Analysis on Attenuation Law of Skid Resistance Performance of Asphalt Pavement with Thin Overlay

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Abstract. In order to study the attenuation law of skid resistance performance of asphalt pavement with thin overlay, the long-term tracking observation of the scrim force coefficient and the analysis of the attenuation change law were carried out on the asphalt pavement with AC-10 and OGFC-10 thin layer overlay. The volume index, water stability and high temperature stability were tested. The results show that, the attenuation law of the scrim force coefficient of OGFC-10 and AC-10 thin overlay asphalt pavement conforms to the Asymptotic model, showing a trend of rapid decrease first and then stability. It is recommended that “the value of stable scrim force coefficient” and “the time to reach the value of stable scrim force coefficient” should be used as the evaluation index of long-term skid resistance performance of asphalt pavement. The stability value is taken as the first evaluation index of asphalt pavement skid resistance performance, and the time to reach the stability value is the second evaluation index. Considering “the initial scrim force coefficient value”, “the stable scrim force coefficient value”, and “the time to reach the stable scrim force coefficient value”, the skid resistance performance of OGFC-10 thin layer overlay asphalt pavement is better than AC-10 thin layer overlay asphalt pavement.

Key words: road engineering; thin overlay; asphalt pavement; skid resistance; attenuation law.

1. Introduction

With the gradual improvement of expressway construction, the speed of vehicle and the flow of vehicle are increasing, the functional layer of asphalt pavement is often damaged before the structural layer. Among them, the rapid attenuation of anti-skid performance is one of the main manifestations.

In order to meet the requirements of road surface quality, researchers have carried out a series of research work, and put forward to use the form of thin layer cover surface to repair the surface function of road surface, and achieved good results. Xiao Liming et al. [1] made a comparative analysis of the performance of the cement road surface in the test section of the tunnel before and after the pavement covered by the thin overlay, and confirmed that the repair effect of the surface covered by the thin overlay is good. Zhang Zhengliang et al. [2] carried out the application research of ultra-thin abrasion layer (ECA10) relying on solid engineering, and found that the addition of thin overlay can effectively...
improve the smoothness and anti-skid performance of road surface. Li Yunhua et al. [3] carried out research on the application of ultra-thin wear layer (Novachip) in physical engineering, and showed that the anti-skid performance of the road surface after adopting this maintenance measure has been significantly improved.

In recent years, the traffic characteristics of heavy load and large flow become more and more prominent. The anti-skid performance indexes of newly built or paved asphalt pavement with thin overlay can meet the requirements of specifications and design documents at the time of acceptance, but the anti-skid performance of the pavement will rapidly decline within 1~2 years after service [4-5]. Tang Wei et al. [6] used sand laying method and british pendulum number coefficient tester to compare and analyze the skid resistance performance of different thin-layer overlay asphalt mixtures, and recommended the types of thin-layer overlay asphalt mixtures. Wu Han [7] used british pendulum number coefficient tester to compare and analyze the initial skid resistance of SMA-5 and AC-13 thin coated asphalt mixes, but did not study the long-term skid resistance effect. Based on the laboratory accelerated wear test, Qu Tian et al. [8] studied the attenuation law of british pendulum number and structural depth with wear times, and analyzed the long-term skid resistance performance of different thin layer overlay asphalt mixture. Huang Yunyong et al. [9] analyzed the test data of british pendulum number and structural depth under different axle loads, and found that logarithmic function and exponential function can simulate the skid resistance attenuation law in different loading times. Sun Hongli [10] used the Asymptotic model to simulate the british pendulum number and the attenuation of the structural depth of the asphalt mixture during actual use.

The research on the skid resistance performance of thin layer overlay asphalt pavement mainly focuses on the evaluation of the initial performance of pavement. There are also some studies on long-term tracking observation and analysis of skid resistance performance of asphalt pavement. However, there is a lack of observation and analysis of the attenuation law of the scrim force coefficient. In view of this, based on two expressways in Guangdong Province, this paper uses the scrim force coefficient detection vehicle to carry out long-term tracking observations on the asphalt pavement with AC-10 and OGFC-10 thin-layer overlays, and analyze the attenuation changes of skid resistance performance law.

2. Field test scheme

2.1. Gradation of thin overlay

(1) In order to ensure the surface function of pavement, AC-10 thin layer overlay with thickness of 2cm was laid on a highway in Guangdong Province after it was opened to traffic for a period of time. SBS modified asphalt is selected as asphalt for thin layer overlay, and its performance indexes are shown in Table 1. The aggregate is selected from the crushed stone of the Heyuan Zijin Yufeng Quarry, and the ore powder is selected from the limestone ground ore powder. All the physical and chemical indexes are in compliance with the relevant technical specifications. The gradation curve of AC-10 asphalt mixture is shown in Figure 1, and the asphalt aggregate ratio is 6.0%.

| Test Indicators | Penetration (25°C, 100g, 5s)/0.1mm | Ductility (5°C, 5cm/min)/cm | Softening Point / °C |
|-----------------|---------------------------------|-----------------------------|----------------------|
| Measured Values | 67.6                            | >100                        | 70.3                 |
In order to ensure the surface function of pavement, OGFC-10 thin layer overlay with thickness of 2cm was laid on a highway in Guangdong Province after it was opened to traffic for a period of time. High viscosity modified asphalt is selected, and its performance indexes are shown in Table 2. The aggregates of the thin layer are selected from the crushed stones of Heyuan Furong Stone Farm, and the mineral powder is selected from the limestone ground fine mineral powder. The physical and chemical indexes of the aggregate are in line with the requirements of the relevant technical specifications. The gradation curve of OGFC-10 asphalt mixture is shown in Figure 2, and the asphalt aggregate ratio is 5.0%.

