Study on the Adhesion Properties of Asphalt-aggregate Interface Based on Pullout Test

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Abstract. The attenuation of adhesion between asphalt and aggregate is the main cause of pavement disease. The research on the interface between asphalt and aggregate is a hot issue to improve the performance of asphalt mixture and the durability of asphalt pavement. In this paper, Haiyun 70#, Haiyun 90# asphalt and limestone, basalt, granite and other aggregates as the research object, using the macro mechanical point of view of the drawing test, through testing the different degrees of aging asphalt and aggregate interface drawing strength, analysis of the interface adhesion properties of the change law, and then for the actual engineering to improve the adhesion of asphalt mixture to provide a reference. The results show that the drawing strength of 70# matrix asphalt and aggregate is greater than that of 90# matrix asphalt; The order of drawing strength of the three aggregates and bitumen is limestone > basalt > granite; Short-term aging can enhance the adhesion to a certain extent, while long-term aging can lead to a decrease in adhesion.

Keywords: Asphalt, aggregate, interface, adhesion, pull-out test

1 Introduction

Asphalt concrete pavement is the main pavement form of highway in China[1]. In its service process, due to the decrease of asphalt aggregate interface adhesion, the service performance of asphalt pavement will be attenuated, which will affect the service life of asphalt pavement to a great extent[2,3]. Asphalt mixture is a kind of complex multiphase composite material, which is composed of three parts: asphalt matrix phase, aggregate and filler component reinforcement phase and the interface phase between them. The interface phase between asphalt and aggregate is the weak point of asphalt mixture which is easy to be destroyed by external force. The lack of interface bond strength can directly lead to the reduction of road service function and life. At present, many scholars at home and abroad have carried out relevant studies on the properties and interface effects of asphalt/aggregate, and have successfully accumulated certain experience. For example, Zheng[4], Xu[5] et al. have studied the interface adhesion behavior of asphalt and aggregate, and believe that the lithology, aging degree and wet state of aggregate all have an impact on its interface adhesion. Yao et al.[6] confirmed the mechanism that the self-healing property of asphalt mixture increases with the

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increase of system temperature; Huang et al.[7] analyzed that the polarity between asphalt and aggregate was the fundamental reason affecting the adhesion, and the simulation results also showed that asphaltene and gum played an important role in the adhesion process. Thermal oxygen aging also significantly affects asphalt properties. After short-term aging, the average surface roughness of asphalt increases, the content of asphaltene components increases, and the polarity of asphalt materials increases, which has a certain effect on the adhesion to aggregates. However, with the extension of aging time, asphaltene flocculates and no longer plays a role, most of the bee structure disappears, and the surface roughness of asphalt decreases. At this time, the adhesive properties of asphalt/aggregate decreased significantly [8,9]. On the basis of the above research, this paper takes the asphalt-aggregate interface as the research object, adopts the macro-mechanical drawing test, and uses the drawing strength index between asphalt and aggregate to characterize the adhesion property between asphalt and aggregate, and further explores the interface behavior law between different asphalt and aggregate.

2 Raw material preparation

2.1 Asphalt

Haiyun 70# and Haiyun 90# asphalt produced by Jingbo Petrochemical in Shandong were selected as the asphalt source for the test. The basic properties are shown in Table 1.

Table 1. Basic properties of Haiyun 70# and 90# asphalt

Type	Needle penetration 25 ℃/0.1mm	Softening point / ℃	extension 15℃ /cm	dynamic viscosity 60℃
70# Haiyun	62	50.0	> 100	232.3
90# HaiYun	83	46.8	> 100	180.2
Technical requirements (70#)	60 ~ 80	P 46	P 100	P 180
Technical requirements (90#)	80 ~ 100	P 45	P 100	P 160
Test method	T0604	T0606	T0605	T0620

Note: The test refer to "Test Regulations for Asphalt and Asphalt Mixture of Highway Engineering" (JTG E20-2011).

2.2 Aggregate

The aggregate selected limestone, basalt and granite, are obtained from Lingshou County mineral products processing plant, Shijiazhuang, Hebei. XRF analysis was carried out on the mineral powder samples[10]. The main compounds and content results are shown in Table 2. It can be judged that granite is acidic aggregate, basalt is neutral aggregate and limestone is alkaline aggregate.

