Study on Mixing Proportion for AC-13C Asphalt Mixture and Construction Control

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Abstract. With good waterproof performance and high stability under high temperature, SBS modified AC-13C asphalt mixture can meet the requirements in highway construction nowadays. In this article, the Loudi test highway section is mainly used to carry out discussions on the design and test of the production mix proportion for AC-13C asphalt mixture, and at the same time studies are carried out for the construction methods such as mixing and rolling, to further improve highway pavement quality.

Keywords: AC-13C · Asphalt mixture · Mix proportion · Construction control

1 Introduction

With continual development of economy and technology, urbanization is increased day by day, and higher requirements on highway construction speed and quality are raised. Due to its economy and convenience, SBS modified asphalt construction technology is widely used in highway construction. However, due to different effects resulted from indoor mixing and on-site mixing as well as different mineral specifications and gradation change, usually there are differences from the design requirements when carrying out gradation for the mixture in accordance with the target mix proportion during construction, and therefore, the production mix proportion must be designed for asphalt mixture before production. In this article, the test data in Loudi test highway section are used to introduce the mix proportion design schemes and construction quality control measures for AC-13C asphalt mixture.

2 About the Project

Loudi test highway section is located in a continental subtropical monsoon humid climate zone, with four distinct seasons, and in summer, it is hot and rainy, and in winter, it is warm, and the annual average air temperature is between 16–18 °C, and the annual precipitation is between 1200–1700 mm. The highway pavement consists of two layers: a 34 cm thick reinforced cement concrete layer and a 16 cm thick cement stabilized crushed stone base layer.

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3 Material Inspection

To ensure high performance of asphalt highway pavement structure, the quality of all the raw materials must be checked to ensure that the raw materials are qualified.

3.1 Asphalt

AC-13C asphalt was used, which has such advantages as low needle penetration, good bonding performance, high stability under high temperature, and good ductility under low temperature. Through special tests, all the indexes of the asphalt meet the requirements in Standard JTG F40-2004 Technical Specifications for Construction of Highway Asphalt Pavements. The test results are shown in Table 1:

Table 1. Test results of AC-13C asphalt

Item of test		Unit	Technical index	Test result	Conclusion
Needle penetration (25 °C, 100 g, 5 s)		0.1 mm	40–60	58	Pass
Ductility (5 °C, 5 cm/min)		cm	≥ 20	35	Pass
Softening point ($T_{R\&B}$)		°C	≥ 60	68	Pass
Residue after RTFOT	Quality loss	%	±1.0	0.1	Pass
	Needle penetration ratio after heating (25 °C)	%	≥ 65	69.5	Pass
	Ductility (5 cm/min, 5 °C)	cm	≥ 15	19.0	Pass

3.2 Filler

The filler for the highway section consists of cement and mineral powder, and all the mineral powder was prepared by grinding water repellent limestone, and the maximum metric particle size of crushed stones used in cement stabilized crushed stone base layer was 26.5 mm, and the crushed stones must be hard, durable and clean and has a good bonding performance. The particles must meet the requirements in Table 2.

The material for the base layer is higher than 4.75 mm, and coarse aggregate is classified into three grades, i.e.: 19–26.5 mm, 9.5–19 mm, and 4.75–9.5 mm, and

Table 2. Range of gradation for porous cement stabilized crushed stone base

Mesh size	Passing percent
31.5	100
26.5	95–100
13.2	25–60
4.75	0–10
2.36	0–5
0.075	0–2

coarse aggregate of these three particle grades should be separately stored. The highway in the material storage area and the mixing area must be hardened to prevent mixing mud. For particles with a size below 0.6 mm in the aggregate, tests for liquid limit index and plastic limit index must be carried out, and the liquid limit index must be lower than 28%, and the plastic limit index must be lower than 9.

The crushing value for aggregate should not be higher than 30%, and the content of needle and strip shaped aggregate should not be higher than 20%.

