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The Testing Method for Aggregate Internal Structure Types in Asphalt Pavements after Construction

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Abstract: The aim of this study is solving the problem of acceptance of the aggregate internal structure types of asphalt pavements after construction. The core sample from pavement was taken as the research object. A method for evaluating the aggregate internal structure types was put forward. The steps of the testing method are as follows: measuring the height of the core sample from pavement (H_{mix}), getting coarse aggregate through burning the core sample, preparing the contrast sample by dry rodded method, and measuring the height of the sample (H_{DRC}). When H_{mix} is less than or equal to H_{DRC}, the aggregate structure in asphalt mixture is the skeleton structure; if not, it is the suspension structure. The testing specimens were obtained from three sections of an express way, and the AC-20 in middle surface and SMA-16 in upper surface were adopted in this test. We researched the effect of aggregate internal structure types on high temperature deformation resistance. The results show that the evaluation of aggregate internal structure types, namely H_{mix}/H_{DRC}, is closely related to the high temperature deformation of mixture. The result of this study offers a new method to check the internal aggregate structure types of asphalt pavements after construction.

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Key words: *Acceptance; Aggregate structure type; Asphalt pavement; Evaluation; Pavement core sample.*

Introduction

The importance of aggregate structure in the performance of asphalt concrete pavements is well recognized [1-2]. A better aggregate skeleton in the pavement will ensure resistance to rutting, reduction in strains resulting in increase in fatigue life and an overall improvement in performance.

Aggregate structure of asphalt mixture in asphalt pavements can be divided into skeleton structure and suspension structure. Skeleton type mixtures includes Stone matrix asphalt (SMA), Asphalt-treated permeable base (ATPB), Open-graded friction courses (OGFC) and so on. They rely on stone-on-stone contacts among particles to resist applied forces and permanent deformation. In stone matrix asphalt, the dry-rodded technique has been suggested as a method to ensure aggregate interlock [3].

It proposes requirements for structure types of the mixture in Technical Specification for Construction of Highway Asphalt Pavements（JTG F40-2004）[4]. That means that the voids in coarse aggregate of asphalt mix (VCAmix) are no more than the voids in coarse aggregate by the dry-rodded method (VCADRC). This is described in “Table 5.3.3-3 Technical requirements of mixture’s ratio design of Marshall test” in the Specification. However, there are no technical requirements for VCAmix in “Table 11.5.1-1 Highway hot mix asphalt pavement completion inspection and acceptance standards” of the Specification. That means that there are no acceptance standards of the structure type of asphalt mixture. Therefore, the acceptance standards cannot reflect mixture’s variability which is due to pavement paving and rolling process. And it cannot reflect if the structure of the asphalt pavement after construction can meet with its design requirements either. Thus it is difficult to conduct a comprehensive evaluation for the quality of construction of asphalt pavement.

The objectives for this study are to put forward a testing method and evaluation of the aggregate internal structure types of asphalt pavements after construction.

Basic principles

Measuring the Height of the Core Sample from Pavement

According to the method mentioned in Field Test Method of Subgrade and Pavement for Highway Engineering（JTG E60-2008）T0901 [5], after 3 days construction of asphalt pavement, core sample of asphalt mixture in asphalt pavement is drilled by core drilling rig. The core sample is 20 cm in diameter. Drilling depth should be 1 more centimeter than the thickness of the mixture in this layer. Then the core sample should be sawn along the combination of surface of the different structure. After dried to a constant weight the height H_{mix} of the core sample is measured at 4 sections along the perimeter.

Getting Coarse Aggregate Through Burning the Core Sample

The core sample is placed in the oven which is 110℃ - 150℃ to heat for 2 to 3 hours until it becomes loose-shaped. Then the loose core sample is put into the asphalt mixture dedicated burner for burning until its mass loss rate per minute is less than 0.01% in continuous two minutes. The burning temperature is between 450°C and 550°C.

After the core sample cooling, mineral aggregate and combustion residues will be screened. If the nominal aggregate size of the

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asphalt mixture is more than 13.2 mm, 4.75 mm is used as cut-off limit between size of the coarse aggregate and that of the fine aggregate. These remaining coarse aggregate whose particle sizes are more than 4.75 mm will be used to shape specimen. If the nominal aggregate size is less than or equal to 13.2 mm, 2.36 mm is used as cut-off limit between size of the coarse aggregate and that of the fine aggregate. These remaining coarse aggregate whose particle sizes are more than 2.36 mm will be used to shape specimen.

Shaping the Contrast Sample by the Dry-rodded Method and Measuring the Height of the Sample

These remaining coarse aggregate are put into a capacity cylinder which is 20 cm in diameter all at once. Then they are rodded from the edge of the capacity cylinder to the central for 75 times with a steel bar. This bar is 600 mm long and 16 mm in diameter. After leveling the aggregate of the surface of the specimen, the height of the specimen which has been dry rodded (H_{DRC}) is measured at 4 sections along the perimeter.

