Mix Proportion Design of Asphalt Concrete

Xianhu Wu[1], Lingling Gao[2] and Shoujun Du[3]

[1]Hebei University of Science and Technology, China. Email: 835671852@qq.com
[2]Hebei University of Science and Technology, China. Email:dutumu@163.com
[3]Hebei University of Science and Technology, China. Email: 34436371@qq.com

Abstract: Based on the gradation of AC and SMA, this paper designs a new type of anti slide mixture with two types of advantages. Chapter introduces the material selection, ratio of ore mixture ratio design calculation, and determine the optimal asphalt content test and proportioning design of asphalt concrete mix. This paper introduces the new technology of mix proportion.

1. Introduction

At present, there are a lot of large longitudinal slope pavement in mountainous highway, however, we hope that it has better anti sliding performance for the long and steep slope pavement. There are many factors that determine the performance of pavement skid resistance, among which asphalt concrete mix design is one of the key factors. In this paper, the advantages of AC-13 and SMA asphalt concrete are combined to design an economical and practical asphalt concrete mixture ratio.

2. Selection and Testing of Asphalt Concrete Raw Materials

The experiment of coarse aggregate by basalt, fine aggregate selection mechanism of sand filling, limestone slag, asphalt with SBS modified asphalt. Inspection results of raw materials are shown in Table 1, Table2, Table3, Table 4. The experiment of powder of 5 types of ores were sieved, the results shown in Table 1~5.

Table 1. Test results of basalt coarse aggregate

Index	Unit	Test result				Technical requirement
Stone specifications	mm	13.2mm	9.5mm	4.75mm	2.36mm	-
Crushed stone	%	14.1				≤26
Losangeles abrasion loss	%	12.8				≤28
Apparent relative density	g/cm^3	2.867	2.818	2.862	2.775	≥2.60
Gross volume relative density	g/cm^3	2.829	2.782	2.817	2.715	-
Water absorption	%	0.35	0.44	0.48	0.51	≤2.0
Needle particle content	%	5.7	7.6	3.9	3.4	≤15
Washed process<0.075mm Particle content	%	0.5	0.6	0.6	0.7	≤1

Table 2. Test results of fine aggregate

Index	Unit	Test result					Technical requirement
Stone specifications	mm	1.18	0.6	0.3	0.15	0.075	-
Apparent relative density	g/cm3	2.688	2.699	2.705	2.695	2.703	≥2.50
Mud content (less than 0.075mm)	%	0.9	0.9	1.0	1.1	1.1	≤3
Sand equivalent	%	95.1	95.6	95.4	96	95.0	≥60

Table 3. The main technical index of mineral powder

Index	Unit	Test result	Technical requirement
Apparent relative density	g/cm^3	2.781	≥2.50
Water content	%	0.2	≤1
Hydrophilic coefficient	-	0.70	**< 1**
Sand equivalent	%	/	No caking aggregate

Table 4. Technical results of modified asphalt SBS

Test items	Unit	Test value	Specified value
Penetration（25°C, 100g,5s）	0.1mm	71.8	60~80
Penetration index	-	0.296	≥-0.4
Softening point（R & B）	°C	87.2	≥55
15°C Ductility	Cm	≥100	≥100
135°C Kinematic viscosity	Pa.s	2.23	2.0～3
Density	g/cm3	1.080	-
ΔElastic recovery 25°C	（%）	83	≥65

Table 5. Screening results of mineral materials

Screen size(mm)	Pass rate(%)				
	10~15	5~10	3~5	0~3	Powder
16	100	100	100	100	100
13.2	81.55	100	100	100	100
9.5	0.67	95.27	100	100	100
4.75	0.67	25.09	94.67	99.55	100
2.36	0.67	1.04	96.66	81.05	100
1.18	0.67	1.04	92.74	57.44	100
0.6	0.67	1.04	8.39	32.59	95.0
0.3	0.67	1.04	2.32	18.43	88.3
0.15	0.67	1.04	0.5	10.95	81.9
0.075	0.67	1.04	0.33	8.07	67.6

3. Target mix Design

3.1. selection Gradation
As the main body of the mixture, the gradation of aggregate plays an important role in the structure and performance of the mixture. The experiment was conducted based on AC grading, SMA grading, according to the grading range and performance index, mixture was given to study the anti slide pavement gradation advice, specific data is shown in Table 6.

