Study on Normative Standards of Hard Asphalt for highway engineering in China

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Abstract: Hard asphalt has been applied and studied on Chinese highway asphalt pavement for nearly 20 years. Although it has excellent road performance, it has not been applied on a large scale. The main reason is that there is no clear technical standard and technical system for hard asphalt, which restricts the popularization and application of hard asphalt as a good material in the highway engineering. Therefore, it is urgent to formulate standards for hard asphalt products of highway engineering in China. In order to promote the large-scale application of hard asphalt for asphalt pavement in China, a draft definition of hard asphalt for highway use and a draft technical standard for engineering are proposed through a large number of tests and research analysis of various samples, drawing lessons from the current technical specifications and relevant international standards for hard asphalt.

1 Introduction

Hard asphalt is a kind of Low-grade asphalt, which is called high modulus asphalt or Low-grade asphalt in some countries or regions. It first appeared in France in the 1980s, and has been widely used in Britain, Finland, Netherlands and other European countries [1]. China began to research and apply hard asphalt in asphalt pavement engineering around 2000.

Research results and engineering practices at home and abroad show that [1-5,9-11]: hard asphalt and asphalt mixture pavement has good high temperature stability, water stability, anti-fatigue performance, especially its excellent high temperature stability, which can improve the rutting resistance of asphalt pavement in high temperature areas. The structural strength and service life of asphalt pavement can reduce the thickness of asphalt pavement and the cost of construction. It has good technical economy.

At present, the international technical standards for hard asphalt mainly include the hard asphalt paving Specifications in EN13924 of European Union commonly used in France and the hard asphalt paving Specifications in EN12591 in European Union commonly used.

At present, there is no technical standard for hard asphalt in China. Although the current "Technical Specifications for Construction of Highway Asphalt Pavement" (JTG F40-2004) refers to the technical requirements of 50# and 30# asphalt, there is no clear definition of hard asphalt and classification standard for hard asphalt. Influenced by the supply and demand relationship in China's market and the engineering

application habits, the application of 50# and 30# asphalt is less, and there is no large-scale application. This is one of the main reasons that restrict the large-scale application of hard asphalt in China's highway Engineering. Therefore, it is urgent to formulate technical standards for Chinese hard asphalt.

Through a large number of experiments and research, this study puts forward the definition and the draft of technical standards of hard asphalt for highway engineering, which has an important technical support role in standardizing the quality of hard asphalt products, giving full play to the excellent road performance of hard asphalt and promoting its application.

2 Materials and Methods

2.1. Materials

In this study, 115 representative samples of hard asphalt for highway engineering from domestic asphalt producers (agents) were selected as samples to study the index system and standards of for highway engineering. Among them, 24 samples with penetration range of 10-20 (0.1 mm), 39 asphalt samples with penetration range of 20-30 (0.1 mm), 31 asphalt samples with penetration range of 30-40 (0.1 mm) and 21 asphalt samples with penetration range of 40-50 (0.1 mm) are included.

2.2. test methods

According to the test method stipulated in "Technical Specifications for Construction of Highway Asphalt

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Pavement" (JTG F40-2004,). See below for specific methods.

3 Results

115 kinds of hard asphalt for highway engineering are tested. The test results are as follows: Table 1-Table 5.

3.1. Test results of hard asphalt for highway engineering with four penetration ranges

Table1. Test results of samples of penetration range 10-20 of hard asphalt with for highway engineering (0.1 mm)

Serial number	Penetration (25°C,5s,100g),0.1mm	Softening point, °C	Kinetic Viscosity /60°C, Pa.s	Kinetic Viscosity /135°C, Pa.s	Ductility /25°C	Weight change by TFOT, %	Weight change by RTFOT, %
1	16	66.2	6100	2.72	12	0.10	0.09
2	15	70.1	12600	3.21	14	0.09	0.12
3	19	64.5	6760	2.32	25	0.12	0.21
4	14	64.4	6420	1.74	11	0.37	0.29
5	17	64.2	6388	1.70	20	0.28	0.17
6	18	64.1	6391	1.72	19	0.19	0.21
7	18	64.0	6401	1.70	19	0.22	0.22
8	17	64.1	6400	1.71	12	0.10	0.30
9	16	64.1	5170	1.79	9	0.10	0.11
10	18	65.0	6231	1.90	12	0.19	0.21
11	19	63.7	3421	1.92	17	0.22	0.21
12	16	64.7	3879	1.32	27	0.34	0.32
13	13	65.9	4952	1.48	6	0.44	0.29
14	15	64.8	4003	1.32	20	0.12	0.09
15	13	65.4	5046	1.45	6	0.22	0.19
16	20	62.5	2634	1.09	21	0.17	0.23
17	17	63.5	3054	1.25	19	0.56	0.39
18	15	63.9	3425	1.31	12	0.23	0.37
19	18	62.9	3031	1.23	11	0.23	0.22
20	14	63.5	3378	1.32	27	0.46	0.21
21	17	63.5	3390	1.20	10	0.17	0.31
22	13	64.9	4357	1.75	9	0.09	0.12
23	19	62.7	2548	0.95	21	0.23	0.07
24	16	64.1	3812	1.81	17	0.16	0.17
AVG	16.38	64.45	4991.29	1.66	15.67	0.23	0.21
Max	20	70.1	12600	3.21	27	0.56	0.39
Min	13	62.5	2548	0.95	6	0.09	0.07

