Abrasion Resistance and Rutting Resistance of Micro-Surfacing with Crumb Rubber of Dry Process

Yali Ye, Yan Hao* and Chuanyi Zhuang

School of Transportation and Civil Engineering, Shandong Jiaotong University.
No.5001 Haitang Rd, University Science and Technology Park, Jinan, Shandong, China
Email: 1084667087@qq.com

Abstract. In order to improve the common micro-surfacing is easy to lose and fall off, and improve the wear-resistance and anti-rutting performance of pavement, this paper uses waste rubber powder as the filler of micro-surfacing mixture, and adopts the method of dry adding. The test of micro-surfacing with crumb rubber of dry process based on APA test was carried out at 40 ℃ without water. Asphalt pavement analyzer shows that the micro-surfacing with crumb rubber of dry process has better wear-resisting and anti-rutting performance.

Keywords. Micro-surfacing with crumb rubber of dry process, wear-resisting, anti-rutting, asphalt pavement analyser.

1. Introduction
Micro-surfacing technology is the main means of pavement preventive maintenance in developed countries in Europe and the United States. It is a thin layer with high skid resistance and durability, which is made by mixing polymer modified emulsified asphalt, coarse and fine aggregate, filler, water and additives into slurry mixture according to the design ratio and spread it on the original pavement [1]. One-hour wet-wheel abrasion test is used to evaluate the abrasion resistance of the micro-surfacing in the existing technical guidelines in China. However, this test method does not fully consider the stress state of the pavement structure at the micro-surfacing, resulting in the disconnection between the evaluation result and the actual road performance. In order to clarify the performance degradation law of micro-surfacing with crumb rubber of dry process under repeated action of vehicle load and environmental coupling, provide technical guidance for the scientific design of waste rubber powder dry micro-surfacing mixture[2]. In view of the drawbacks of wet-wheel abrasion test, this project took APA Hamburg rutting test system as the test platform to evaluate the road performance of the mixture at the micro-surfacing with waste rubber powder, such as abrasion resistance, peeling resistance and rutting resistance, etc., through high temperature environment. Micro-surfacing with crumb rubber of dry process [3-5].

2. Test

2.1. Test Plan
APA asphalt pavement analyzer and rut tester were used to test the composite structure specimen "SMA-13+MS-3" and the composite structure specimen "granite +MS-3" [6].
2.2. Test Conditions
High temperature effect (air bath): In order to compare the performance of micro-surfacing in the high temperature water bath environment, it is proposed that the temperature of air bath rut test is 40℃ [7].

2.3. The Test Results
According to the test plan, mix the dilute slurry mixture and form the test piece. After curing, conduct high-temperature rut test. Make statistics on the development and changes of the rut of the mixture at the micro-table of the two types, as shown in figure 1.

![Hamburg wheel rut curve at 40℃ for air bath.](image)

2.4. Test Analysis
Generally speaking, rut development is divided into three stages: initial compaction, consolidation creep and shear instability. It can be seen from figure 1 that: (1) When the number of load actions is small, the rut deformation rate is large, and the specimen is mainly in the compaction deformation stage, which cannot truly reflect the anti-rut performance of the mixture, so it must have enough times of load actions. However, in the actual paving process, the mixture at the micro-surface does not adopt the roller for rolling, and completely relies on the channelization of vehicles after open traffic [8].

(2) After loading for about 200 times, the rut depth of the mixture at the two micro-surfaces develops slowly, and the mixture enters the creep stability stage. As can be seen from the figure, the rutting development rate of the rubber powder micro-surfacing at this stage is slightly lower than that of the ordinary micro-surfacing. Linear function, logarithm function, binomial function, logarithm function, power function, exponential function and Logistic function were used for curve regression fitting, and it was found that power function had the best fitting property.

| Type at micro-table                        | Prediction model                      |
|-------------------------------------------|---------------------------------------|
| "SMA+ ordinary micro-surfacing" rut change | $y = 0.2052x^{0.3185}$ ($R^2 = 0.9825$) |
| "SMA+ rubber powder micro-surfacing" rut change | $y = 0.0872x^{0.4122}$ ($R^2 = 0.9848$) |
As APA loading steel wheel adhered to more mixing materials at the common micro-surfacing in this test (as shown in figure 2), the common micro-surfacing was adhered to a large amount of mixing materials by the loading wheel, and the actual rut depth was close to the layer thickness at the micro-surfacing, so the test was stopped. After analysis, the proportion of asphalt mixture at the ordinary micro-surfacing during the shaping was the same as that at the micro-surfacing with the addition of waste rubber powder. This resulted in the lateral verification of the conclusion that the asphalt mixture at the micro-surfacing with the addition of waste rubber powder increased by about 1% compared with that at the ordinary micro-surfacing.