Table 6. Design range of anti slide pavement material

Gradation types	The following screen (mm) quality percentage%									
	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
Grading limit	100	100	80	40	30	27	22	18	15	10
Gradation limit	100	90	55	25	20	16	14	9	8	6

Because of this experiment are not graded fiber stabilizer, so compared to ordinary SMA mixture, the contents of above 4.75mm decreased, the content of fine aggregate increased, gradation of the fine, but not on the formation of interlocking skeleton structure formation important influence. Due to the fine gradation, the aggregate clearance rate will be reduced, and the amount of asphalt will be reduced accordingly. The gradation given in this test is shown in Table 6. The position of the curve in the recommended range of AC, SMA and anti slide pavement is shown in Figure 1~3.
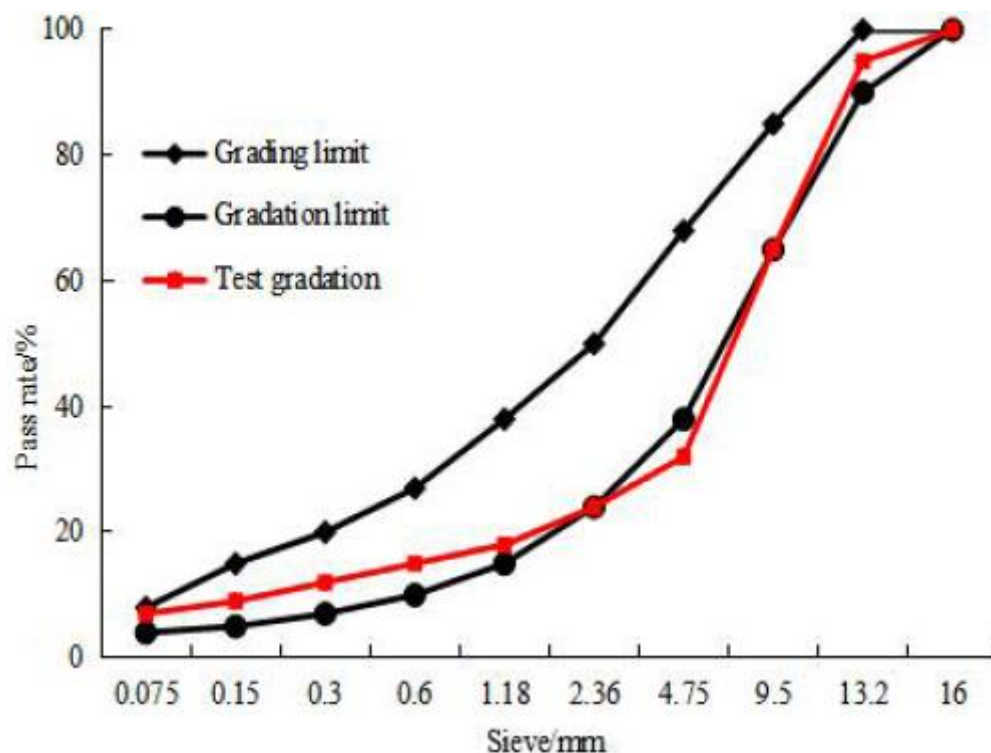