Table 2. Test results of samples of penetration range 20-30 of hard asphalt with for highway engineering (0.1 mm)

Serial number	Penetration (25°C,5s,100g),0.1mm	Softening point, °C	Kinetic Viscosity /60°C, Pa.s	Kinetic Viscosity /135°C, Pa.s	Ductility /25°C	Weight change by TFOT, %	Weight change by RTFOT, %
1	23	61.2	2460	1.73	45	0.32	0.22
2	25	62.1	2490	1.74	54	0.44	0.46
3	24	61.8	2436	1.73	49	0.47	0.27
4	25	59.7	1900	1.57	53	0.77	0.56
5	21	63.5	3130	1.81	31	0.62	0.43
6	22	60.2	1710	1.32	31	0.45	0.54
7	21	60.4	2010	1.40	19	0.51	0.47
8	22	62.5	5001	1.64	42	0.51	0.47
9	21	62.6	5013	1.65	32	0.44	0.56
10	22	62.6	5021	1.63	29	0.35	0.27
11	20	62.5	2634	1.09	17	0.37	0.33
12	25	60.3	1329	0.76	49	0.43	0.41
13	29	60.5	2180	1.62	57	0.44	0.45
14	30	60.3	1760	1.47	67	0.52	0.39

15	29	60.5	2000	1.61	54	0.33	0.27
16	26	59.7	1750	1.26	52	0.27	0.32
17	26	60.0	1875	1.42	70	0.33	0.21
18	30	57.4	1070	1.06	54	0.56	0.51
19	28	58.9	1420	1.19	53	0.51	0.53
20	30	60.9	2310	1.21	52	0.47	0.45
21	25	62.0	2347	1.31	47	0.38	0.36
22	22	60.7	2334	1.26	39	0.62	0.61
23	22	60.7	2321	1.24	32	0.55	0.45
24	22	60.8	2338	1.26	28	0.23	0.21
25	25	59.2	1980	1.17	51	0.19	0.17
26	26	59.4	1990	1.18	54	0.44	0.45
27	26	59.6	2013	1.25	49	0.42	0.41
28	27	59.4	2010	1.24	61	0.37	0.39
29	25	59.7	2015	1.23	52	0.45	0.42
30	26	62.8	2464	1.10	51	0.24	0.37
31	27	62.4	2297	1.05	56	0.19	0.10
32	29	61.7	2132	0.99	49	0.27	0.27
33	29	58.4	1035	0.69	43	0.26	0.25
34	30	58.1	686	0.53	60	0.33	0.31
35	26	59.8	1519	0.71	47	0.37	0.41
36	27	58.9 740.9	740	0.58	70	0.31	0.29
37	29	58.9	1293	0.79	71	0.47	0.41
38	27	59.4	1363	0.85	52	0.29	0.24
39	25	61.9	1647	0.83	42	0.51	0.46
AVG	2.42	33.17	631.03	0.27	9.89	0.10	0.10
Max	30	740.9	5021	1.81	71	0.77	0.61
Min	20	57.4	686	0.53	17	0.19	0.1

Table 3. Test results of samples of penetration range 30-40 of hard asphalt with for highway engineering (0.1 mm)