3.3 Hot Aggregate

For the test highway section, intermittent mixing plant is used, and the mesh gauge of the vibration screen is 3 mm, 6 mm, 11 mm and 19 mm, and when the cold aggregate in the mixing plant is screened for a second time, the size of hot aggregate obtained is 11–19 mm, 6–11 mm, 3–6 mm, and 0–3 mm, and the test results are shown in Table 3.

Table 3. Test results of hot aggregate

Item		Specification of mineral material			
		0–3 mm stone chips	3–6 mm rubbles	6–11 mm rubbles	11–19 mm rubbles
		Hot aggregate passing percent (%)			
Mesh size (mm)	16.00	100.0	100.0	100.0	100.0
	13.20	100.0	100.0	100.0	67.0
	9.50	100.0	100.0	76.8	6.1
	4.75	100.0	84.2	7.1	0.4
	2.36	81.2	12.8	1.7	0.2
	1.18	51.8	3.8	1.1	0.2
	0.60	29.8	1.2	0.7	0.2
	0.30	14.8	0.9	0.6	0.2
	0.15	8.5	0.8	0.4	0.2
	0.075	3.3	0.4	0.2	0.1
Specific gravity (g/cm^3)	Apparent specific gravity	2.559	2.618	2.601	2.619
	Bulk specific gravity	–	2.456	2.449	2.458

3.4 Determination of Proportion in Hot Aggregate Bin

The target mix proportion for the asphalt mixture should be consistent with the requirements in Standard JTG F40-2004 Technical Specifications for Construction of Highway Asphalt Pavements, and moreover, when preparing asphalt mixture, the requirements in the above standard must also be met in the process of design of the production mix proportion, and at the same time the production requirements in the

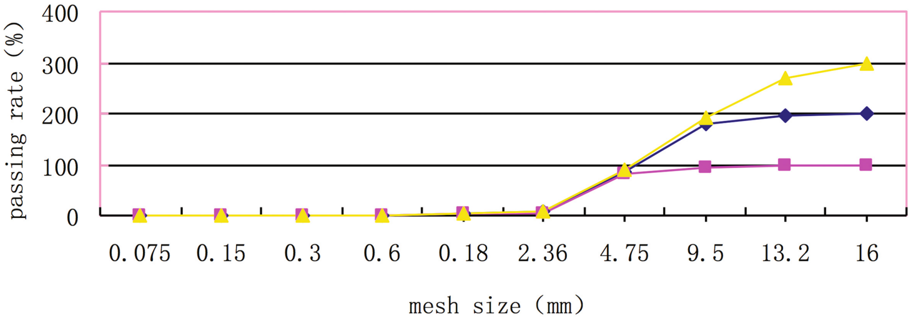

Fig. 1. Curve of mixing of mineral material

construction drawings must be met. It is required to be consistent with the target mix gradation required in production. With the above data, the mixing results of the asphalt mixture are shown in Fig. 1.

3.5 Design of Asphalt Content

In the process of designing the production mix proportion for the asphalt mixture, normally ±0.3% of the optimum asphalt content determined in the target mix proportion is used to carry out Marshall test (4.3%, 4.6%, and 4.9%), and one optimum asphalt content within the production mix proportion of the asphalt mixture is determined with the test results. As the production mix proportion for the highway section is substantially consistent with the target mix proportion in design, to ensure more accurate test results, we used ±0.1% of the target mix proportion in the Marshall test, that is to say, in the tests, the asphalt content was 4.4%, 4.5%, 4.6%, 4.7% and 4.8%.

3.6 Marshall Test

3.6.1 Test of Mechanical Indexes

Marshall tests were carried out by following the mix proportions for the hot aggregate determined above, and for the asphalt content, references were made to the requirements in Standard JTG 052-2000 Test Procedures for Asphalt and Asphalt Mixtures for Highway Engineering, and the maximum specific gravity was provided by the laboratory of the construction organization. The test results are shown in Table 4.

