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Evaluation Method for Surface Structure Segregation of Asphalt Pavement

Danfeng Hu [1], Bing Hu [1], Hongbo Dong [1], Xuquan Hu [2, 3], Yangyang Wang [2, 3]

[1] Hangzhou Transportation High Level Highway Maintenance Co., Ltd, Hangzhou 310024, China;

[2] Zhejiang Scientific Research Institute of Transport, Hangzhou 310023, China;

[3] Research and Development Center on A New Generation of Artificial Intelligence Technology for Transport Industry Ministry of Transport, Hangzhou 310023, China.

Abstract. In order to evaluate the degree of surface segregation on asphalt pavement, a manually pushed laser texture analyzer (TM2) was used to detect the average structural depth of the pavement surface, and it was proposed to use the average structural depth ratio to evaluate the surface segregation of asphalt pavement. The results indicate that the manual push laser texture analyzer (TM2) has good reproducibility, high testing efficiency, and stable testing results. Compared with traditional evaluation methods, the average construction depth ratio can effectively evaluate the degree of segregation on the surface of asphalt pavement. It is necessary to strengthen the rolling of the edges of the guardrail and the joints of the paver, and minimize the number of times the paver collects the bucket, in order to reduce surface segregation and improve the uniformity of asphalt pavement construction.

Keywords: Road surface segregation; TM2； Average construction depth ratio.

1. Introduction

Traffic safety has always been a challenge faced by countries around the world, and improving the skid resistance of road surfaces can effectively reduce the rate of traffic accidents on rainy days [1,2]. The anti-skid performance of asphalt pavement characterizes the frictional force between the pavement and vehicle tires, and the surface texture of the pavement has a significant impact on the anti-skid performance of the pavement [3,4]. The methods for detecting road surface texture mainly include manual sanding, electric sanding, and laser construction depth gauge detection. The manual sanding method is simple to operate and has low cost, but it is greatly influenced by human factors and has low efficiency [6-8]. The electric sanding method can avoid the disadvantage of large variability in test results caused by human operation differences in the manual sanding method. However, the operation process of this method is more complex than that of the manual sanding method, so its current popularity in China is not high. The laser construction depth gauge detection method has high testing efficiency and stable test results [9-11].

Asphalt pavement segregation has always been a key issue during construction, as it reduces pavement durability and increases maintenance costs [12]. Usually divided into gradation segregation, temperature segregation, and compaction segregation [13]. Among these three, uneven distribution of coarse and fine aggregates has always been the most common. Moderate segregation can shorten the road surface's lifespan by 5 years and increase additional maintenance costs by 30% [14]. Therefore, the uniformity of pavement construction is an important factor in evaluating the quality of asphalt pavement construction. Accurate evaluation of the uniformity of asphalt pavement is beneficial for strengthening construction quality control. Therefore, it is necessary to quickly evaluate the uniformity of asphalt pavement to control the occurrence of early asphalt pavement diseases and extend its service life. The surface segregation of asphalt pavement can to some extent reflect the uniformity of pavement construction. The commonly used methods for evaluating the uniformity of asphalt pavement include visual inspection, sanding, and core drilling [15], but these methods have certain limitations. The visual inspection method is highly subjective and can only qualitatively describe the degree of road surface segregation [16]. The sand laying and

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core drilling methods are slow, and the core drilling method also damages the road surface structure, making it only suitable for small-scale inspections [17]. Therefore, many studies [18-20] have proposed using new non-destructive testing methods to achieve long-distance and wide range testing, which not only improves detection efficiency but also complies with national environmental protection, energy conservation, and emission reduction policies. The laser construction method is easy to operate, has high testing efficiency, stable results, and is more objective and scientific. This study is based on a highway in Zhejiang Province and focuses on the application of the manual push laser texture analyzer (TM2) in evaluating the surface segregation of asphalt pavement. The promotion and application of manual push laser texture analyzer and the quality control of asphalt pavement construction are of great significance.

2. Working Principle and Detection Method

2.1 Working Principle

The laser texture analyzer emits laser pulse signals and then receives reflected light. It uses optical sensors and digital imaging technology to convert the texture contour of the road surface into digital signals, and through computer processing and analysis, obtains the texture parameters of the road surface. The handheld laser texture analyzer (TM2) consists of three wheels, two in the front and one at the back. This design ensures the stability of straight-line driving during the testing process. The left front wheel is equipped with a rotary encoder for testing the distance traveled. The tail wheel is equipped with a foot brake device, which can be freely switched between ON/OFF positions through the brake lever. The vertical distance is measured by a laser located between the two front wheels. The vertical acceleration measurement is carried out through an acceleration sensor installed on the laser. The normal operating temperature range of the instrument is 0-50 ℃. During the measurement of texture, the ground should be dry under ideal conditions.