Serial number	Penetration (25°C, 5s, 100g), 0.1mm	Softening point, °C	Kinetic Viscosity /60°C, Pa.s	Kinetic Viscosity /135°C, Pa.s	Ductility /25°C	Weight change by TFOT, %	Weight change by RTFOT, %
1	30	60.3	1760	1.47	64	0.42	0.42
2	31	59.5	1630	1.44	52	0.54	0.49
3	34	57.1	1240	1.33	66	0.67	0.61
4	30	57.4	1070	1.06	30	0.77	0.79
5	32	57.2	1010	1.02	56	0.72	0.64
6	30	60.9	2310	1.21	78	0.45	0.53
7	32	60.1	1690	0.88	80	0.61	0.67
8	31	62.2	2479	1.08	75	0.51	0.41
9	32	56.8	423	0.43	75	0.64	0.56
10	30	58.1	686	0.53	50	0.35	0.53
11	35	56.8	785	0.58	>100	0.37	0.42
12	31	58.1	1101	0.70	89	0.43	0.41
13	35	56.5	1320	1.26	90	0.47	0.49
14	40	56.5	1060	1.15	80	0.22	0.21
15	35	57.1	1140	1.22	76	0.33	0.35
16	38	59.6	980	1.13	57	0.57	0.61
17	32	58.4	1250	1.08	88	0.33	0.21
18	38	56.0	925	1.00	90	0.66	0.44
19	38	55.4	815	0.89	>100	0.51	0.57
20	39	54.8	756	0.86	89	0.47	0.42
21	37	54.8	791	0.74	54	0.48	0.44
22	40	53.5	752	0.70	85	0.72	0.62
23	39	53.0	732	0.68	>100	0.55	0.57
24	39	53.1	745	0.70	80	0.23	0.33
25	35	57.9	1100	0.95	77	0.89	0.77
26	40	55.9	848	0.80	80	0.44	0.41
27	38	56.8	860	0.64	59	0.42	0.39
28	40	55.9	604	0.58	79	0.57	0.42

29	39	54.2	403	0.46	90	0.25	0.27
30	38	55.6	646	0.54	92	0.44	0.41
31	40	55.7	574	0.51	73	0.39	0.32
AVG	35.42	56.94	1047.90	0.89	73.36	0.50	0.48
Max	40	62.2	2479	1.47	92	0.89	0.79
Min	30	53	403	0.43	30	0.22	0.21

Table 4. Test results of samples of penetration range 40-50 of hard asphalt with for highway engineering (0.1 mm)

Serial number	Penetration (25°C, 5s, 100g), 0.1mm	Softening point, °C	Kinetic Viscosity /60°C, Pa.s	Kinetic Viscosity /135°C, Pa.s	Ductility /25°C	Weight change by TFOT, %	Weight change by RTFOT, %
1	40	56.5	1060	1.15	>100	0.52	0.49
2	41	54.9	844	1.10	90	0.34	0.32
3	41	54.3	751	0.81	87	0.68	0.69
4	40	53.5	752	0.70	>100	0.27	0.33
5	41	52.9	712	0.69	>100	0.73	0.76
6	40	55.9	848	0.80	>100	0.48	0.55
7	42	53.4	710	0.70	>100	0.63	0.39
8	43	53.3	702	0.71	53	0.51	0.49
9	43	53.4	702	0.72	>100	0.48	0.48
10	42	56.0	670	0.59	>100	0.39	0.32
11	42	56.4	623	0.60	80	0.31	0.31
12	41	55.7	587	0.48	93	0.44	0.45
13	40	55.9	604	0.58	87	0.67	0.66
14	42	52.6	469	0.47	99	0.23	0.33
15	42	53.0	301	0.39	>100	0.46	0.45
16	43	52.2	286	0.32	>100	0.44	0.42
17	42	53.1	302	0.35	85	0.41	0.48
18	42	56.0	514	0.49	86	0.39	0.31
19	40	55.7	574	0.51	90	0.29	0.30
20	43	55.4	524	0.50	>100	0.32	0.27
21	41	56.2	683	0.55	>100	0.27	0.22
AVG	41.48	54.59	629.43	0.63	85.00	0.44	0.43
Max	43	56.5	1060	1.15	99	0.73	0.76
Min	40	52.2	286	0.32	53	0.23	0.22

3.2. Tracking test in the production of hard asphalt for highway engineering by major asphalt producers

At the same time, the indexes of penetration, softening point and kinetic viscosity of hard asphalt produced by major domestic asphalt producers were tested and

analyzed. The results of the test and analysis are shown in Fig.1 and Fig.2.

The test results show that when the penetration (25 C, 5s, 100g) is less than 50(1/10mm), the kinetic viscosity (60°C) is above 300 Pa. s, the softening point is above 50 °C. When the penetration is lower, the increase of kinetic viscosity is larger, which is consistent with the test results of the samples collected in the laboratory.