Table 2. Main technical indexes of high viscosity modified asphalt

| Test Indicators          | Penetration (25°C, 100g, 5s)/0.1mm | Ductility (5°C, 5cm/min)/cm | Softening Point / °C |
|--------------------------|------------------------------------|-----------------------------|----------------------|
| Measured Values          | 44.2                               | 25.7                        | 91.0                 |

2.2. Observation scheme

(1) Considering the climate characteristics of high temperature and rainy in Guangdong Province, AC-10 and OGFC-10 asphalt mixture samples were formed indoor, and the volume indexes of asphalt mixture was tested, and the water stability and high temperature stability were verified.

(2) An AC-10 thin layer overlay of 2cm was added to the surface of a highway in Guangdong Province. The scrim force coefficient detection vehicle is used to track the lateral force coefficient of the road section before opening (0 months), 12 months, 24 months, 36 months, 48 months, and 60...
months. The attenuation law of skid resistance performance of AC-10 thin layer overlay asphalt pavement is analyzed comprehensively.

(3) An OGFC-10 thin layer overlay of 2cm was added to the surface of a highway in Guangdong Province. The scrim force coefficient detection vehicle is used to track the lateral force coefficient of the road section before opening (0 months), 6 months, 16 months, 22 months, and 29 months. The attenuation law of skid resistance performance of OGFC-10 thin layer overlay asphalt pavement is analyzed comprehensively.

3. Test results and analysis

3.1. Volume index of thin overlay asphalt mixture

The theoretical maximum relative density of asphalt mixture was obtained by calculation method. The bulk specific gravity of AC-10 and OGFC-10 asphalt mixture was measured by surface dry method and volume method respectively. The percent air voids is obtained by calculation. The test and calculation results are shown in Table 3.

| Type of asphalt mixture | AC-10 | OGFC-10 |
|-------------------------|-------|---------|
| Bulk specific gravity   | 2.507 | 2.028   |
| Theoretical maximum specific gravity | 2.634 | 2.704 |
| Percent air voids/%     | 4.8   | 25.0    |

3.2. Water stability of thin overlay asphalt mixture

The water stability of AC-10 and OGFC-10 asphalt mixture is verified by immersion Marshall Test and freeze-thaw splitting test. The test results are shown in Table 4.

| Type of asphalt mixture | AC-10 | OGFC-10 |
|-------------------------|-------|---------|
| Stability of immersion residue/% | 94.9 | 94.7 |
| Freeze-thaw splitting tensile strength ratio/% | 89.1 | 95.2 |

According to table 4:

The residual stability of OGFC-10 and AC-10 asphalt mixture is the same. The freeze-thaw splitting tensile strength ratio of OGFC-10 asphalt mixture is better than that of AC-10 asphalt mixture. They all meet the requirements of the current technical specification for construction of highway asphalt pavements.

3.3. High temperature stability of thin overlay asphalt mixture

The high temperature stability of AC-10 and OGFC-10 asphalt mixture is verified by high temperature rutting test. The test results are shown in Table 5.

| Type of asphalt mixture | AC-10 | OGFC-10 |
|-------------------------|-------|---------|
| Dynamic stability/%     | 6300  | 5857    |

According to table 5:

The high temperature stability performance of AC-10 and OGFC-10 asphalt mixture can meet the requirements of the current technical specification for construction of highway asphalt pavements, and AC-10 is slightly better than OGFC-10.
3.4. Skid resistance performance of thin overlay asphalt pavement

At present, domestic and foreign researchers mainly use logarithmic model, exponential model and Asymptotic model to simulate the variation law of skid resistance attenuation of asphalt concrete pavement [11-12]. After simulation and comparison, it is found that the fitting curve obtained by using the asymptotic model is better. Therefore, this paper adopts the asymptotic model to analyze the attenuation change law of the measured scrim force coefficients of AC-10 and OGFC-10 thin-layer asphalt pavements with different opening times. The Asymptotic model formula is shown in Equation 1. The fitting results are shown in Figure 3 and Figure 4.

\[ y = A + B \times e^{(-x/C)} \]  

(1)

Where, \( y \) is the fitting value of scrim force coefficient of thin-layer asphalt pavement; \( X \) is the opening time; \( A, B \) and \( C \) are the coefficients.

