Laboratory evaluation on functional characteristics of open-graded epoxy asphalt mixture

Ke Zhong, Mingzhi Sun*, Xiong Tang
Research Institute of Highway Ministry of Transport, Beijing, China
*Corresponding author’s email address: mz.sun@rioh.cn

Abstract: Epoxy asphalt binder is one kind of thermosetting asphalt binder composed by epoxy resin and asphalt mixed with curing agent in a certain temperature and a certain proportion. Relying on its excellent high temperature stability performance and strength characteristics, in recent years, epoxy asphalt has achieved successful application on many multi-span steel bridge deck pavement projects in China. In order to better grasp the functional characteristics such as drainage, noise reduction and anti-skid performance of open-graded epoxy asphalt mixture, this paper selects the epoxy asphalt as a cementing material to form OGFC4.75 and OGFC13 asphalt mixture. The permeable performance test, the pendulum test, the dynamic friction coefficient test and acoustic absorption coefficient test were applied to research the functional properties of epoxy asphalt mixture, the test results show that the larger size of OGFC gradation mixture has better permeability performance, then permeability performance of PG64 is slightly better than that of epoxy asphalt mixture. The pavement anti-skid performance of epoxy asphalt binder is better than that of PG64 asphalt binder. The acoustic absorption coefficient test shows that the epoxy asphalt can improve the noise reduction performance.

1. Introduction
The epoxy asphalt binder is a thermosetting asphalt binder formed by mixing epoxy resin and petroleum asphalt with curing agent at a certain temperature and mixing ratio. Relying on its excellent high temperature stability performance and strength characteristics, since the successful implementation of Epoxy Asphalt Mixture Pavement in Nanjing No. 2 Yangtze River Bridge in 2000, it has been successively applied to many large-span steel bridge deck pavement projects in China, which has created enormous economic and social benefits [1-3]. The functional properties of asphalt mixtures mainly include skid resistance, smoothness, water permeability, absorption noise, and reflection characteristics[4]. Compared with other road performances, the related results of the study on the functional characteristics of epoxy asphalt mixtures are quite less. In order to study the functional properties of small particle size and large pore drainage epoxy asphalt mixture, epoxy asphalt and PG64-16 asphalt were selected to form mixture in this paper. Through a series of comparative tests, the functional characteristics of the open-graded epoxy asphalt mixture are mainly studied, which can provide certain technical support for the promotion and application of the steel bridge surface epoxy asphalt mixture.
2. Mixture design
In order to study the functional properties of open-graded epoxy asphalt mixture, epoxy asphalt and PG64-16 asphalt binder were used in the test, and the aggregate is made of high quality wear-resistant basalt aggregate. For performance comparison, two types of OGFC open-graded test specimens with nominal maximum diameters of 4.75mm and 13.2mm were used for the test study, the specific grading is shown in Table 1. According to the leakage test, the optimum oil-stone ratio of the four asphalt mixtures composed of two asphalt binders and two gradation types was determined as shown in Table 2.

| Table 1. Two gradation patterns used in the test |
|-----------------------------------------------|
| Nominal maximum aggregate size  | 13.2mm | 4.75mm |
| Aperture size/mm                  | Pass rate/% |
| 16                               | 100     | 100     |
| 13.2                             | 97.5    | 100     |
| 9.5                              | 83.5    | 100     |
| 4.75                             | 32.5    | 91      |
| 2.36                             | 12.5    | 14      |
| 1.18                             | 5       | 12      |
| 0.6                              | 5       | 10      |
| 0.3                              | 4       | 8       |
| 0.15                             | 3       | 7       |
| 0.075                            | 1.5     | 6       |

| Table 2. The optimum oil-stone ratio of the four kinds of asphalt mixtures |
|--------------------------------------------------------------------------|
| Nominal maximum aggregate size  | 13.2mm | 4.75mm |
| Optimum oil-stone ratio (%)      | Epoxy asphalt | PG64-16 | Epoxy asphalt | PG64-16 |
| 5.2                             | 5.9     | 5.5     | 7.9          |

3. Test results and analysis
3.1. Water permeability performance
Flexible Wall Permeameter was used to perform a falling head permeability test on the mixture specimen, which was conducted strictly accordance with ASTM PS 129. The cylindrical test specimens with a diameter of 100 mm and a height of 80 mm were used for the test, and the specimens were formed by rotary compaction method. Prior to the test, the test specimen was placed in water 25 mm above the surface, and vacuum was drawn for 5 minutes under a pressure of 70 kPa, so that the test piece was in a saturated state. Then, the test specimen was placed in a Flexible Wall Permeameter and tested, and the hydraulic head height $h_1$ and $h_2$ at the test start time $t_1$ and the end time $t_2$ were recorded respectively. The permeability coefficient of the test piece can be calculated using Darcy’s law. The formula is shown in eq.1.

$$k = \frac{al}{A \Delta \ln \frac{h_1}{h_2}}$$

In which, $k$ is the permeation coefficient (cm/s), $a$ is the internal sectional area of the hydraulic pressure riser (cm²), $l$ is the thickness of the test piece (cm), $A$ is the area of the test specimen (cm²), and $\Delta t$ is time difference ($t_2 - t_1$).