Figure. 1 Hand push laser texture analyzer (TM2)

Table 1. TM2 Equipment Detection Parameters

parameter	400Hz
Laser sampling frequency	400Hz
Laser sampling length	100mm
Construct depth measurement range	50mm
Construct depth measurement resolution	<0.05mm
Range of walking speed	>10km/h

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2.2 Testing Plan

Based on the characteristics of asphalt pavement construction, three typical locations are selected as inspection positions: 1 meter away from the guardrail edge, in the middle of the first lane, and at the joint position between two pavers. TM2 is used to detect 200 meters along the driving direction at these three locations, with a travel speed of 3.6 km/h. Which can create a road contour measurement strip with a width of 100mm and a length of 200m, and output MPD measurement results every 10m.

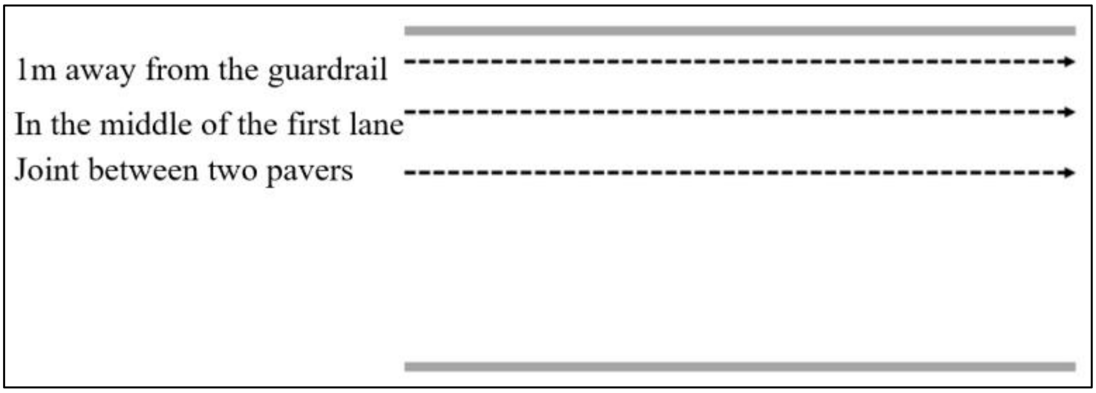

Figure. 2 Schematic diagram of detection scheme

3. Evaluation Method for Pavement Surface Segregation

The surface structure depth of asphalt pavement can be used to evaluate the degree of segregation of asphalt pavement. NCHRP Report441 proposes a method for determining the degree of segregation of asphalt surface layer. This method is used to evaluate segregation by comparing the surface structure depth measured by a laser section meter with the assumed surface structure depth in the non segregated area. The criteria of segregation degree are shown in Table 2.

Table 2. NCHRP Separation Evaluation Criteria

Measurement indicators	No segregation	Mild segregation	Moderate segregation	Serious segregation
Texture ratio	0.75-1.15	1.16-1.56	1.57-2.09	＞2.09

Due to TM2 outputting the average construction depth of the test section every 10m or 50m, this article uses the average construction depth ratio UMPD instead of the construction ratio. Using visual inspection, select a 10m section with good construction uniformity, and use the average structural depth (MPD) of this section as the surface structural depth in the non segregated area.

4. Engineering Application Examples

4.1 Project Overview

Based on a newly built expressway in Zhejiang Province, the pavement structure of the super large bridge is SMA-13 upper layer and SMA-10 lower layer, with thicknesses of 4cm and 6cm respectively. Both the upper and lower layers of coarse aggregate are made of diabase, while fine aggregate is made of limestone. SBS modified asphalt is used for the asphalt. The designed porosity of both is 4.0%. By using a manual laser texture analyzer, the average structural depth of the selected road section is measured according to the experimental plan to evaluate the uniformity of asphalt pavement construction on that section.

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4.2 Reproducibility Analysis of Test Results

To analyze the reproducibility of TM2 detection and ensure the stability of the detection method, a section of SMA-13 road surface was selected for 5 tests on the same road section. The average structural depth and error statistics of the road surface are shown in Table 3. According to Table 3, the maximum relative standard deviation is 2.4%, the minimum is 0.7%, and the average relative standard deviation is 1.4%, indicating that TM2 has good reproducibility. The factors that affect the reproducibility of test results mainly include two aspects: (1) Trajectory error: During the repeated detection process, there is a deviation in the trajectory pushed by TM2, which leads to a deviation in the actual road surface position at the same point, resulting in a deviation in surface texture; (2) Road surface smoothness: TM2 may experience some bumps during driving, and good road surface smoothness has less impact on test results.