![Fig. 3 Attenuation curve of scrim force coefficient of AC-10 thin layer overlay](image)

![Fig. 4 Attenuation curve of scrim force coefficient of OGFC-10 thin layer overlay](image)

"The initial scrim force coefficient value", "the stable scrim force coefficient value", and "the time to reach the stable scrim force coefficient value" were selected as the evaluation indexes of skid resistance performance of thin overlay asphalt pavement. To facilitate accurate comparative analysis, "the time to reach the stable scrim force coefficient value" refers to the time when the difference between the scrim force coefficient value and the "the stable scrim force coefficient value" is just less than 1 SFC.

The relevant parameters of scrim force coefficient attenuation curve of AC-10 and OGFC-10 thin overlay asphalt pavement are shown in Table 6.
Table 6. Relative parameters of scrim force coefficient attenuation curve

| Type of asphalt mixture | AC-10                        | OGFC-10                       |
|------------------------|------------------------------|-------------------------------|
| Fitting curve          | $y=41.40+17.58\times e^{(-x/7.57)}$ | $y=50.34+20.36\times e^{(-x/9.87)}$ |
| Fitness                | 0.98                         | 0.96                          |
| The initial scrim force coefficient value | 59.0                         | 70.7                          |
| The stable scrim force coefficient value | 41.4                         | 50.3                          |
| The time to reach the stable scrim force coefficient value/months | 21.7                         | 29.7                          |

It can be seen from Figure 3, figure 4 and table 6 that:

1. With the increase of traffic time, the scrim force coefficient of AC-10 and OGFC-10 thin-layer overlay asphalt pavement presents a trend of rapid decline at first and then tends to be stable, which conforms to the asymptotic model, and the fitting degree is not less than 0.96.

2. "The initial scrim force coefficient value" and "the stable scrim force coefficient value" of OGFC-10 thin-layer asphalt pavement are 70.7 and 50.3 respectively. "The initial scrim force coefficient value" and "the stable scrim force coefficient value" of AC-10 thin-layer overlay asphalt pavement are 59.0 and 41.4 respectively. The results show that the skid resistance performance of thin overlay asphalt pavement is quite different between the initial period of opening to traffic and after a period of opening to traffic. The maintenance time of initial skid resistance of asphalt pavement with thin overlay is relatively short. Therefore, "the initial scrim force coefficient value" can not be used to evaluate the skid resistance performance of pavement, and "the stable scrim force coefficient value" should be observed and paid attention to for a long time.

3. "The initial scrim force coefficient value" and "the stable scrim force coefficient value" of OGFC-10 thin overlay asphalt pavement are obviously larger than AC-10, and the differences are about 10 SFC. The results show that the skid resistance of OGFC-10 thin overlay asphalt pavement is better than that of AC-10, which may be related to the porosity index of asphalt mixture.

4. "The time to reach the stable scrim force coefficient value" of OGFC-10 and AC-10 thin overlay asphalt pavement are 29.7 months and 21.7 months respectively. The results show that OGFC-10 thin layer overlay has a longer time to maintain a higher value of scrim force coefficient. The long-term skid resistance performance of OGFC-10 thin layer overlay asphalt pavement is better than AC-10.

Considering the three evaluation indexes of "the initial scrim force coefficient value", "the stable scrim force coefficient value", and "the time to reach the stable scrim force coefficient value", the skid resistance performance of OGFC-10 thin overlay asphalt pavement is better than AC-10. It is suggested that "the stable scrim force coefficient value" and "the time to reach the stable scrim force coefficient value" should be used as the main evaluation indexes of long-term skid resistance performance of asphalt pavement, and "the initial scrim force coefficient value" should be used as a reference index. "The stable scrim force coefficient value" is recommended as the first evaluation index of asphalt pavement skid resistance performance, and "the time to reach the stable scrim force coefficient value" is recommended as the second evaluation index. The larger the stable value and the longer the time to reach the stable value, the better the long-term skid-resistance performance of thin overlay asphalt pavement.

4. Conclusions

1. The scrim force coefficients of OGFC-10 and AC-10 thin overlay asphalt pavement showed a trend of rapid decrease at first and then tended to be stable, which was in line with the Asymptotic model.

2. Considering the three evaluation indexes of "the initial scrim force coefficient value", "the stable scrim force coefficient value", and "the time to reach the stable scrim force coefficient value", the skid resistance performance of OGFC-10 thin overlay asphalt pavement is better than AC-10.

3. The skid resistance of OGFC-10 and AC-10 thin overlay asphalt pavement is significantly different at the beginning of operation and after a period of operation, so it is not possible to evaluate the skid resistance of pavement simply by using "the initial scrim force coefficient value". It is suggested
that “the stable scrim force coefficient value” and “the time to reach the stable scrim force coefficient value” should be used as the main evaluation indexes of long-term skid resistance performance of asphalt pavement. “The stable scrim force coefficient value” is recommended as the first evaluation index of asphalt pavement skid resistance performance, and “the time to reach the stable scrim force coefficient value” is recommended as the second evaluation index.

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