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Impact of particle morphology on aggregate-asphalt interface behavior

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HIGHLIGHTS

- The interfacial adhesion behavior of asphalt-aggregate by surface microtopography comparison.
- The texture complexity degree on the limestone and granite surface decreased after abrasion.
- The surface texture change of limestone was more significant than granite.
- The asphalt could permeate into the surface of limestone but granite to form embedded structure.

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ABSTRACT

This paper researched interfacial adhesion behavior between asphalt with limestone and granite through surface microtopography comparison. Abrasion was conducted to limestone and granite by Los Angeles Abrader. Angularity coefficient was used to analyze the angularity and roughness changes of limestone and granite before and after abrasion. Digital imaging technique was used to study the macroscopic changes on the particle surface of limestone and granite before and after abrasion. Scanning electron microscope was used to characterize the changes of surface microtopography of limestone and granite before and after abrasion and the interfacial morphology with asphalt binder. The result showed that the texture complexity degree on the particle surface of limestone and granite decreased after abrasion, the relative flat site of surface increased, and the surface texture change of limestone was more significant. The test result of scanning electron microscope showed that asphalt could permeate into the surface texture of particles of limestone longitudinally after limestone was mixed with asphalt to form embedded structure, but there was a single surface adhesion in the interface between granite and asphalt that an embedded structure was not formed.

1. Introduction

Asphalt pavements are widely used due to its excellent road performance, running safety and comfortable ability. However, the increasing number of pavement distresses is commonly observed in times of operation of inchoate asphalt pavements [1–3]. The water-induced distress is one of the primary diseases of asphalt pavement, which mainly involved the shortage of adhesion of asphalt and aggregate [4,5]. Therefore, an urgently needed solution is to prove the interface adhesion behaviors between asphalt and aggregate. Asphalt mixture is constituted by asphalt which is used as a cementing material and covered with a certain gradation of aggregate, of which the performance depends on the strength of aggregate, asphalt and asphalt-aggregate interphase [6]. However, the damage of asphalt mixture is very easy to occur on the interface region of asphalt-aggregate. Therefore, the interfacial strength has direct bearing on the overall performance of mixture [7,8]. It's considered by interface theories that the texture structure of aggregate particle surface has some absorption effect on asphalt. Asphalt can form a certain depth of penetration on the surface of aggregate to further form interphase structure [9,10]. Therefore, the surface morphology of aggregate particle has a significant impact on the adhesion property with asphalt [11].

The occurrence of stripped damage on the surface and interface of aggregate was verified by Podoll [12]. Pei had preliminary investigation on the asphalt-aggregate interphase by some physical and chemical analysis methods [13]. Yan verified that asphalt-aggregate system damage occurred in the interface [14]. Huang also carried out a lot of studies about the adhesivity between acidic aggregate and asphalt [15]. But there were mainly focused on the adhesion influencing factors between aggregate and asphalt. Zhang

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researched to improve mixture water stability, and impact of mixture gradation design on the performance [16]. However, from the particle morphology of composite interphase, the studies on the adhesion mechanism of neutral, basic and acidic aggregates and asphalt are fewer. On the basis of interface theory of composite materialogy, the advanced characterization method of materialogy was used in this paper to analyze the characteristics of the surface morphology of different lithological aggregate particles macroscopically, microcosmically, qualitatively and quantitatively, by which the relationships between different lithological aggregate particle surface morphologies and asphalt-aggregate interphase strength were studied [17,18]. The action of aggregate morphology in the adhesion process of asphalt with aggregate was reflected from a physical perspective. In addition, significant theoretical foundation was provided to further reveal the adhesion mechanism of asphalt and aggregate.

2. Experimental

2.1. Materials

The technical indices of SK-70# base asphalt are as shown in Table 1, and which of granite and limestone in the size of 9.5–13.2 mm are shown as Tables 2 and 3.