Table 2. Main oxides and their contents of different aggregates

Mineral Type	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5
Limestone	6.79	0.01	1.34	0.51	0.33	8.93	39.49	< 0.01	0.08	0.01
Basalt	52.77	2.98	13.98	10.26	0.12	6.12	7.53	2.23	1.94	0.53
Granite	67.16	0.89	14.20	2.10	0.61	0.98	2.16	6.30	4.35	0.04

2.3 Aged asphalt preparation

Through indoor simulation method to simulate the aging of asphalt in the natural environment, mainly divided into two stages, one is to rotate the film oven to simulate the aging of asphalt heating and mixing process (short-term aging); The second is PAV pressure aging test to simulate the thermal oxygen aging (long-term aging) during the use of asphalt pavement, the specific test plan is shown in Table 3, Figure 1, Figure 2.

Table 3. Aging test scheme

Types	Specific test conditions
Rotary film oven test	The temperature was 163°C ± 0.5°C and the time was 85min
PAV pressure aging test	Temperature 105°C, 2.1MPa ± 0.1MPa compressed air, time 20h

Fig. 1. Rotating film oven and aging bottle.

Fig. 2. PAV aging test chamber and asphalt sample after PAV aging.

2.4 Drawing specimen preparation

In all kinds of aggregate plate rubber ring (inner diameter 20mm, outer diameter 25mm) placed in different quality of asphalt to control the thickness of asphalt film; The original asphalt and different degrees of aging asphalt are placed in the oven at 135℃ and 160℃ for 45 minutes, to determine that the asphalt is in a flow state, and then the drawing head is placed in the rubber ring. The drawing specimen should be placed in the normal temperature environment for 26 hours, as shown in Figure 3.

a) Limestone b) Basalt c) Granite

Fig. 3. Preparation of drawing specimen.

3 Test and result analysis

3.1 Test instrument

The United States automatic digital display pull-out adhesion tester is selected as the test instrument, as shown in Figure 4. The drawing speed is 0.7MPa/s, and the thickness of asphalt film is 0.2mm,0.4mm, 0.6mm, 0.8mm. The test condition was dry health.

Fig. 4. Posi Test AT-A automatic digital display puller.

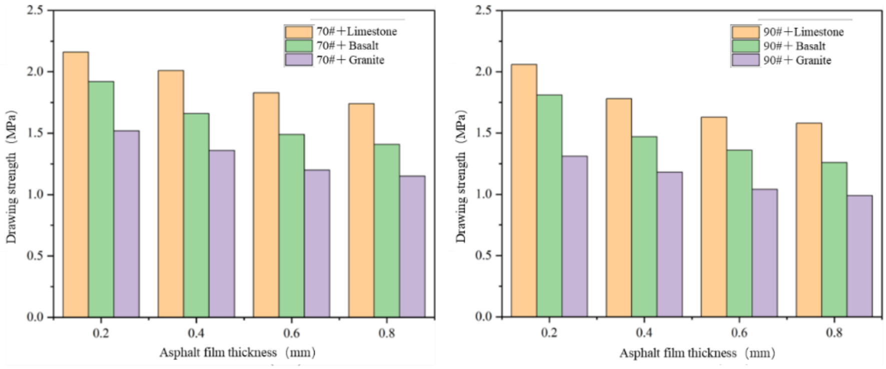
3.2 Test method

Use the drawing tester to test the strength of the specimen after the health, record the maximum strength value when the drawing head and the aggregate surface desorbed as the test result, each group of specimens take three groups of repeatability test to take the average value of the results, to ensure the accuracy of the test data.

3.3 Analysis of results

3.3.1 Influence of asphalt type on drawing strength of adhesion interface.

Drawing tests were carried out with 70# and 90# original asphalt and three different aggregates (limestone, basalt and granite) respectively, and the results were shown in Figure 5.