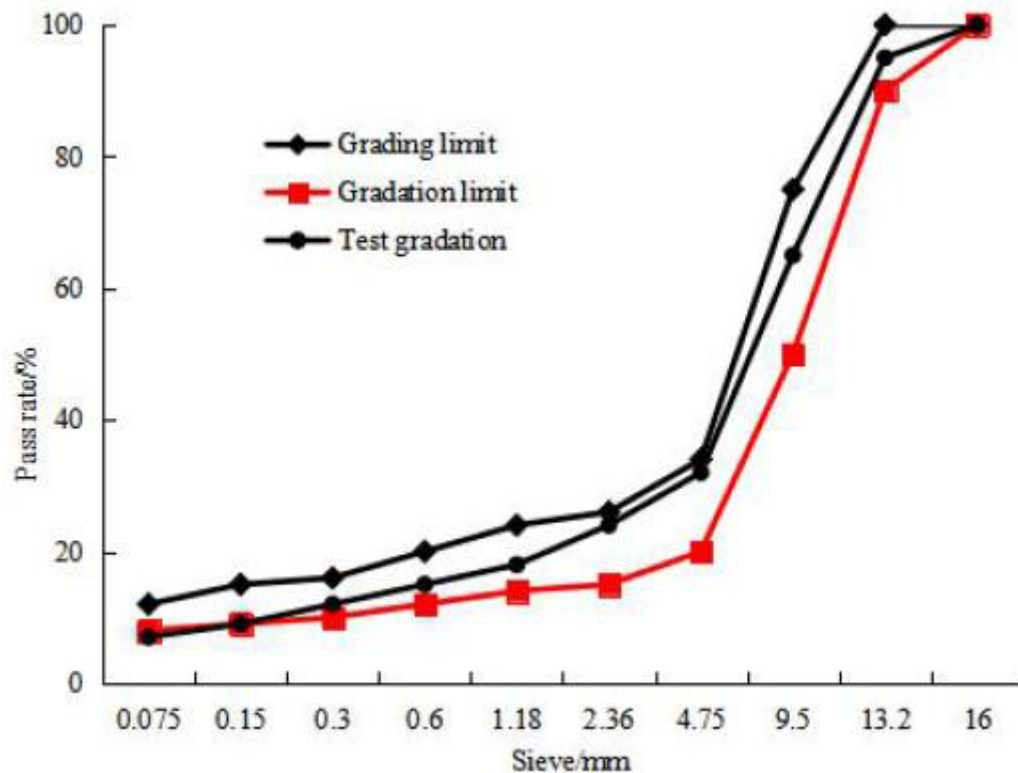**Figure 1.** The location of the test gradation in the AC gradation range

Figure 2. The location of the test gradation in the SMA gradation range
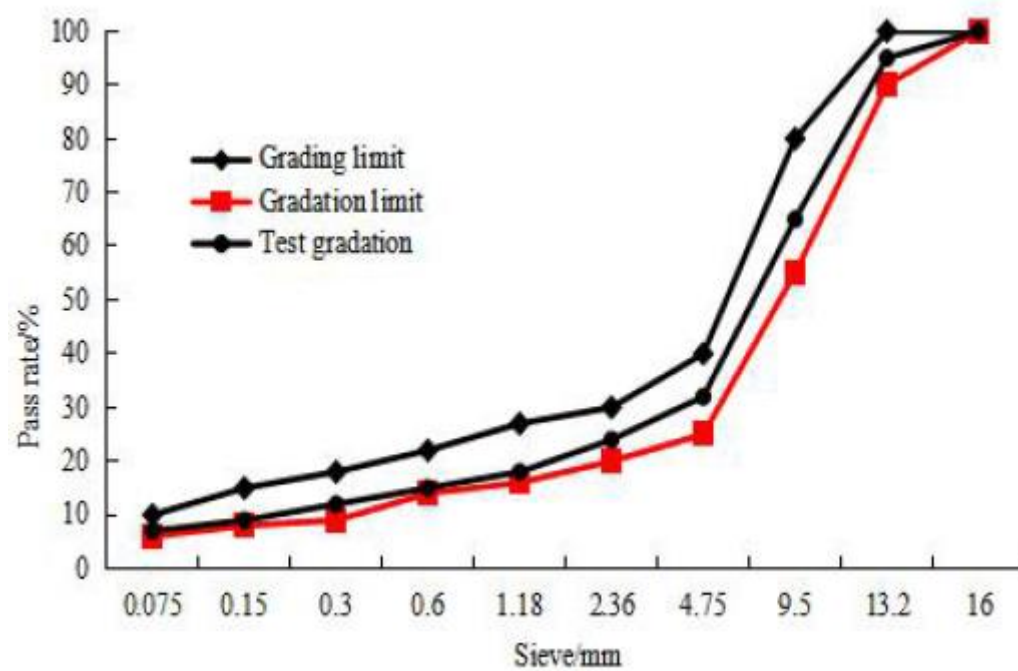

Figure 3. The location of the test gradation in the proposed gradation range

3.2 Determination of Optimum Asphalt Content by Marshall Test
The target mix were 4.9%, 5.3%, 5.7%, 6.1% Marshall test according to the asphalt stone, detection of

different asphalt aggregate ratio of density, porosity, saturation, stability and flow value etc.. According to Marshall and other than the test index of different stone, determine a optimum asphalt content (asphalt aggregate ratio).