Figure1. Variation of kinetic viscosity with penetration

Figure2. The Variation of softening point with penetration

Figure3. Variation of kinetic viscosity with softening point

3.3. Four-component comparison test of road hard asphalt and other road asphalts

The four-component test results of hard asphalt and other asphalts are shown in Table 5.

Table 5. Four-component test results of hard asphalt and 90# and 70# Asphalts

Samples	Saturation constituent, %	aromatics constituent, %	Resin constituent, %	asphaltene constituent, %
90#asphalt	12.3	52.1	27.5	8.1
70# asphalt	11.7	50.1	27.3	10.9
50# asphalt	7.9	47.9	31.5	12.7
30# asphalt	5.1	41.2	37.6	16.1

The test results show that the content of asphaltene in road hard asphalt is higher than that in 90# and 70# asphalt, which shows that hard asphalt mixture has higher cohesion C.

4. Discussion

4.1. Definition of road hard asphalt for highway engineering

4.1.1. Definition of hard asphalt for highway engineering

Definition: asphalt with penetration less than 50 (0.1 mm) for each structural layer of asphalt pavement is produced with petroleum as raw material and appropriate related technology.

Hard asphalt is also used in other professions such as petrochemical, municipal and other industries, but they are different from the technical indicators and requirements of hard asphalt in highway engineering, so it should be called "road hard asphalt" in highway engineering to highlight its road performance characteristics.

4.1.2. Grading label of hard asphalt for highway engineering (draft recommendations)

Grading labels of hard asphalt for highway engineering are Classified into 15#, 25#, 35# and 45 #according to the penetration.

Compared with "Technical Specifications for Construction of Highway Asphalt Pavement" (JTGF40-2004), for the penetration of hard asphalt is lower, so this study proposes the Grading label of hard asphalt for highway engineering should be done with the range of penetration 10, and from small to large, it is Classified into four grades such as 15#、25#、35#、45#.

4.2. requirements of hard asphalt for highway engineering

According to the test results and engineering application requirements, this study proposes the following draft technical standards for hard asphalt for highway engineering, which are divided into general technical requirements and main technical requirements, such as Table 6 and Table 7.

4.2.1. General requirements

It is suggested that the general requirements of hard asphalt for highway engineering should meet the requirements of Table 6

Table 6. General requirements for hard asphalt for highway engineering

Technical Indicators	Control Value of Each Grading label			
	15#	25#	35#	45#
Ductility/25°C,cm	No more than the production plant internal control value			
Kinetic Viscosity/135°C, Pa.s	No more than the production plant internal control value			
Density/15°C,g,cm-3	No more than the production plant internal control value			
Residual ductility after TFOT（or RTFOT）/25°C,cm	No more than the production plant internal control value			
Note 1: The internal control value of each index is indicated in the relevant technical data of the production plant.				
Note 2: Requirements for internal control values between the same and different batches can be agreed by both suppliers and consumers.				
Note 3: TFOT (or RTFOT) is the thin-film oven test (or the thin-film rotary film heating test).				

4.2.2. Main technical requirements

It is suggested that the main technical requirements of hard asphalt for highway engineering should meet the requirements of Table 7.

Table 7. Main technical requirements of hard asphalt for highway engineering

Technical Indicators	Control Value of Each Grading label			
	15#	25#	35#	45#
Penetration (25°C, 5s, 100g), 0.1mm	10~20	20~30	30~40	40~50
Softening point (R&B), °C	≥60.0	≥57.0	≥55.0	≥50.0
Kinetic Viscosity/60°C, Pa.s	≥2000	≥1000	≥500	≥300
solubility, %			≥99.5	
Opening flash point, °C			≥260	
Wax content, %			≤3.0	
Weight change, %			-0.6~+0.6	
After TFOT (or RTFOT) Residual penetration ratio/25°C, %	≥65	≥65	≥65	≥65

4.3. Analysis and basis of standard suggestions

Based on the test results, this study analyzed and drew lessons from the relevant concepts and Technical indexes of "Technical Specifications for Construction of Highway Asphalt Pavement" (JTGF40-2004), European Union Standard EN13924 and European Union Standard EN12591, then put forward the recommended standards in this study.

4.3.1. Ductility/25 °C

With a long-term study, it is found that the ductility index (15/25°C) of asphalt can effectively control the content and uniformity of asphalt impurities, but the ductility index value also have poor correlation with the performance of mixtures in a certain range.

The users and researchers pay more attention to the high-temperature stability of hard asphalt, and the advantages of hard asphalt are mainly due to its high-temperature stability. The proposed standard abandons the low temperature ductility index of 15°C, but in order to ensure the stability and reliability of the source

and processing technology of hard asphalt for highway engineering, the ductility index of 25 °C is still retained, and the index requirement does not exceed the internal control value of the production plant.