The test results are shown in Fig 1. The water permeability coefficients of OGFC4.75 and OGFC13 selected in this paper are all higher than 0.16cm/s which indicated that all the open-graded asphalt...
mixtures have good water permeability performance. For the same asphalt binder type, the permeability performance of OGFC13 gradation is slightly better than that of OGFC4.75, the reason maybe that the larger aggregate size can increase the quantity of connected pores in the mixture. For the same gradation, the permeability performance of the mixture with PG64-16 asphalt binder is slightly better than that of the mixture with epoxy asphalt.

![Figure 1. Water permeability performance test results](image)

3.2. Surface characteristics

1) Pendulum friction coefficient test

The friction coefficient of the epoxy asphalt mixture was tested using an English pendulum friction tester. The test was performed in accordance with the procedures of ASTM E 303-93, and the test specimen was a 502 mm×167 mm×76 mm plate specimen formed by the steel roller mill. The test results of the 4 groups of samples are shown in Figure 2.

![Figure 2. Pendulum friction coefficient test results](image)

Firstly, to compare the effect of the binder on the anti-sliping performance. As shown in Fig. 2, the OGFC13 gradation with large particle size shows that epoxy asphalt binder has better anti-friction performance compared with the PG64-16 bituminous binder, but for the small size of the OGFC4.75 grading, it showed the opposite rule.

Then, to analyze the influence of gradation on anti-friction performance. The overall anti-friction performance of OGFC4.75 grading mixture with small particle size is better than that of OGFC13 gradation mixture with large particle size, which indicates that reduction of the maximum nominal size will increase the skid resistance of the pavement, but the increase is not much.

2) Dynamic friction coefficient test

In order to obtain the friction performance of epoxy asphalt concrete pavement under different vehicle load rates, the dynamic friction coefficient of the epoxy asphalt mixture specimen was measured by Dynamic Friction Tester. The test was conducted in accordance with the procedures of ASTM E 1911-98. The test piece was a 502 mm x 167 mm x 76 mm plate specimen formed by the grinding of steel wheels, and three parallel tests were conducted. The test operation process is shown in Figure 3, and the test results are shown in the Figure 4.
As can be seen from Figure 4, the friction coefficient of the asphalt mixture specimen surface is smaller as the speed of the instrument rotating plate increases. It indicates that in the actual pavement, the faster the driving speed is, the smaller the coefficient of friction between the tire and the pavement layer is, and the worse anti-sliding ability will be. Therefore, when the vehicle is running on the asphalt concrete pavement during rain, the speed should be reduced appropriately so as to avoid the occurrence of skidding.

For the same type of gradation, the dynamic friction coefficient provided by the mixture of epoxy asphalt binders is significantly better than that of PG64 asphalt binders, which proves that the epoxy asphalt has strong advantages in providing road surface anti-sliding performance to ensure vehicle safety.

For the same type of binder, the OGFC4.75 of small particle size can provide higher dynamic friction coefficient compared with OGFC13, which is consistent with the conclusion of the pendulum friction coefficient test.

3）Acoustic absorption coefficient test
Large pore asphalt mixture not only has good drainage performance, but also has good noise absorption function. In this paper, according to the ASTM E1050 regulations, the acoustic absorption coefficients of the four large pore asphalt mixtures were tested. Acoustic wave absorption coefficient refers to the proportion of acoustic energy that is absorbed or not reflected when the acoustic wave enters the surface of the material. Early studies have shown that the acoustic absorption coefficient is well correlated with the California vehicular sound intensity (An index reflect tires/pavement noise), and the test results are shown in Figure 5.

It can be seen from Figure 5 that the acoustic absorption coefficient of the OGFC4.75 mixture with PG64 asphalt is lower than that of the other three types of mixture. The acoustic absorption coefficient of OGFC13 mixture using PG64 asphalt is lower than that of epoxy asphalt mixture except the 600Hz and 700Hz frequency. Therefore, it can be concluded that the epoxy asphalt binder is beneficial to improve the noise reduction performance of the mixture. Meanwhile, it is obvious that larger nominal maximum size can achieve better noise reduction effect due to the characteristic of pore structure.

4. Conclusions
1) The large size OGFC gradation mixture has better water permeability, and PG64 mixture has
slightly better water permeability than epoxy asphalt binder.

2) The anti-skid performance of the pavement provided by the epoxy asphalt binder preparation mix is better than the PG64 asphalt binder, and the reduction of nominal maximum size of aggregate can improve the skid resistance of the pavement.

3) The result of acoustic absorption coefficient test shows that the epoxy asphalt binder is beneficial to improve the noise reduction performance of the mixture.

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