After the specimen is formed, the density is measured by the immersion balance method, and the specific data are shown in Table7.The volume parameters are calculated according to the density. Using Marshall stability meter to measure the stability and flow value and other mechanical indicators, technical requirements and test results are shown in Table 8, Table 9.

Table 7 Test specimen quality

Asphalt aggregate ratio（%）	Air quality m_a（g）	Water quality m_w（g）	Dry mass m_f（g）
4.9	1194.4	711.6	1196.3
5.3	1195.8	714.7	1197.7
5.7	1192.5	713.8	1194.5
6.1	1192.6	713.1	1194.0

Table 8. Technical requirements for mix proportion design of Marshall test

Test items	Nnit	Technical requirement Using modified asphalt
Marshall specimen size	mm	φ101.6mm×63.5mm
Marshall compaction times	-	Both sides hit 50 times
Void fraction VV	%	4
Mine clearance VMA (Not less)	%	15.0
Coarse aggregate clearance VCA_{mix} (Not greater)	-	VCA_{DRC}
Asphalt saturation VFA	%	60~70
Stability (Not less)	kN	6.0
Flow value	mm	-

Table 9. Marshall test parameters

Asphalt aggregate ratio（%）	Coarse aggregate porosity VCR_{DRC} (%)	Clearance rate of coarse aggregate in mixture VCAmix (%)	r_f	VV (%)	VMA (%)	VFA (%)	MS (kN)	FL (mm)
4.9	35.4	35.0	2.465	5.5	15.4	64.2	11.57	5.9
5.3	35.4	35.4	2.476	4.6	15.0	69.5	12.63	6.0
5.7	35.4	35.1	2.481	3.9	14.9	73.3	12.45	6.3
6.1	35.4	34.9	2.480	3.4	14.9	77.0	11.83	5.7

Based on the test results in Table 8~9, draw the curve of the relative density, stability, flow value, air VV, VMA, VFA index and the asphalt content of the hair volume, respectively, see Figure 4~9.
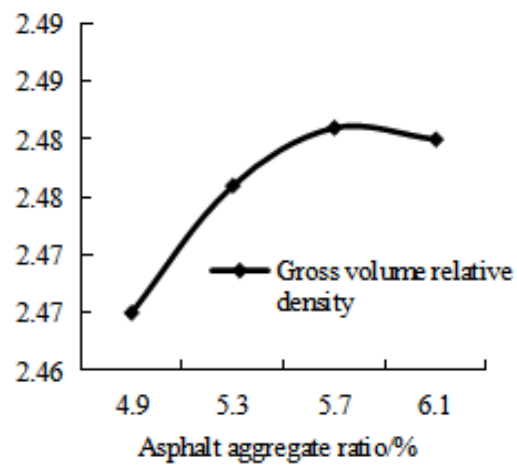
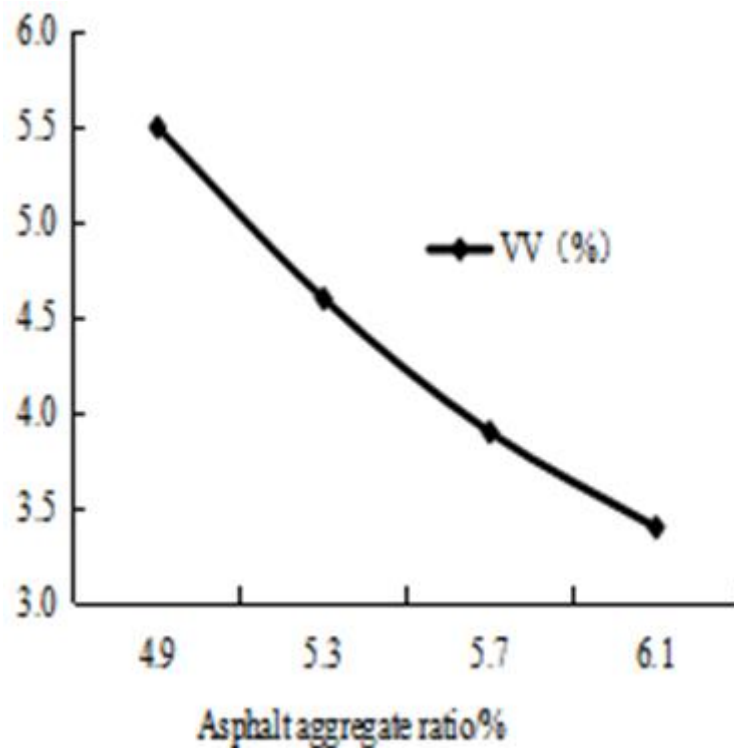**Figure 4.** Relationship between density and aggregate ratio;