4.3.2. Kinetic Viscosity/135 °C

This technical index is designed to facilitate the habits of asphalt pavement workers and related engineering applications, and the index requirements do not exceed the internal control value of the production plant.

4.3.3. Density

This technical index is designed to facilitate the habits of asphalt pavement workers and related engineering applications. Referring to the corresponding technical requirements of JTG F40 standard, the technical index requirements do not exceed the internal control value of the production plant.

4.3.4. Residual Ductility after TFOT(or RTFOT)

In order to ensure the reliable source and processing technology of hard asphalt for highway engineering, the ductility index (25°C) should be retained, and the index should not exceed the internal control value of the production plant.

4.3.5. Penetration

Because the penetration of hard asphalt for highway engineering is lower, and the other properties of hard asphalt vary greatly with the change of penetration within the lower penetration range, the proposed standard is classified according to penetration grade, and each 10 penetrations are classified into four grades: 10-20, 20-30, 30-40, 40-50, with grading labels 15#, 25#, 35#, and 45#.

4.3.6. Softening Point

The high-temperature stability of hard asphalt for highway engineering is good. The softening point of different penetration ranges (ring and ball method) specified in this recommendation is not less than 60, 57, 55, 50 °C, not less than the corresponding index requirements of EU standards EN12591 and EN13924, higher than the index requirements of JTG F40, and suitable for more than 75% of domestic collected samples of hard asphalt (details in Table 1-4).

4.3.7. Kinetic Viscosity/60 °C

High-temperature stability of hard asphalt is good. The Kinetic Viscosity of different penetration ranges at 60 °C is not less than 2000 Pa.s, 1000 Pa.s, 500 Pa.s, 300 Pa.s, higher than that of JTG F40, EN12591 and EN13924, and is suitable for more than 75% of domestic collected samples of hard asphalt (details in Table 1-4).

4.3.8. Solubility

The technical specifications are in accordance with the corresponding technical requirements of JTGF40 standard.

4.3.9. Opening Flash Point

The technical specifications are in accordance with the corresponding technical requirements of JTGF40 standard.

4.3.10. Wax Content

According to the research results of China University of Petroleum and Research Institute of Highway of MOC [21-22], the influence of wax content in asphalt (pyrolysis, total wax content) on asphalt properties was studied in detail. Through research of the influence of wax content on softening point, penetration and ductility (15°C) of asphalt, It is found that when the content of asphalt wax is less than 3%, it has little effect on the properties of asphalt. According to the test results (Table 1-4 for details), the standard content of asphalt wax is set at 3%.

4.3.11. Weight Change After TFOT(or RTFOT)

Compared with ordinary petroleum asphalt, the volatile components of hard asphalt for highway engineering are less, and the weight change after TFOT (or RTFOT) is less than that of other asphalt. This technical index is higher than the corresponding technical requirement of JTG F40 standard. The weight change of this recommended standard is not more than ±0.%) and meets condition of over 85% domestic collected samples of hard asphalt (details in Table 1-4). The weight change in JTG F40 is not more than ±0.8.

4.3.12. Residual Penetration Ratio After TFOT(or RTFOT)

Compared with ordinary petroleum asphalt, for the penetration of hard asphalt is lower, then the change of penetration is smaller after TFOT (or RTFOT) aging. This technical index is higher than the corresponding technical requirements of JTGF40 standard. The recommended standard requires that Residual penetration ratio After TFOT (or RTFOT) should not be less than 65(details in Table 1-4). In JTG F40, the Residual penetration ratio After TFOT (or RTFOT) should be 58-65 according to different grades.

5 Conclusions

Based on the analysis of test results, by analyzing and referring to the relevant concepts and indexes of "Technical Specifications for Construction of Highway Asphalt Pavement" (JTG F40), European Union Standard EN13924 and European Union Standard EN12591, the recommended standards of this study are put forward.

1. The definition of "hard asphalt for highway engineering" is proposed.

2. Proposed draft technical standards for hard asphalt for highway engineering are put forward, and the rationality and basis of the proposed standards are analyzed.

3. The draft proposal has been submitted to the highway administrative department for examination and approval.

Author Contributions

Conceptualization, J.L.; Data curation, J.L., S.Y.; Formal analysis, J.L., D.L.; Investigation, J.L., S.Y.; Methodology, J.L., S.Y.; Writing—original draft, S.Y., D.L.

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Conflicts of Interest

The authors declare no conflict of interest.

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