Evaluation of the Structure Type of Asphalt Mixture

It requires in Technical Specification for Construction of Highway Asphalt Pavements（JTG F40-2004）that VCAmix of stone matrix asphalt (SMA) should be less than VCADRC [4]. That is to say, it must meet the requirement of formula (1).

$$VCAmix \leq VCADRC \tag{1}$$

Formula (1) is recognized as the fundamental difference between skeleton and suspension structure [6-12]. The coarse aggregate volume VC is added to both side of formula (1). After that, formula (1) turns into formula (2).

$$VCAmix + VC \leq VCADRC + VC \tag{2}$$

In addition, VCAmix + VC = Vmix; VCADRC + VC = VDRC.

In the formula, Vmix represents the volume of the mixture and VDRC represents the volume of the sample which has been dry rodded.

It can be concluded from formula (2) that Vmix ≤ VDRC. Because the dry rodded sample diameter is the same with the core sample, formula (Vmix ≤ VDRC) can be turned into this form: $H_{mix} \leq H_{DRC}$.

The ratio of the height of the core sample and that of the contrast sample which is dry rodded, namely H_{mix}/H_{DRC}, is used as an indicator to evaluate the aggregate internal structure types. When the height of core sample (H_{mix}) is less than or equal to the height of contrast sample (H_{DRC}), that is, $H_{mix} \leq H_{DRC}$, the type structure of asphalt mixture is the skeleton structure. If not, the type structure of asphalt mixture is the suspension structure.

Effects of Mixture Structure Types on High Temperature Deformation Resistance

Detection and Evaluation of the Structure Type of Asphalt Mixture

Table 1. Test Result of the Asphalt Mixture Structure Type.

Bid Section	Mixture Type	H_{mix} (mm)	H_{DRC}（mm）	H_{mix}/H_{DRC} (%)
1	AC-20	61.02	59.35	102.81
		59.83	58.56	102.17
		60.24	56.25	107.09
		61.21	54.23	112.87
	AC-20 Mean Value	60.58	57.10	106.24
	SMA-16	50.61	51.26	98.73
		50.23	51.41	97.70
		51.21	51.24	99.94
		49.89	50.14	99.50
	SMA-16 Mean Value	50.49	51.01	98.97
2	AC-20	60.01	59.23	101.32
		59.58	58.69	101.52
		58.23	58.32	99.85
		63.21	60.23	104.95
	AC-20 mean value	60.26	59.12	101.91
	SMA-16	49.58	51.23	96.78
		49.23	52.05	94.58
		49.87	50.56	98.64
		49.36	50.65	97.45
	SMA-16 mean value	49.49	51.09	96.89
3	AC-20	63.25	54.56	115.93
		61.25	59.56	102.84
		60.45	57.58	104.98
		58.98	55.86	105.59
	AC-20 mean value	60.98	56.89	107.33
	SMA-16	51.65	49.65	104.03
		52.41	50.65	103.47
		50.24	48.23	104.17
		50.56	49.85	101.42
	SMA-16 Mean Vlue	51.07	49.58	103.02

Styrene-butadiene-styrene polymer (SBS) modified asphalt modified asphalt is used in both surface and middle course of the three bid sections of an expressway in Guangdong province of China. AC-20 mixture type is used in the middle course while SMA-16 type is used in the surface course. The design thickness of the middle course is 6 cm and that of the surface course is 5 cm. The core sample is cored in accordance with the above method to detect the structure type of the mixture. The results are shown in Table 1.

In Table 1, H_{mix} represents the height of the core sample and H_{DRC} represents the height of the sample which has been dry rodded.

Fig. 1. Rotary Loading Wheel Tester (RLWT).

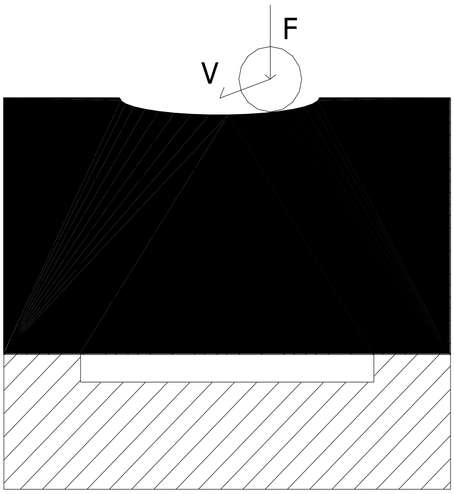

Fig. 2. The Loading Model of a RLWT Test.

Table 2. Deformation of Mixture after Loaded 16,000 Times by RLWT (mm).

Specimen Number	Section 1		Section 2		Section 3	
	AC -20	SMA -16	AC -20	SMA -16	AC -20	SMA-16
1	0.83	0.63	0.75	0.62	0.85	0.78
2	0.84	0.68	0.74	0.63	0.86	0.77
3	0.81	0.71	0.78	0.60	0.87	0.80
4	0.82	0.69	0.72	0.65	0.82	0.75
Mean Value	0.83	0.69	0.75	0.63	0.85	0.77

It can be drawn from Table 1 that the values of H_{mix}/H_{DRC} of AC-20 mixture in the three bid sections are all more than 100%. That is to say, they belong to the suspension structure. When it comes to SMA-16 mixture, the values of H_{mix}/H_{DRC} of section 1 and section 2 are less than 100%. So the mixtures belong to the skeleton structure. However, the values of H_{mix}/H_{DRC} of section 3 are more than 100%. The mixtures belong to the suspension structure.

