Evaluation of Anti-skid Performance of Asphalt Pavement: Correlation Analysis between Manual Sand Spreading Method and Texture Scanner Method

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Abstract: In the performance system of asphalt pavement, the anti-skid performance plays a crucial role in the driving safety of road users. Aiming at the anti-skid performance of asphalt pavement, this paper conducts a comparative study on the traditional manual sand spreading method and the advanced texture scanner method. The Laser Texture Scanner 9400 device is used to accurately collect the surface macroscopic texture distribution characteristics and structural depth data of asphalt mortar, Stone Mastic Asphalt (SMA), and Asphalt Concrete (AC) mixtures. The research results show that the structural depth of different types of asphalt mixtures is positively correlated with the nominal maximum particle size, and the structural depth of SMA mixtures is better than that of AC mixtures with the same nominal maximum particle size. The results of the surface texture test have the same trend and a good correlation with those of the sand spreading method. Moreover, the texture testing method has smaller data dispersion, which can effectively avoid many disadvantages of the sand spreading method, providing a more reliable basis for the evaluation of the anti-skid performance of asphalt pavement.

Keywords: Asphalt Pavement; Anti-Skid Performance; Manual Sand Spreading Method; Texture Scanner Method; Structural Depth

1. Introduction

Among the numerous performances of asphalt pavement, the anti-skid performance is of vital importance as it directly affects the driving safety of road users. Currently, there are various evaluation methods for the anti-skid performance of asphalt pavement. Among them, the sand spreading method is widely applied in engineering practice due to its advantages such as simple operation and low cost [1,2]. However, this method has several drawbacks, including strong subjectivity, low efficiency, and large data dispersion. Although the surface texture meter method can provide more accurate and comprehensive texture information, it faces problems such as expensive equipment and high requirements for the professional quality of operators. In order to further explore the differences in the surface structural characteristics of different asphalt mixtures, this paper uses the advanced Laser Texture Scanner 9400 device to collect the surface macroscopic texture distribution characteristics and structural depth of asphalt mixtures, and conducts a comparative analysis with the traditional sand spreading method, aiming to provide a more reliable basis for the evaluation of the anti-skid performance of asphalt pavement.

2. Test Methods and Materials

2.1 Manual Sand Spreading Method

The manual sand spreading method is a classic technique for determining the surface texture depth of asphalt pavements and assessing their skid resistance performance. In this paper, the test is conducted on the formed rutting specimens in accordance with T0961-1995 of the "Field Test Procedures for Highway Subgrade and Pavement" (JTG 3450-2019) [3]. Firstly, sweep the test pavement thoroughly to ensure there is no debris. Take a certain quantity of clean, dry standard sand with a particle size conforming to the requirements, fill it into a dedicated measuring cylinder and level it off to measure the specified volume. Pour the sand onto the test point on the pavement, and use a spreading plate to spread it into a circular shape from the inside out, making the sand surface as parallel to the pavement surface as possible [4-6]. Finally, measure the diameter of the sand surface with a steel ruler, take the average value of at least three measurements, and substitute it into the calculation formula for the texture depth to obtain the result.

2.2 Texture Scanner Method

In this paper, the Laser Texture Scanner 9400 device manufactured by AMES Engineering Company (as shown in Figure 1) is employed to carry out the scanning of surface texture characteristics. Its scanning accuracy can reach up to 0.5mm, enabling precise and efficient determination of both microscopic and macroscopic textures. Once the device system is initiated, it can automatically execute the scanning process and then accurately output the texture measurement data. Through the analysis of relevant indices of the surface texture, it is possible to evaluate the skid resistance performance of the pavement, its noise absorption capacity, and the resistance of vehicle wheels and tires[7]. The testing principle of this device is to use a line-scanning laser to scan the pavement surface, calculate key indices such as the Mean Profile Depth (MPD) based on the measured elevation data, and thus achieve a quantitative assessment of the pavement roughness.