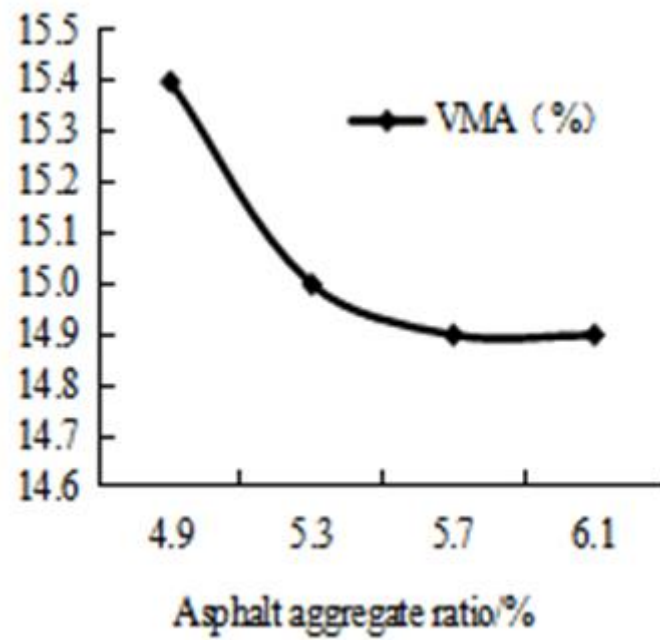**Figure 5.** VV and asphalt aggregate ratio

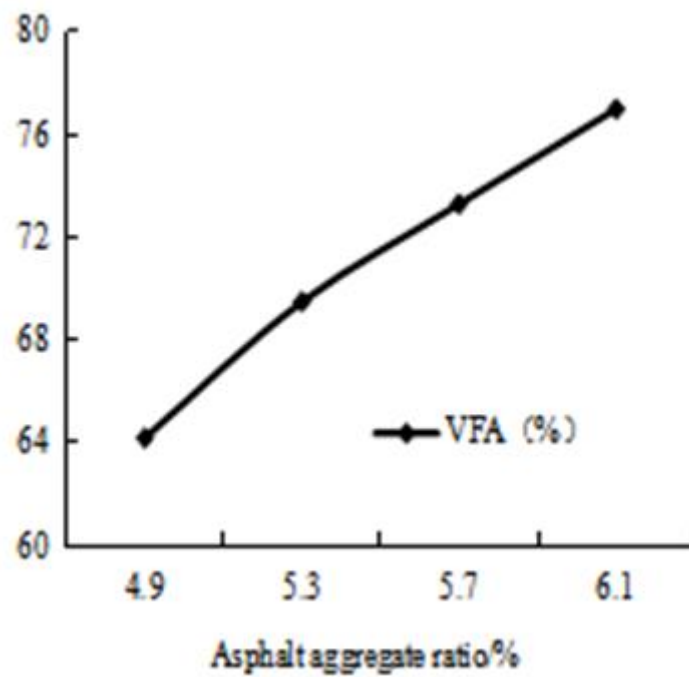**Figure 6.** VMA and asphalt aggregate ratio;

