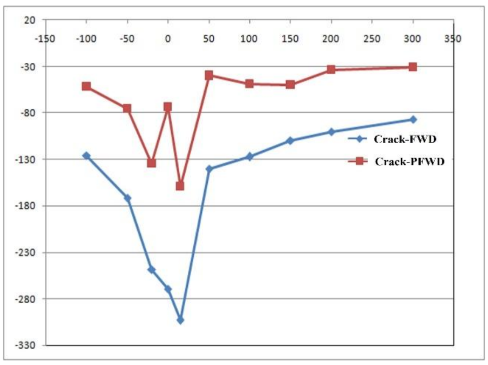


2) Distance of Crack and Measuring Points on Both Sides - Bending Curve

Figure 5. Deflection Response of Shallow Lateral Crack

4.2 Bending Response of Cracks with Supported Joints

FWD and hand-held drop hammer bending meter are used to test the bending of pavement with supported asphalt cracks, and the bending - distance curve is drawn, as shown in Figure 6. At the crack with supported joints, the data of PFWD fluctuated due to the mesh cracks at the transverse joints and the small load of PFWD, but the regularity of FWD was obvious, and the influence range of the crack was within ±75cm.



1) Crack Field Test

2) Distance of Crack and Measuring Points on Both Sides - Bending Curve

Figure 6. Bending Response of the Crack with Supported Joints

5. Conclusions

Combined with the maintenance requirements of semi-rigid base asphalt pavement in China, the non-destructive identification of semi-rigid base asphalt pavement crack based on FWD was carried out through field investigation and physical engineering verification and other technical means. The main conclusions are as follows:

(1) Based on the isometric bending response, the crack damage evaluation method of semi-rigid base layer is used to detect the bending of a certain range on both sides of the crack, and the bending curve drawn according to the distance from the detection point to the crack and its bending value. According to the "distance-bending" curve, the changes of two types of characteristic values (wave crest and wave spacing) with the cracking depth are analyzed. The results show that: There is a good correlation between wave crest and crack width, and the greater the difference, the more serious the fracture damage. The wave spacing has a good correlation with the slope of the fracture, and the internal morphology of the fracture is inclined to the side with small deflection. The crack influence range and damage state are accurately judged.

(2) The affected area of transverse fracture subsidence is about 1m. The center of the crack has the largest bending, and the bending subsidence tends to be stable 50cm away from the symmetry between the left and right of the crack. Therefore, thorough treatment of the crack requires a treatment area of at least 1 meter wide.

(3) The deflection of the penetrating crack with pulping is obviously greater than that without

pulping. Is due to the water into the pavement structure, the impact on the bearing capacity of the pavement structure is very obvious, so we should avoid water infiltration into the crack, should be discharged as soon as possible the water in the crack.

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