3.6.2 Test Characteristics

Draw plots with the test results obtained in the above tests, with the horizontal ordinate representing the asphalt content, and with the vertical ordinate representing the compacted bulk specific gravity, porosity, voidage, saturation, stability, and flow value respectively, to show the curve relationship between the individual indexes and the content of asphalt, and plots as shown in Fig. 2 are obtained.

Table 4. Test results in Marshall tests for AC-13C asphalt mixture in Loudi test

Content of asphalt (%)	Thickness of test piece (mm)	Compacted bulk specific gravity (g/cm^3)	Maximum specific gravity actually measured (g/cm^3)	Porosity (%)	Voidage (%)	Saturation (%)	Stability (kN)	Flow value (0.1 mm)
4.8	64.1	2.450	2.551	4.0	15.3	74.1	14.6	35.4
4.7	63.2	2.450	2.558	4.2	15.3	72.6	14.1	35.0
4.6	63.6	2.465	2.561	3.8	14.7	74.5	18.7	40.9
4.5	62.6	2.493	2.597	4.0	14.8	73.1	19.2	38.3
4.4	67.0	2.445	2.601	6.0	16.4	63.4	14.3	34.9

3.6.3 Determination of Optimum Asphalt Content

(1) Determination of OAC_1: From plots in Fig. 2, the corresponding maximum value of the compacted bulk specific gravity, the voidage and the stability in the plots is obtained, and the asphalt content corresponding to these maximum values is 4.46%, 4.44% and 4.53%, and we take the arithmetic mean value calculated with these three indexes as OAC_1, and the calculation is conducted with the following formula:

$$OAC_1 = (\alpha_1 + \alpha_2 + \alpha_3)/3 = 4.48\% \quad (1)$$

(2) Determination of OAC_2: From plots in Fig. 2, we know that when the various Marshall mechanical indexes meet the requirements in the technical specifications (not including VMA), the asphalt content should be in the range between 4.2%–5.2%, and we take the mean value of the maximum value and the minimum value in the content range as OAC_2, and the calculation is conducted with the following formula:

$$OAC_2 = (OAC_{\min} + OAC_{\max})/2 = 4.7\% \quad (2)$$

(3) Determination of OAC: We take the arithmetic mean value obtained from OAC_1 and OAC_2 above as the value of OAC, the optimum asphalt content, and the calculation is conducted with the following formula:

$$OAC = (OAC_1 + OAC_2)/2 = 4.59\% \quad (3)$$

At the same time, we can see from the plots in Fig. 2 that, for OAC, the optimum asphalt content, all the corresponding mechanical indexes such as porosity, voidage and flow value meet the requirement in Marshall test.