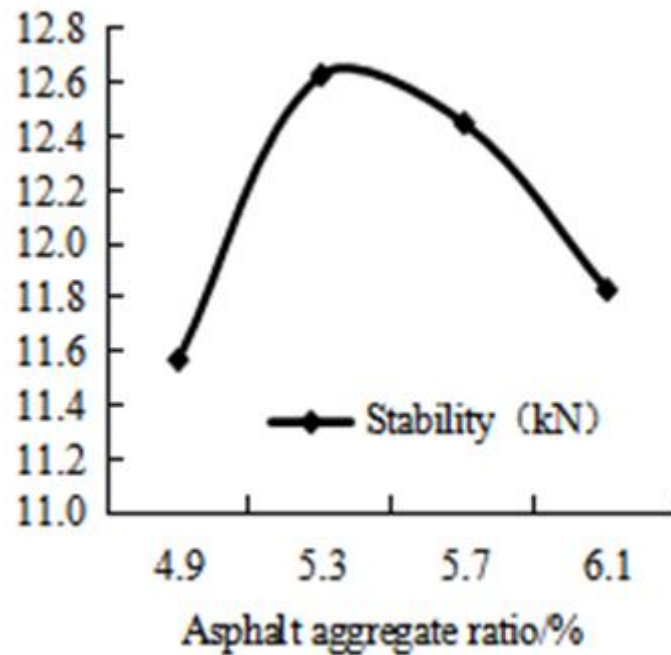**Figure 7.** VFA and asphalt aggregate ratio
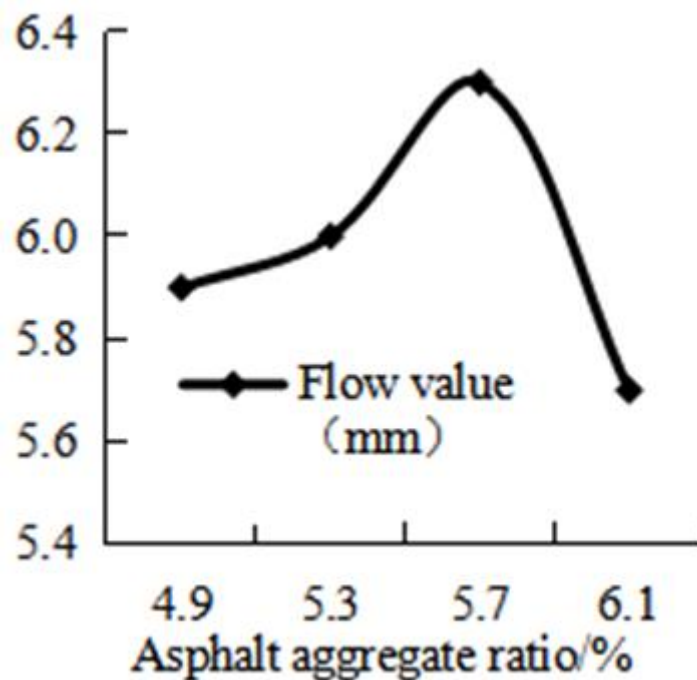
Figure 8. Stability and asphalt aggregate ratio;

Figure 9. Diagram and flow value of asphalt aggregate ratio

The graph can be obtained by density maximum a1=5.4% and stability when the maximum a2=5.4%, void rate was 4%, a3=5.6%, the asphalt content range chosen not covered asphalt saturation range, the average value for 3 so as =5.47%.Since the Table 7 is the recommended indicators, not the strict requirements of the specification, determined, is of no practical significance.So as the optimum asphalt content calculation, the optimum asphalt aggregate ratio is 5.5% design gradation.

4 Mix Design Inspection

The Marshall mixture ratio design of asphalt mixture was carried out by using the volume design method of the test piece of Marshall, and the stability and flow value of the test were not the only index to accept or reject the mixture ratio design.The test results of the stability test is a key evaluation index, comprehensive rationality and residual stability test, leakage test, cantabro test to test the gradation and asphalt content.

The 4.75mm passing rate for the key rate, i.e. 25%, 32%, 40% for 3 groups of mix design, concrete gradation results and grading curve shown in Table 10 and Figure 10.

Table 10. Gradation composition

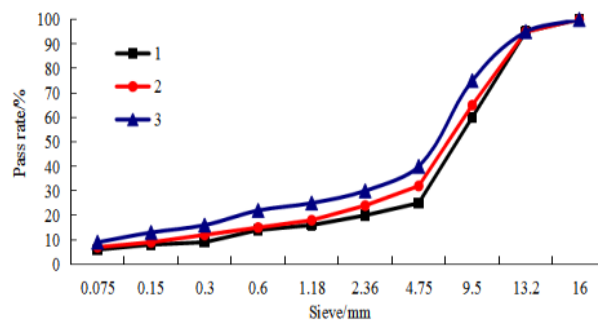| Gradation Types	Through the mesh quality percentage (mm)									
	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
1	100	95	60	25	20	16	14	9	8	6
2	100	95	65	32	24	18	15	12	9	7
3	100	95	75	40	30	25	22	16	13	9

Figure. 10. Gradation curve

From Table 11 and Figure 10 shows that No.1 gradation of coarse, No.3 gradation is fine, so based on the optimum asphalt aggregate ratio on the corresponding changes in aggregate ratio were 5.2%, 5.8%, made Marshall specimen test stability and flow value is reasonable, the key is to verify the dynamic stability will how to change with the gradation. The 300mm * 300mm * 50mm size specimen was measured by a rut tester and its dynamic stability was measured at 60 degrees celsius. Test results are shown in Table 10.