![Figure 2. Adhesion of ordinary micro-surfacing by steel wheel.](image)

2.5. Contrast Test
In order to intuitively analyze the influence of waste rubber powder on the mixture at the micro-surfacing, the rut depth of the mixture at the micro-surfacing is compared when the load times are 1000, 2000, 3000, 4000 and 5000, respectively, as shown in figure 3.

![Figure 3. Comparison of rut depth.](image)

The creep rate of rubber powder micro-surfacing and ordinary micro-surfacing can be obtained by high temperature rutting test, as shown in table 2.
Table 2. High temperature rutting test results at the micro-table.

| type                             | Creep rate/times •mm^{-1} | Number of breaks/times |
|----------------------------------|---------------------------|------------------------|
| Ordinary micro-table             | 1532                      | 5000                   |
| Waste rubber powder micro-surfacing | 1585                      | /                      |

Creep rate reflects the deformation rate of asphalt mixture under the coupling action of high temperature, water and load. The larger the value is, the slower the deformation rate is and the better the rutting resistance performance is. It can be seen from table 2 that the creep rate at the micro-surfacing of rubber powder is slightly higher than that at the ordinary micro-surfacing, indicating that its resistance to rutting at high temperature is slightly stronger than that at the ordinary micro-surfacing, but not significant. The difference of high temperature anti-rut performance of the mixture on the micro-surfacing of rubber powder is not obvious by using creep change rate. The difference of creep change rate of the mixture on the micro-surfacing is only 53 times/mm, and the final rut depth differs greatly. Therefore, it can be seen that there are some limitations in using creep change rate to evaluate the anti-rut performance of the mixture on the micro-surfacing [9].

3. Conclusions
(1) Rubber particles have the characteristics of high damping and great elasticity, and the mixture at the micro-surfacing has a good elastic deformation recovery ability. The mixed ruts at the micro-surfacing with the rubber powder dry method are smaller than those at the ordinary micro-surfacing.

(2) Under the condition of repeated wheel load in high temperature environment, shear failure is easy to occur at the micro-surfacing, and the high temperature creep rate at the micro-surfacing of rubber powder is higher than that at the ordinary micro-surfacing, indicating that its high temperature resistance to rutting is better than that at the ordinary micro-surfacing.

(3) A test method based on APA asphalt pavement analyzer for the wear resistance of micro-surfacing is presented. The results show that the wear resistance of micro-surfacing under the action of wheel and grind is improved after the addition of waste rubber powder.

In conclusion, the high temperature effect is one of the reasons that lead to the decrease of the rutting resistance of the mixture at the micro-surfacing.

Acknowledgements:
This paper was financial supported by National Key R&D Program of China (Grant Number: 2018YFB1600100) and Shandong Province Higher Educational Science and Technology Program (Grant No.J18KA209).

References:
[1] Xu X M, Ding L M, Zhou J and Zhuang C Y 2019 Analysis of influencing factors on construction performance of micro-surface slurry mixture Shandong Jiaotong Science and Technology (03) 32-35.
[2] Wang R X, Ye Y L, Jiang Z Y and Guo J K 2017 Influence of fineness of waste rubber powder on mixing performance of dry micro-surface of rubber powder Road Building Machinery and Construction Mechanization 34(06) 58-61.
[3] Yao X G, Zhang Z Q, Luo Y F, et al. 2016 Study on properties and Indexes of Discontinuous gradation Fiber Micrometer Journal of Central South University (Natural Science edition) 47(9) 3264-3272.
[4] Cui W B and Hao P W 2014 Analysis of rut damage on asphalt pavement based on Hamburg rut test Chinese and Foreign Highways 34(1) 95-98.
[5] Li P L, Zhang Z Q, Li H H, et al. 2010 Asphalt mixture Hamburg Rutting test method Journal of
[6] Wang L 2008 Research on Design Method of Permanent Asphalt pavement in Shandong Province Shandong Institute of Transportation Science.

[7] Yao X G, Zhang Z Q and Luo Y F 2016 Study on properties and indexes of discontinuous gradation fiber micrometer Journal of Central South University (Natural Science edition) 47(9) 3264-3272.

[8] Jie X, Zi Y Y, Guang Y and Qing H H 2020 Research on crumb rubber concrete: From a multi-scale review Construction and Building Materials 232 117-282.

[9] Mohajerani A, Burnett L, Smith J V, et al. 2020 Recycling waste rubber tyres in construction materials and associated environmental considerations: A review Resources, Conservation and Recycling 155 104679.