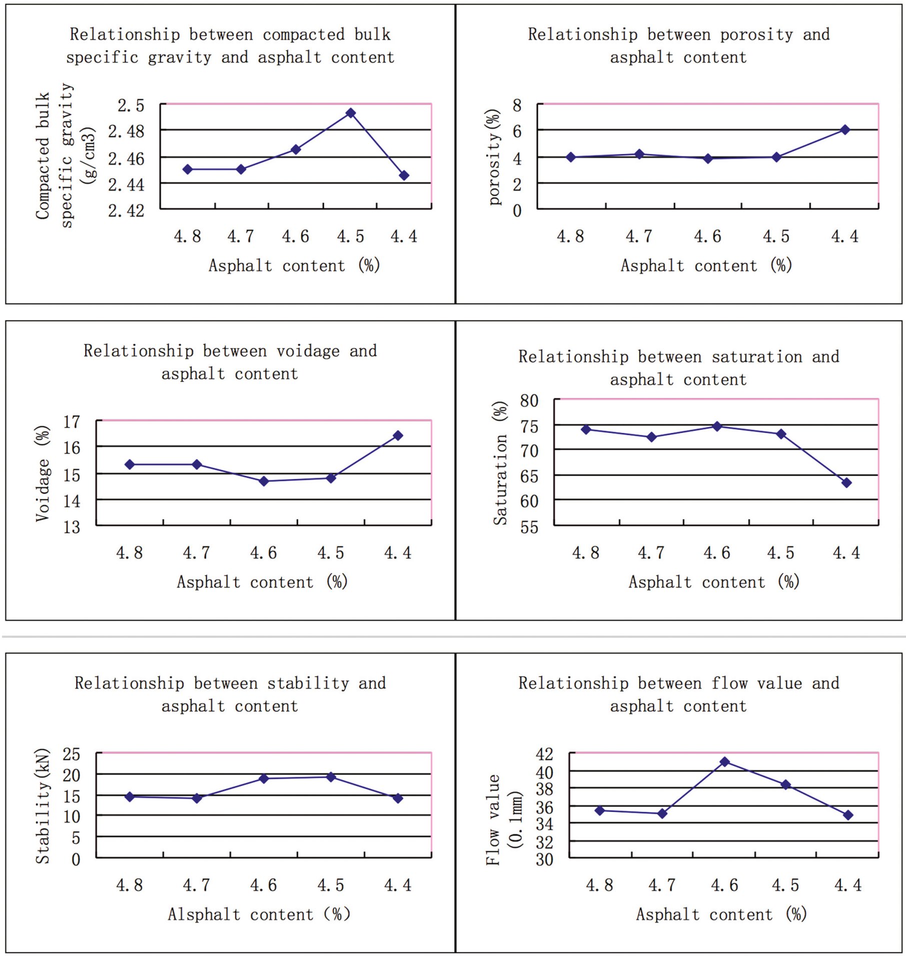

Fig. 2. Characteristic plots in the tests

3.7 Design and Test of the Mix Proportion

As for the design and test of the mix proportion, we followed the optimum asphalt content determined according to the calculations above under standard test conditions, and the tests were carried out by testing the water stability and high temperature stability for the mix proportion, and the test results are as follows:

According to test, when the asphalt mixture is prepared at 4.59%, the optimum proportion of stone and asphalt, Marshall residual stability test meets the requirements in the specifications. Moreover, the result of stability test under high temperature is 3,860 times/mm, and the high temperature stability also meets the requirements in the specifications.

3.8 Test Conclusions

With the mix proportion for asphalt mixture designed with the source data in the construction of Loudi highway section, we carried out tests for them, and took the climate and environment features as well as the construction experiences in Loudi into consideration to determine that the optimum proportion of stone and asphalt in asphalt mixture is 4.59%.

4 Construction Processes and Quality Control

4.1 Mixing

(1) Before mixing, the materials in the mixing site can be used for paving for 3–5 days.
(2) Before mixing every day, check the water content in the aggregate in each area in the site, calculate the mix proportion for the day, and the total content of added water and natural water should be slightly higher than the optimum water content. The actual cement quantity can be about 0.5% higher than the cement quantity determined when designing the materials for the mixture, but the cement quantity actually used and the actual cement quantity in the bottom base layer spot checked on site should be less than 4.0%; and the cement quantity in the base layer should be less than 6.0% (the cement quantity in PCC and CRC base layer can be 6.0%). Meanwhile, when adequately evaluating the surplus strength of construction, start from control by reducing the construction deviation, but do not increase the strength by increasing the quantity of cement used.
(3) When starting to mix every day, take samples from the feeding conveyor belt of the mixer when mixture is fed to check whether the design mix proportion is met, and when formal production is carried out, check the mixing every 1–2 h, and spot check whether the mix proportion and water content are changed. During work under high temperature, the water content in the morning and in the evening should be different, and adjustment should be made in time according to change of temperature.
(4) Equip a mixture bin with a flap-panel funnel, and directly feed mixture from the funnel into trucks and transport. When loading mixture, move the transport truck back and forth, and load mixture by three times, with the height of loaded mixture not higher than 1.5 m to prevent mixture separation. At the same time, take measures to reduce the drop distance when loading mixture.

