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Rutting resistance of asphalt mixtures in the middle course

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Abstract: In order to improve the rutting resistance of asphalt mixtures in the middle course to reduce the rutting of asphalt pavement, the influence of different types of gradation with their own optimal asphalt-aggregate ratios is analyzed. Some investigations are made out on the mixture in the middle course through the modified wheel tracking test in air bath and the Hamburg wheel tracking test (HWTT) in water bath, and the results of which are compared with the corresponding research in Germany. Results show that the Sup20 and the modified AC-20I have better performance than that of AC-20I under the same test conditions. In addition, the high-quality bitumen and hard aggregate can improve the rutting performance of the mixture in water-submerged conditions. The selection of modified asphalt, hard aggregate and a reasonable gradation are essential to the improvement of the rutting resistance of the mixtures used in the middle course.

Key words: middle course; rutting; modified asphalt; modified wheel tracking test; Hamburg wheel tracking test

With the increase in traffic volume and axle load, especially the high channelization, rutting has become more and more severe in the asphalt pavement of highways in recent years in China. Previous research on rutting concentrated mainly on the contribution of the upper layer caused this kind of failure, however the results of mechanical analysis indicate that the maximum shear stress always occurs in the layer 5 to 10 cm below the surface which is usually regarded as the middle layer[1,2]. Rutting distress investigation in both the laboratory and field cases validates the fact that rutting deformation of the middle course accounts for the majority of total deformation cases of pavement, which makes it quite necessary and meaningful to focus on the research of the rutting resistance of asphalt mixtures in the middle course.

1 Indices and Criteria

In this research, the criterion of Grade 3, used in the wheel tracking test in France, is adopted, which requires a relative deformation rate lower than 15% after 10^4 repetitions of wheel loading. The index of dynamic stability popular in China is also adopted, which is calculated according to wheel tracking test results by the following formula:

$$D_s = \frac{(t_2 - t_1)N}{d_2 - d_1} C_1 C_2 \qquad (1)$$

where D_s is the dynamic stability; d_1 is the rut depth at time t_1 (45 min); d_2 is the rut depth at time t_2 (60 min); N is the repetition per minute, 52 in the Hamburg wheel tracking test (HWTT); C_1 is the calibration factor for the type of testing equipment; C_2 is the calibration factor for the type of specimen. Considering the size of the slab specimen and the type of the propelling system of the machine employed, both C_1 and C_2 are set to 1.0.

2 Middle Course by Modified Wheel Tracking Test in Air Bath

In the test, the wheel tracking device made in China is used and the total loading repetition is 10^4, which is four times that which used to be. Therefore, this test is called the modified wheel tracking test.

The test environment is 60 ℃ in air bath. The volumetric indices are acquired directly from the wheel tracking test specimens instead of Marshall specimens. This is thought to be more accurate. Limestone aggregate and filler are used with the SBS modified asphalt. All these materials well meet the requirements of related criteria[3]. The gradation of the subjected mixtures and the optimal asphalt-aggregate ratios (OAARs) are shown in Tab. 1[4].

The results of the volumetric indices, dynamic stability and rut depth after 10^4 repetitions of wheel loading of three kinds of structures are shown in Tab. 2.

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Tab. 1 Proportioning of asphalt mixtures in the middle course

Sieve size/mm	Passing percent/%		
	Sup20	Modified AC-20I	AC-20I
26.5	100	100	100
19	95	95	97.5
16	87	86	82.5
13.2	82	75	71
9.5	65	64	62
4.75	44	45	48
2.36	29	31	37
1.18	18	21	27
0.6	13	14.5	21
0.3	10	10.5	15
0.15	7	7.5	10
0.075	5	5	6
AAR/%	4.5	4.5	4.4

Note: AAR means asphalt-aggregate ratio.

Tab. 2 Modified wheel tracking test results of asphalt mixtures

Mixture type	AAR/%	Air void/%	VMA/%	Rut depth* /mm	D_s/(repetition·mm^{-1})
Sup20	4.5	5.4	15.1	2.580	4 245
Modified AC-20I	4.5	4.7	14.8	1.883	5 000
AC-20I	4.4	2.5	12.7	5.144	2 147

Note: * After 10^4 repetitions of where loading.

What can be seen in Tab. 2 is that both Sup20 and modified AC-20I perform better than AC-20I in rutting resistance. The difference between Sup20 and AC-20I is obvious. AC-20I is of a suspending-dense structure, which gives the mixture a low air void. The modified AC-20I and Sup20 can be categorized as the framework-dense structure with moderate air voids, which gives them better rutting resistance performance at high temperatures[5].