Figure 1. Laser Texture Scanner 9400

2.3 Materials

In this paper, limestone and basalt aggregates from Weifang, Shandong Province, and 70# base asphalt produced by Qingdao Refining of Sinopec are selected. The physical and mechanical indexes of the coarse aggregates are shown in Table 1, and the basic performance parameters of the asphalt are shown in Table 2. Referring to the relevant specifications, all the index parameters meet the requirements of the specifications. Seven different gradation types are adopted for the specimens, as shown in Figure 2. The volume indexes of various types of asphalt mixtures are shown in Table 3.

Table 1. Physical and Mechanical Indexes of Part of the Coarse Aggregates

Type of Coarse Aggregate	Limestone	Basalt
Crushing Value (%)	18	16
Resistance to Degradation (%)	2.5	2.1
Los Angeles Abrasion Loss (%)	17.9	16.8
Polished Stone Value	42	44
Adhesion to Asphalt (Grade)	4	4

Table 2. Basic Performance Parameters of Asphalt

Type of Asphalt	Penetration (25°C, 5s, 100g), 0.1mm	Ductility at 10°C, cm	Softening Point (R&B), °C
70# Base Asphalt	72	24	49.0

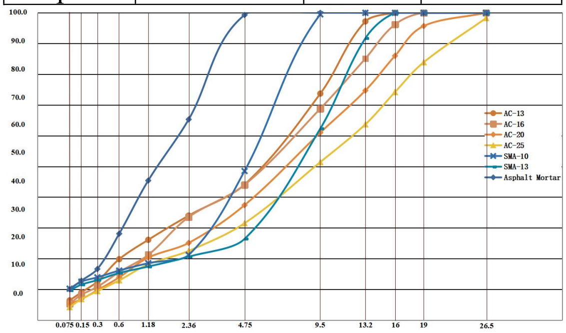


Figure 2. Curves of Seven Different Gradations

3. Sand Spreading Method Test

The test results of the sand spreading method for rutting specimens of various types of asphalt mixtures are shown in Figure 3 and Figure 4.

It can be obtained from Figure 4 that for SMA and AC asphalt mixtures, with the increase of the nominal maximum particle size, their structural depth gradually increases. When the construction uniformity of the structure is guaranteed, the anti-skid performance of the pavement is improved accordingly [8,9]. When SMA and AC asphalt mixtures are used as the middle and lower pavement layers, the greater and more uniform the structural depth is, the higher the bonding strength between the upper structural layers will be. The interface between structural layers is a weak part of the structural layers. The higher the roughness of the underlying layer is, the better the integrity of the structural layers will be, which can effectively prevent water from intruding between the structural layers and enhance the ability to resist water damage and shear failure. Therefore, the roughness and uniformity of the middle and lower pavement layers as well as the base layer are the key points for the control of construction quality.

Table 3. Volume Indicators of Various Types of Asphalt Mixtures

Test Index	Test Results						
	AC-13	AC-16	AC-20	AC-25	SMA-10	SMA-13	Asphalt Mortar
Asphalt Content(%)	5.0	4.7	4.3	4.0	6.3	5.8	6.8
VV (%)	4.3	4.4	4.3	4.4	4.3	4.3	3.7
VMA (%)	14.7	13.8	13.3	12.7	17.6	17.5	18.5
VFA (%)	70.1	68.8	67.0	67.2	76.9	75.3	78.3
Stability(kN)	12.1	13.2	14.1	15.2	9.7	10.8	23.5
Flow Value (mm)	3.3	3.1	2.8	2.6	3.7	3.5	4.9