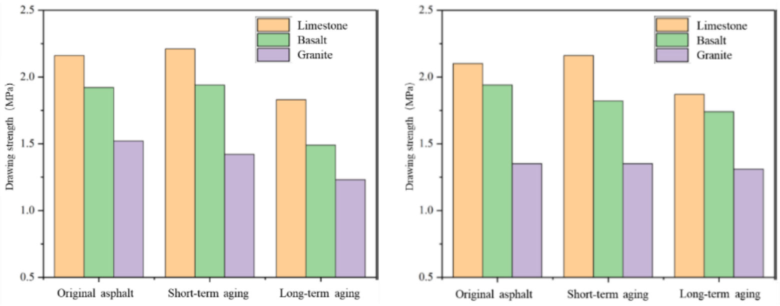
a) 70# asphalt b)90# asphalt

Fig. 5. Drawing strength of original asphalt and aggregate.

The results show that the drawing strength of 70# original asphalt ranges from 2.16MPa-1.15MPa, and that of 90# original asphalt ranges from 2.06MPa-0.99MPa. With the increase of asphalt film thickness, the drawing strength of asphalt/aggregate interface decreases gradually. The drawing strength between 70# original asphalt and aggregate is better than that between 90# original asphalt.

3.3.2 Influence of asphalt aging degree on drawing strength of adhesive interface.

Drawing tests were carried out between 70# and 90# asphalt with different aging degrees and three aggregates, and the results were shown in Figure 6.



a) 70# asphalt b)90# asphalt

Fig. 6. Comparison of drawing strength of original asphalt, short-term aging and long-term aging asphalt.

The results show that:

- After short-term aging, the drawing strength between the two kinds of asphalt and aggregate is greater than that of the unaged asphalt, that is, short-term aging increases the adhesion between the asphalt and aggregate.
- The adhesion effect between asphalt and aggregate decreases after long-term aging. The reason is that under the action of long-term aging, the asphalt is subjected to the combined action of heat and oxygen, which not only shows the change of component content, but also the molecular structure of the original asphalt is forced to deteriorate, the hardness of asphalt increases, the proportion of viscous components decreases, the proportion of elastic components increases, and the strain decreases under the same stress. And the adhesion effect between the aggregate becomes worse.

3.3.3 Influence of aggregate category on drawing strength of adhesion interface. The drawing test of 3 aggregates with different degrees of aging asphalt was carried out to analyze the characteristics of interface adhesion. Among them, the aggregate types under the thickness of 200μm asphalt film affect the drawing strength between asphalt and aggregate, as shown in Figure 7.

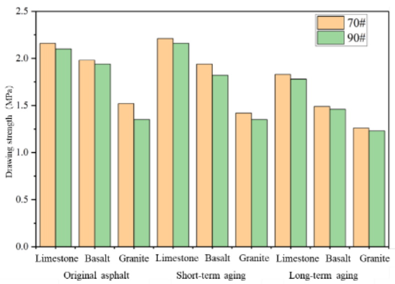


Fig. 7. Drawing strength between different kinds of aggregates and asphalt under 200μm asphalt film thickness.

The results show that the variation of drawing strength between the three aggregates and different kinds of asphalt is consistent, and the order of drawing strength is limestone > basalt > granite. Combined with the chemical composition results in Table 2, it can be seen that the absorption capacity of acid aggregate granite for light components is not as good as that of alkaline aggregate limestone and basalt. In the adhesion process with asphalt, weak points are easy to occur, resulting in the worst interface adhesion effect. It can be seen that the aggregate type has a significant influence on the drawing strength.

4 Conclusions

(1) The drawing test of bitumen aggregate interface with thickness of 200μm, 400μm, 600μm and 800μm shows that the drawing strength decreases with the increase of asphalt film thickness. At the same time, different types of asphalt, its interface drawing strength is different, 70# original asphalt drawing strength is greater than 90# original asphalt drawing strength results.

(2) The drawing strength between asphalt and aggregate increases under the action of short-term aging, and decreases with the deepening of aging.

(3) The type of aggregate has a significant influence on the drawing strength. The adhesion effect of alkaline aggregate and asphalt is generally stronger than that of acidic aggregate. The variation law of drawing strength between the three aggregates used in this paper and different kinds of asphalt is consistent, and the order of drawing strength is: limestone > basalt > granite.

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