4.2 Rolling

(1) Use three-wheeled or dual steel wheeled roller and vibration roller for rolling immediately after every paver, and note to roll slightly firstly and forcefully later and statically first and dynamically later, and roll normally for 50 m–80 m every

time. The rolled sections must be clearly marked, and clear boundary marks must be set, and supervisor must be available nearby.

(2) During rolling, follow the procedures and processes determined in the trial paved highway section. Note to use sufficiently stable rolling, and cause no waving and shift during vibration rolling. When compacting, first compact stably (with suitable number of times of rolling, and with the compactness reaching 90%)→Start slight vibration rolling→Then carry out heavy vibration rolling. A nucleonic instrument can be used to check the compactness on site, and when failed, re-compact (note to check the compacting time). When the rolling is completed, use sand replacement method to test the compactness (Table 5).

(3) When rolling with rollers, 1/2 wheel width should be overlapped.

(4) When the roller is reversed and the gear is shifted, operate smoothly, never move the bottom base layer or the base layer, and when initial compaction is completed in rolling for the first time, try to return along the previous route after reversing, and gears are shifted on compacted sections, and when gears are shifted and roller is reversed on the end which is not rolled, the positions must be staggered to form serrations, and where individual swellings occur, workers should be appointed to level.

(5) The recommended driving speed of the roller when rolling is 1.5–1.7 km/h for the 1^{st} and 2^{nd} time of rolling, and the speed is 1.8–2.2 km/h for every subsequent time of rolling.

(6) During the period of constructing the base layer, if the mixture quantity and the number of rolling devices are sufficient, when the bottom layer is rolled for about 100–150 m, the starting position which was just rolled can be immediately returned, and cement and crushed stones on the upper layer can be immediately paved continuously, but the upper layer must be rolled before initial cement coagulation of the bottom layer. Where it has no time to complete such work, this construction method cannot be used. When this method is used, there are advantages as follows: The upper and bottom layer can be bonded well, and there is no need to spray pure liquid cement or dry cement.

(7) Rollers must be parked in a staggered way and with an interval of 3 m, and it is better to park them on a rolled highway section, to prevent any damage to the base layer structure.

(8) Never turn around and brake the roller on any highway section which has been rolled or is being rolled, to ensure that the stable aggregate layer pavement is not damaged.

Ninth, the rolling should be completed before initial cement coagulation and within the delay time determined in tests, and the required compactness should be reached.

Table 5. Test of residual stability of mix proportion

Optimum proportion of stone and asphalt	Stability when the test piece is immersed in water for 0.5 h (KN)	Stability when the test piece is immersed in water for 48 h (KN)	Residual stability (%)
4.59%	12.3	15	16

4.3 Setting Transverse Seam

(1) When paving cement stabilized mixture, work must be carried out constantly with no interruption. When any work is discontinued for over 2 h due to any reason, a transverse seam should be set; and after completion of work every day, the cross section of the seam commenced the next day should also be set with a transverse seam; and when passing through bridges and culverts, in particular open culverts and open passages, a transverse seam should be set on both sides, and it is better to fit the transverse seam on the base layer and the bottom base layer with the end of the bridge end transition slab. Pay special attention to the rolling of the cement stabilized aggregate before the bridge end transition slab.

(2) Where the paving is interrupted for over 2 h and no transverse seam is set, the uncompacted mixture near and under the paver should be removed, and the end which has been rolled and compacted and of which the elevation and levelness meet the requirements is evacuated so that level is perpendicular to the center line of the highway and the cross section is perpendicular to the pavement, and then new mixture is paved.

5 Conclusions

In highway construction, whether the target mix proportion can realize the production mix proportion and the mix proportion during production construction can be controlled are closely related, and for highway engineering, the individual indexes for asphalt highway pavement can be increased through tests designed for mix proportion for asphalt mixture, so the highway is more suitable for the climate and environmental need in the region and the service quality of highway is further improved.

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