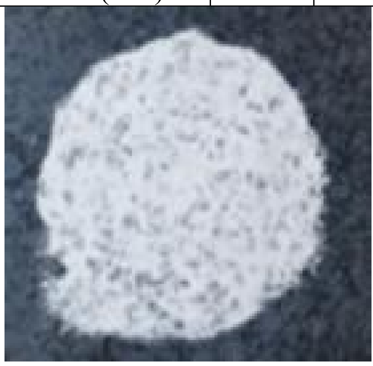


Figure 3. Structural Depth of Different Mixtures

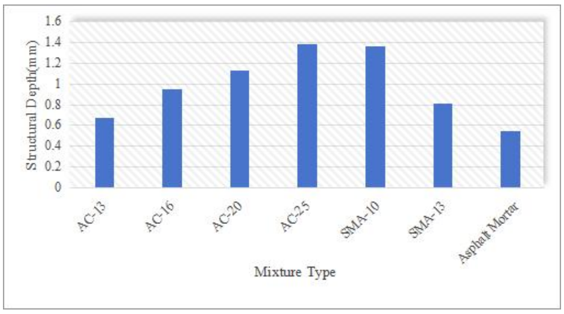
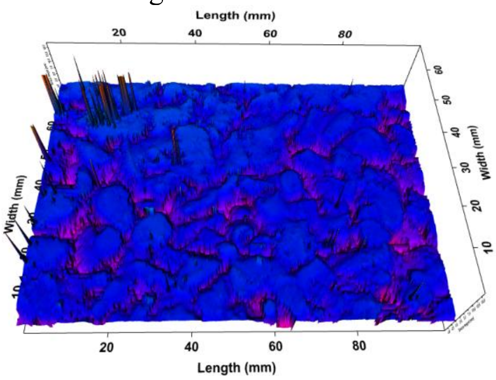


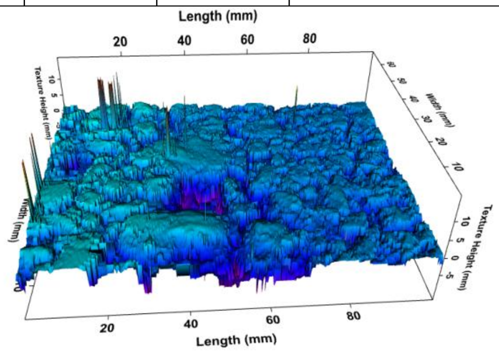
Figure 4. Structural Depth of Different Mixtures

4. Surface Texture Test

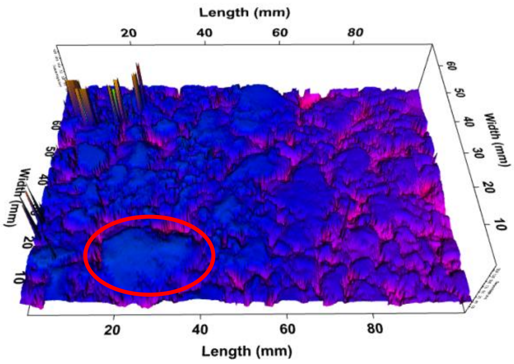
The surface texture collection results of rutting specimens of various types of asphalt mixtures are shown in Figure 5.



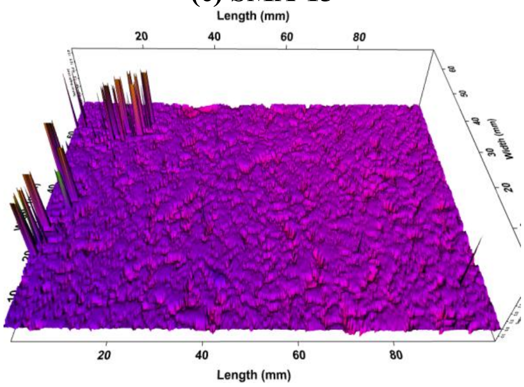
(a) AC-13



(b) AC-25



(c) SMA-13



(d) Asphalt Mortar

Figure 5. Texture Test Results of Different Types of Asphalt Mixtures

After texture scanning, the surface structure distribution of the asphalt mixture is clearly presented. Among them, the surface texture distribution of the asphalt mortar shows good uniformity, while the surface texture of AC-25 has a large degree of dispersion. Studies have shown that the smaller the nominal maximum particle size is, the smaller the gaps between the surface aggregates are, and the more uniform the surface structure distribution is, making it easier to control the construction uniformity of the asphalt mixture. According to construction practice experience, the coarser the particle size of the asphalt mixture is, the more likely it is to segregate during the paving process, and the worse the uniformity is. Therefore, using a texture meter to conduct texture scanning at different positions of the same construction section can more accurately determine the construction uniformity of the asphalt mixture.