Evaluation of High Temperature Deformation Resistance of Asphalt Mixture

The high temperature deformation resistance of AC-20 mixture and SMA-16 mixture in different bid section is evaluated through high-temperature soaking rutting test. This experiment is conducted by Rotary Loaded Wheel Tester or Rutmeter (RLWT).

RLWT was first produced in the United States in the late 1990s. This instrument is shown in Fig. 1. RLWT uses unidirectional rotating loading device which has no horizontal displacement. Ten small rubber wheels are set at the edge of the rotating big wheel. As the wheel turns a circle, the specimen is polished 10 times by the rubber wheel. The RLWT is capable of applying 125 N loads to each spinning single wheel in the load application assembly. And it is designed to approximate a contact pressure of 690 kPa. The loading model of a RLWT test is shown in Fig. 2. Most testing is carried out to 16000 individual wheel loadings. During the test, the rutting depth and corresponding number of loading are automatically tested and then recorded. The maximum tested rutting depth is 6.35 mm and the maximum loading times are 60000.

The application of RLWT compared with asphalt road analysis (APA) and the Hamburg loaded wheel tester has been studied in the National Center for Asphalt Technology (NCAT) test track [13]. The curve of the total depth of ARAN-measured track rutting and the total depth of rutting in laboratory simulations show that RLWT can give reasonable results for evaluating the anti-rutting performance of asphalt pavement.

In that expressway in Guangdong Province, pavement core samples which are 10 cm in diameter were cored. Then they were cut into specimens with a thickness of 4 cm. In the soaking conditions of 60℃, the multi-wheel rutting test was carried on. The specimen was loaded for 16000 times, and then its surface deformation was measured. The results are shown in Table 2.

It can be seen from Table 2 that the deformation of AC-20 mixture is obviously more than that of SMA-13 mixture. These two mixtures use the same styrene-butadiene-styrene polymer (SBS) modified asphalt. The deformation of the suspension SMA-16 mixture in section 3 is obviously more than that of skeleton SMA-16 mixture in section 1 and section 2.

Fig. 3 shows the relationship between H_{mix}/H_{DRC} and the rutting deformation (RD). RD varies with H_{mix}/H_{DRC} according to the following approximate linear relation. R^2 represents the coefficient of determination. And it is 0.9931. The regression equation is as follows:

$$RD = 0.0205\ H_{mix}/H_{DRC} - 1.3493 \tag{3}$$

In Eq. (3), RD represents the deformation after being multi-wheel loaded for 16000 times. Its unit is mm.

Eq. (3) shows that the rutting deformation gradually increases with the increase of H_{mix}/H_{DRC}. It is shown that the structure type of mixture influences the high temperature deformation resistance of mixture a lot.

Conclusions

This study puts forward a testing method and evaluation of the aggregate internal structure types of asphalt pavements after construction. The results make up the shortcoming of existing specifications, it is conducive to test the conformance of construction quality and design of asphalt pavement, control the

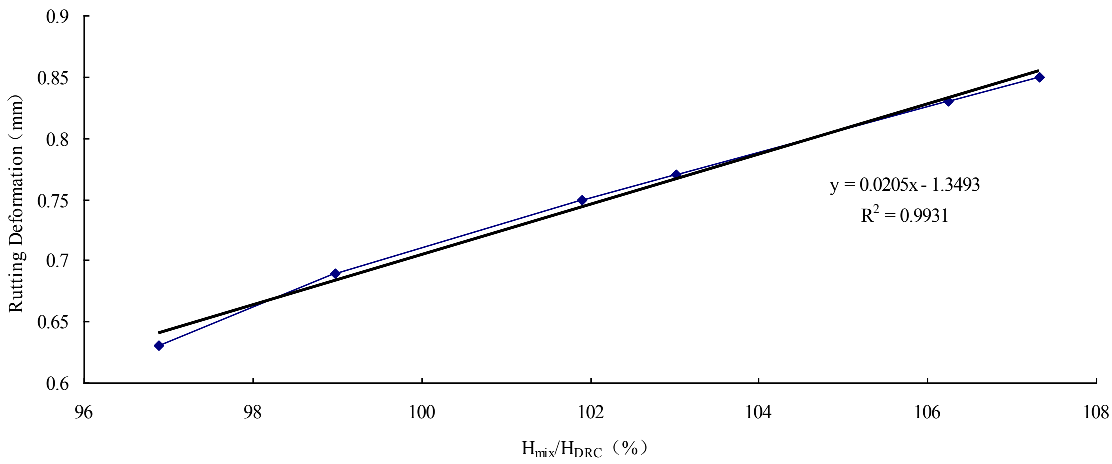

Fig. 3. H_{mix}/H_{DRC} vs. Rutting Deformation.

pavement construction quality, and extend the service life of road.

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