Table 3 Statistics of TM2 repeatability testing errors

Pile number		No.1	No.2	No.3	No.4	No.5	Data analysis		
Starting station number	End station number	MTD (mm)	MTD (mm)	MTD (mm)	MTD (mm)	MTD (mm)	average value	standard deviation	Relative standard deviation
K21+800	K21+790	1.28	1.24	1.28	1.27	1.28	1.27	0.017	1.4%
K21+790	K21+780	1.27	1.25	1.25	1.27	1.28	1.26	0.013	1.1%
K21+780	K21+770	1.29	1.26	1.27	1.24	1.29	1.27	0.021	1.7%
K21+770	K21+760	1.23	1.24	1.25	1.25	1.25	1.24	0.009	0.7%
K21+760	K21+750	1.28	1.23	1.28	1.27	1.28	1.27	0.022	1.7%
K21+750	K21+740	1.28	1.25	1.26	1.25	1.27	1.26	0.013	1.0%
K21+740	K21+730	1.3	1.29	1.3	1.29	1.28	1.29	0.008	0.6%
K21+730	K21+720	1.25	1.22	1.27	1.23	1.27	1.25	0.023	1.8%
K21+720	K21+710	1.26	1.25	1.25	1.23	1.27	1.25	0.015	1.2%
K21+710	K21+700	1.28	1.22	1.28	1.23	1.28	1.26	0.030	2.4%

4.3 Evaluation of Pavement Surface Segregation

Firstly, using visual inspection method, select a SMA-13 section with good construction uniformity. The average structural depth (MPD) of this section was measured using TM2 as the surface structural depth of the non segregated area, and the measurement result was 1.18. According to the testing plan in section 1.2, the average structural depth of the tested road section was measured, and the average structural depth ratio was calculated. The results are shown in Table 4. According to Table 4, there are certain differences in uniformity among different detection positions. There is a slight segregation of 20% in the detection section at a distance of 1m from the edge. Due to the influence of edge guardrails, the roller did not compact the edges properly during the rolling process, resulting in a larger surface texture of the asphalt pavement. There is a mild segregation of 5% in the detection section in the middle of the first lane. Upon visual inspection of the segregation location, it was found that there was segregation caused by the paver hopper, resulting in a relatively large average structural depth detected in this section. There is 15% mild segregation in the inspection section of the paver joint position. This is because the temperature of the asphalt mixture at the joint position of the paver is lower than that in the middle of the paver, and the uniformity of the mixture is poor, which makes it difficult to compact the mixture and results in a deeper surface structure. Therefore, it is necessary to strengthen the compaction of the edges of the guardrail and the joints of the paver. In addition, the number of times the paver collects the hopper should be minimized as much as possible to reduce surface segregation and improve the uniformity of asphalt pavement construction.

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Table 4. Average structural depth ratio of the tested road section

Pile number		At a distance of 1m from the edge		The position in the middle of the first lane		The position of the joint of the paver	
Starting station number	End station number	MPD (mm)	Average construction ratio	MPD (mm)	Average construction ratio	MPD (mm)	Average constructio n ratio
K15+480	K15+490	1.32	1.12	1.17	0.99	1.16	0.98
K15+490	K15+500	1.2	1.02	1.17	0.99	1.15	0.97
K15+500	K15+510	1.22	1.03	1.17	0.99	1.19	1.01
K15+510	K15+520	1.53	*1.30*	1.18	1.00	1.18	1.00
K15+520	K15+530	1.21	1.03	1.19	1.01	1.2	1.02
K15+530	K15+540	1.21	1.03	1.18	1.00	1.19	1.01
K15+540	K15+550	1.23	1.04	1.42	*1.20*	1.32	1.12
K15+550	K15+560	1.32	1.12	1.18	1.00	1.17	0.99
K15+560	K15+570	1.32	1.12	1.2	1.02	1.38	*1.17*
K15+570	K15+580	1.22	1.03	1.03	0.87	1.05	0.89
K15+580	K15+590	1.19	1.01	1.16	0.98	1.14	0.97
K15+590	K15+600	1.46	*1.24*	1.12	0.95	1.16	0.98
K15+600	K15+610	1.43	*1.21*	1.2	1.02	1.25	1.06
K15+610	K15+620	1.21	1.03	1.22	1.03	1.39	*1.18*
K15+620	K15+630	1.24	1.05	1.17	0.99	1.18	1.00
K15+630	K15+640	1.41	*1.19*	1.21	1.03	1.2	1.02
K15+640	K15+650	1.27	1.08	1.19	1.01	1.49	*1.26*
K15+650	K15+660	1.23	1.04	1.2	1.02	1.22	1.03
K15+660	K15+670	1.29	1.09	1.21	1.03	1.17	0.99
K15+670	K15+680	1.27	1.08	1.19	1.01	1.18	1.00

5. Conclusion and Discussion

(1) The manual push laser texture analyzer (TM2) has good reproducibility, high testing efficiency, and stable testing results, and can be used to detect the surface texture of asphalt pavement.

(2) The main factors affecting the reproducibility of TM2 detection results are trajectory errors and road surface roughness.

(3) This study overcomes the shortcomings of traditional evaluation methods such as low accuracy and efficiency, and proposes to use the average construction depth ratio to evaluate the surface segregation of asphalt pavement. The engineering application results show that this evaluation index can effectively evaluate the surface segregation of asphalt pavement.

(4) The evaluation results of asphalt pavement surface segregation in three typical locations show that segregation is more likely to occur near the guardrail position, joint position, and paver hopper position. It is necessary to strengthen the rolling of the edges of the guardrail and the joints of the paver, and minimize the number of times the paver collects the bucket, in order to reduce surface segregation and improve the uniformity of asphalt pavement construction.

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