Texture scanning shows that obvious "oil spots" often appear on the surface of SMA. This is because SMA belongs to the discontinuous gradation. If the degree of discontinuity of the gradation is unreasonable and the content difference of particles with adjacent particle sizes is too large, it will lead to the discontinuous particle distribution of the mixture[10]. This discontinuous distribution will also make the distribution of asphalt in the mixture lose uniformity, and it is easy to form "oil spots" in the areas where particles of certain particle sizes are concentrated. If there are problems with the mixture ratio and construction process of the mixture, the "oil spots" will develop into large-area "bleeding", reducing the surface structural depth of the asphalt mixture and affecting the durability of the asphalt mixture pavement and driving safety. In addition, the number of compaction passes of the SMA asphalt mixture pavement can be controlled by measuring the structural depth through texture scanning.

5. Correlation between the Sand Spreading Method and the Texture Testing Method

As a new technology for detecting the surface texture and structural depth of physical objects, the texture testing method can effectively avoid the defects of the sand spreading method and has the advantages of rapid and efficient detection and accurate results. However, it has not yet been included in the current specification detection methods. Therefore, this paper conducts a correlation study between the sand spreading method and the texture testing method. The comparison of the structural depth of the two methods is shown in Figure 6.

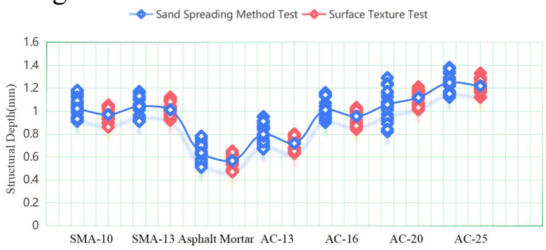


Figure 6. Comparison of Structural Depth and Texture MPD

It can be analyzed from Figure 6 that the SMA asphalt mastic mixture exhibits superior structural depth performance due to its own unique advantages of the mixture gradation structure. Compared with the continuous dense-graded AC-type asphalt mixtures with the same nominal maximum particle size, the structural depth values of the AC-type asphalt mixtures are significantly lower. Moreover, as the nominal maximum particle size increases, the structural depths of both types of asphalt mixtures show a significant upward trend.

By comparing the average values of the results obtained by the two detection techniques for various types of mixtures in the figure, the structural depth measured by the sand spreading method is highly consistent with the variation trend of the average profile depth (MPD) data measured by the texture meter, showing a good correlation. In addition, the manual sand spreading method is easily affected by uncertain factors such as the external environment and operation methods, and the discreteness of its detection data is relatively large; while the MPD detection data obtained based on the surface texture test are relatively concentrated in distribution, and the discreteness is significantly smaller.

6. Conclusions

(1) The structural depth of different types of asphalt mixtures is positively correlated with the nominal maximum particle size. The gradation structure of SMA makes its structural depth superior to that of AC types with the same particle size. Moreover, the roughness and uniformity of the middle and lower pavement layers and the base layer are crucial for the construction quality.

(2) There are differences in the surface texture characteristics of different types of asphalt mixtures. The mixtures with a smaller nominal

maximum particle size have smaller gaps between surface aggregates, a uniform structure distribution, and the construction uniformity is easier to control. The "oil spot" phenomenon on the surface of SMA is closely related to the rationality of the gradation, the mixture ratio of the mixture, and the construction process, which will affect the durability of the pavement and driving safety.

(3) The texture testing method can effectively avoid the deficiencies of the sand spreading method. Although it has not been included in the specifications, it is consistent with the trend of the structural depth results of the sand spreading method and has a good correlation, and the discreteness of the detection data is significantly smaller.

(4) Overall, the texture testing method shows great application potential in the detection of the anti-skid performance of asphalt pavements, providing a new reliable way for the performance evaluation of asphalt pavements. In the future, the feasibility of incorporating it into the specification detection methods should be further studied to promote the development and improvement of the detection technology for asphalt pavements.

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