Table 11 Experimental results

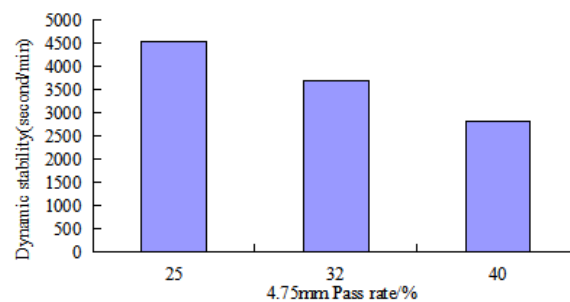| Number	Stability（kN）	Flow value(mm)	Dynamic stability(second/min)
1	10.39	4.29	4532>3000
2	11.70	5.34	3684>3000
3	9.88	4.96	2815<3000

Figure 11. 4.75Pass rate and dynamic stability

It can be seen from Table 11 that there is no necessary relation between the Marshall stability and dynamic stability of the mixture. So when testing its performance, as long as the stability is greater than 6kN.From Figure 11 shows that 4.75mm pass rate is small, the dynamic stability is larger, indicating coarse aggregate content on the dynamic stability has obvious effect, the reason is that the content of coarse aggregate, > degree is bigger, the easier the formation of interlocking skeleton structure, make the mixture with high temperature stability good.

In addition to stability and dynamic stability, residual stability test, leakage test, cantabro test results page should meet the requirements, to number 2 as an example, to test the results as shown in Table 12, Table 13.

Table 12. Immersion Marshall test results

Specimen	Stability of 0.5h（kN）	Stability of 48h(kN）	Residual stability(%)
1	9.52	8.71	91>80
2	9.81	9.04	92>80
3	11.90	11.21	94>80

Table 13. Leakage and dispersion test results

Specimen	Leakage analysis	Scattering loss(%）
1	0.06<0.1	12.3<15
2	0.07<0.1	11.6<15
3	0.06<0.1	13.0<15

5. Production Mix Design

In the design of the target mix ratio, due to the screening of various specifications of the aggregate is too cumbersome and time-consuming, so according to the screening results of the various sets of production mix design. However, no matter how to change the proportion of the 5 kinds of aggregate, cannot match with the target mix ratio. Description of aggregate gradation used in the test is not very reasonable, so in the actual construction, should adjust the aggregate rate by itself, improve the levels of mineral aggregate gradation, the construction will be carried out through the development of 5 construction aggregate proportion, greatly improve work efficiency.

6. Conclusions

This paper through the research of AC, SMA grading, gives a mixture of anti slide the proposal and determine the target gradation range, design gradation, using the Marshall test method, to determine the optimum asphalt aggregate ratio, and verify the rationality of the physical and mechanical indexes. Through rutting test, Xie lueneburg asphalt leakage test, cantabro test performance test of asphalt

mixture, pointed out that the dynamic stability and stability are not necessarily related, as well as the coarse aggregate effect on dynamic stability, the dynamic stability in a certain extent with the increase of coarse aggregate.

7. References

[1] JTGF422005. technical specification for construction of highway asphalt pavement S.
[2] Liang Qiyong. Design method of mix proportion of asphalt mixture [J]. Shanxi architecture, 2003, (4): 118-119.
[3] JTGF40-2004, technical specification for construction of highway asphalt pavement.
[4] AASHTO. Standard practice for Designing Stone Matrix Asphalt (SMA). 1998.
[5] Peng Bo. Influencing factors and variation law of pavement skid resistance. North China Communications, 2011, (8): 9-10.
[6] Kanhdal P. S,Koehler W S,The Alsphalt Handbook. The Alsphalt Institute Manual Series No4, 1989.