2.2. Los Angeles abrasion test

Los Angeles Abrader was used to abrade the particle surface of aggregate. 2.50 kg of Limestone and granite in the particle size of 9.5–13.2 mm weighed respectively to clean and dry with the mass constant. Furthermore, the coarse aggregate abrasion test with Los Angeles method was operated based on Highway Engineering Aggregate Test Regulation (JTG E42-2005). In order to avoid that the aggregate would be smashed by steel balls in the abrasion process, steel balls should not be put in this abrasion test.

The aggregate to abrade was divided into 5 categories according to the number of times of abrasion, which were A limestone aggregate for 2 time of abrasion, B limestone aggregate for 1000 times of abrasion, C limestone aggregate for 2000 times of abrasion, D granite aggregate for 0 time of abrasion, E granite aggregate for 1000 times of abrasion. See Table 4 for the specific aggregate preparation and dosage.

2.3. ASTM D3398 aggregate particle shape evaluation method

Angularity coefficient was used to have quantitative characterization on the angularity and roughness of aggregate particle, which was ASTM D3398 aggregate particle shape evaluation method [19,20]. An appropriate amount of all the types of aggregates was taken from Table 1 to measure the bulk density ρ (g/cm^3) of those aggregate particles, and then each type of aggregate particle was put into cylinder container (know volume (cm^3) and mass). Two load modes were used, of which the first was mode to fill up the container with aggregate particle in three layers. After each layer was loaded, tamping rod was used to insert and smash for 10 times evenly for each layer. When the three layers of aggregate particle caught the margin of container, the mass of aggregate particle and container was weighed to obtain the aggregate particle mass filled in the contained, which was marked as m_{10} (g). The second mode was also to fill up the container in three layers. After each layer was loaded, tamping rod was used to insert and smash for 10 times evenly for each layer, and other procedures were the same. Finally, the aggregate particle mass filled in the container by this method was weighed, which was marked as m_{50} (g). The voidages of q_{10} (%) and q_{50} (%) for each type of aggregate particle loaded in each layer of the container to insert and smash for 10 times and 50 times were calculated according to formula (1) and (2).

$$q_{10} = \left[1 - \frac{m_{10}}{\rho V}\right] \times 100 \quad (1)$$

$$q_{50} = \left[1 - \frac{m_{50}}{\rho V}\right] \times 100 \quad (2)$$

And the angularity coefficient Ia for the single particle size of each type of aggregate particle was calculated, the calculation formula is as shown below:

$$Ia = 1.25 \times q_{10} - 0.25 \times q_{50} - 32 \quad (3)$$

Table 2
Technical indices of granite.

Test item	Requirements	Results	Test basis
Apparent relative density	≮ 2.5	2.8	T0304
Bulk volume relative density	–	2.754	T0304
Water absorption/%	≯ 3.0	0.2	T0304
Acicular content/%	≯ 20	6.1	T0312
<0.075 mm particle content/%	≯ 1.0	0.27	T0310

Table 3
Technical indices of limestone rubble.

Test item	Requirements	Results	Test basis
Apparent relative density	≮ 2.5	2.9	T0304
Bulk volume relative density	–	2.936	T0304
Water absorption/%	≯ 3.0	0.74	T0304
Acicular content/%	≯ 20	2.1	T0312
<0.075 mm particle content/%	≯ 1.0	0.75	T0310

Table 1
Technical indices of SK-70# asphalt.

Test item		Requirements	Results	Test basis
Penetration/0.1 mm (100 g, 5 s)	10 °C	≮ 15	37.6	T0604
	15 °C	–	–	
	25 °C	60–70	60.4	
Penetration index (PI)		−1.5 to +1.0	0.29	
Softening point (TR&B)/°C		≮ 47	47.8	T0606
Ductility (15 °C, 5 cm/min) /cm		≮ 100	>100	T0605
Flash point/°C		≮ 260	290	T0611
Solubility/%		≮ 99.5	99.74	T0607
Density (15 °C)/ g/cm^3		–	1.031	T0603
Mass loss/%		≯ ±0.8	0.027	T0609
Penetration ratio (25 °C)/%		≮ 61	67.1	T0609
Ductility (10 °C) /cm		≮ 60	>60	T0604