3 Hamburg Wheel Tracking Test Results

3.1 Test result

Sup20, modified AC-20I and AC-20I are tested at their own OAARs, under a condition of 50 ℃ water bath, steel wheels and 2×10^4 repetitions. The results are shown in Tab. 3. Compared with Tab. 2, it is quite easy to find that water has a remarkable influence on rutting resistance of asphalt mixtures and test results also show that the rut depth will increase as the air void content ascends.

Tab. 3 Hamburg wheel tracking test results of asphalt mixtures

Mixture type	AAR/%	Air void/%	VMA/%	Rut depth* /mm
Sup20	4.5	5.4	15.1	34.2
Modified AC-20I	4.5	4.8	14.8	24.1
AC-20I	4.4	2.3	12.7	19.8

Note: * After 2×10^4 repetitions of where loading.

3.2 Comparison with the research in Germany

Gradation BI 0/16S is used in German research (see Tab. 4) and different types of aggregate and asphalt are used in the test. Under a condition of 50 ℃ water bath, steel wheel and 2×10^4 repetitions the Hamburg wheel tracking tests were conducted. The results are shown in Tab. 5.

Tab. 4 German gradation BI 0/16S

Sieve size/mm	Passing percent/%
22.4	100
16	100
11.2	70.6
8	53.8
5	40.4
2	28.8
0.71	18.2
0.25	11.0
0.09	6.9

Tab. 5 shows that the German mixtures are more effective than those used in China. The main reasons are as follows:

1) Compared with the nature of aggregates, the German BI 0/16 S gradation has more fine aggregates, and Basalt and Grit stone (ranging from 0 to 16 mm) are used in the mixture. But the limestone ranging from 0 to 20 mm is used in China. It shows that the aggregate's nature has some influence on the rutting resistance of the asphalt mixture.

2) Compared with the nature of bitumen, in the German research a combination of hard bitumen and TLA is used. It performs better than the SBS modified asphalt. Even its air void is larger, the German mixture still has a better performance than those made in our laboratory. This implies that the nature of the asphalt has a determinant effect on the rutting resistance under water conditions.

Tab. 5 German research results of asphalt mixtures in the middle course

Mixture type	Asphalt type	Aggregate type	AAR/%	Air void/%	Thickness of specimen/mm	Rut depth*** /mm
German BI 0/16S	30/45 *	Basalt	4.9	6.7	60	4.8
	PmB 45	Grit stone	4.9	7.4	60	4.0
	30/45 + NAF501 **	Grit stone	5.3	6.8	60	2.9

Notes: * Penetration ranged from 30 to 50 hard bitumen; ** NAF501 is a product of lake asphalt in the European market;
*** After 2×10^4 repetitions of where loading.

4 Conclusions

The rutting resistance of three different asphalt mixtures in the middle course through the modified wheel tracking test and the Hamburg wheel tracking test are evaluated and the differences of the mixtures with German research are analyzed. The main conclusions are as follows:

1) In view of the performance of rutting resistance in air bath, the mixture of modified AC-20I is almost the same as that of Sup20 and rutting resistance of AC-20I proves to be the poorest. Even with the same asphalt content, the three kinds of mixtures vary in air voids due to their different gradation types, AC-20I is of suspending-dense structure, which gives the mixture a low air void. The modified AC-20I, and Sup20 can both be categorized as the framework-dense structure with moderate air voids, which gives them better performance at high temperatures.

2) While in view of rutting resistance exposed to water, AC-20I is the best, followed by modified AC-20I, and Sup20 occupies the last place. It is due to the lower air void that prevents more water flowing into the mixture and decreases the chance of bitumen peeling from the aggregate.

3) Compared with the German research, the nature of the asphalt used in the mixture has a determinant effect on the rutting resistance under water conditions. It is better to use high performance bitumen to improve the mixture's performance under water conditions.

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中面层沥青混合料抗车辙性能研究

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摘要:从提高中面层沥青混合料抗车辙性能以减少沥青路面车辙出发,探讨了在各自最佳油石比条件下,不同级配结构对中面层抗车辙性能的影响.通过中面层空气浴改进车辙试验及汉堡浸水车辙试验,对中面层沥青混合料的抗车辙性能进行了研究,并与德国的相关研究成果进行了比较与分析.结果表明:Sup20 和 AC-20I 改进型抗车辙性能优于 AC-20I 型;硬质石料、优质沥青有助于提高浸水条件下沥青混合料抗车辙性能.因此,选用合适的改性沥青、硬质石料和合理级配有助于提高中面层沥青混合料抗车辙性能.

关键词:中面层;车辙;改性沥青;改进型车辙试验;汉堡车辙试验

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