

Study on the Shear Performance of Different Gradation Types of Asphalt Mixture Based on Triaxle Test

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Abstract. In order to evaluate the shear performance of asphalt mixtures with different gradation types, two kinds of substances, glycerol and asphalt, were used as the media of mixture for triaxle test. The test results show that the shear performance of the mixture is greatly influenced by the gradation of the mixture. It also shows that the more the gradation structure is embedded and squeezed, the greater the internal friction angle, the stronger the shear resistance, and by improving the performance of the cementing material can also improve the shear resistance of the mixture.

1. Introduction

As one of the main deteriorations in highway asphalt pavement, rutting jeopardizes driving easement and traffic safety. Rutting is such a kind of shear flow deformation born of shortage of shear strength resulting in failing to stick up to the shear stress caused by traffic load. However, till now the researches on shear strength of asphalt mixture have not been that consummated to be brought into the design specification. Regarding the severity of rutting distress, the shear properties of asphalt mixtures are studied through triaxle shear test. The shear strength index and criteria are discussed in this dissertation [1]-[2].

2. Gradation

In order to evaluate and compare the shear performance of asphalt mixture of the different grading types of mixture, this paper chooses the dense gradation(AC-13), broken gradation (SMA-13) [3]and EME-14according to the gradation of asphalt mixture design guidelines for the design of French[4]-[8]. Two different aggregates of basalt and limestone are selected for the type of SMA-13 gradation. Two structures of continuous and discontinuous gradation are selected for EME-14 asphalt mixture, which are recorded as EME-14I and EME-14II. In this paper, five typical gradation structures are selected. The gradation is shown in Table 2.1.

Table 2.1. Mixture synthesis gradation

Gradation	Passing rate (%)										
	19	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
AC-13	100	96	89.4	77.0	46.3	29.8	21.1	16.2	11.7	8.7	5.5
SMA-13	100	100	88.6	67.5	26.5	19.7	17.2	15.8	14.7	14.0	10.8



SMA-13 basalt	100	100	93.9	66.3	26.3	19.5	17.2	15.6	14.4	13.9	10.2
EME-14I	100	100	90.8	74.7	51.4	32.8	24.3	19.8	15.9	13.6	9.1
EME-14II	100	100	84.3	58.5	50.6	32.7	24.2	19.7	15.9	13.6	9.0

3. Triaxle Shear Test [9]

In this paper, the triaxle shear test is used to test the internal friction angle value, and it is more intuitively analyzed and compared the influence of the structure of the gradation on the performance of the mixture. The three axis compression test is carried out by the advanced universal material test system (UTM-100). The test parts are made by vibration molding. Test process and test parts are shown in Figure 3.1. The diameter of the molded specimen is 100mm and the height is 200mm. The loading rate of the test is 1.27mm/min and the confining pressure is 0kPa, 138kPa and 276kPa respectively. The shear test is carried out under these three different confining pressures.



Figure 3.1 Forming and testing before and after test of three axis test

3.1. Determination of the Dosage of Glycerol

In order to compare and analyze the influence of the aggregate structure on the shear resistance of the mixture, the uniform thickness of the asphalt film is $9 \mu\text{m}$. Glycerol instead of asphalt is used in this experiment. The purpose is to reduce the influence of cohesive force C on the shear strength of mixture, so as to highlight the effect of aggregate internal friction angle on shear performance. According to the difference of the structure and composition of gradation, different amounts of glycerol were converted. The conversion formula is as follows.

$$SA = \sum (P_i \times FA_i) \quad (1)$$

$$P_{be} = \frac{r_b \times SA \times DA}{10} \quad (2)$$

Where: SA : Specific surface area of aggregate, m^2/kg ;

P_i : Percentage pass percentage of various particle sizes, %;

FA_i : Surface area coefficient of aggregates corresponding to various particle sizes;

DA : Thickness of bitumen film, $9\mu\text{m}$;

r_b : Relative density of bitumen (25 /25 C), dimensionless;

P_{be} : Amount of effective bitumen, %.

From the above formula, the amount of different glycerol in each gradation can be calculated. The result is shown in Table 3.1.

Table 3.1. The amount of glycerol in different gradation structures

Gradation	AC-13	SMA-13	SMA-13 (basalt)	EME-14I	EME-14II
Effective glycerol dosage (%)	4.8	6.8	6.6	6.7	6.7

3.2. Triaxle Shear Test of Glycerol Mixture

Due to the particularity of glycerol, the experiment was carried out at normal temperature. The results of the test are shown in table 3.2 as shown below.

Table 3.2. The data of three axis test results for different gradation of glycerol mixture

Gradation	Confining Pressure (Kpa)	σ_1 (Kpa)	σ_3 (Kpa)	Shear Index		
				C (Kpa)	φ (°)	R ²
AC-13	0	367	0	59.82	33.31	0.990
	138	464.62	138			
	276	724.38	276			
SMA-13	0	417.25	0	56.94	38.52	0.993
	138	641.1	138			
	276	875.5	276			
SMA-13 (basalt)	0	442.75	0	58.84	39.48	0.991
	138	671.55	138			
	276	893.55	276			
EME-14I	0	429.7	0	60.45	37.62	0.990
	138	648.3	138			
	276	796.55	276			
EME-14II	0	469.2	0	61.15	38.29	0.992
	138	629.0	138			
	276	1003.3	276			

From table 3.2, it can be seen that in the three gradation types, the internal friction angle of SMA-13 mixture is the largest, indicating that the grading structure of this type of mixture is interlocked skeleton. For the SMA-13, the internal friction angle of the basalt SMA-13 is the largest, which is 2% more than the limestone mixture. From the results we can say that the aggregate lithology, have certain effects on the frictional resistance of mixture. Because basalt has better angularity and wear resistance than limestone, the internal friction angle of aggregate in its mixture has greater internal friction angle, and its shear performance is better.

For the AC-13 type continuous dense gradation of internal friction angle of the minimum is 33.31%, 18% less than the SMA mixture. This shows that the AC-13 mixture in the inner frictional resistance is relatively small, easy to slip between the aggregate.

In addition, we can see from the table that the cohesive force C is almost the same. It is proved that it is scientific and feasible to study the influence of the friction angle of the aggregate on the strength of the mixture by using glycerol instead of asphalt. The cohesiveness produced by glycerol is very small, about 60kpa. The effect of glycerol is to reduce the effect of cohesive force on the shear resistance of the mixture, so this test of the shear strength of the mixture mainly depends on the internal friction force between the aggregate. At the same time, we see from the experimental data that cohesion C has a certain regularity. Under the same glycerol film thickness, the cohesion of EME mixture is the largest, indicating that cohesive force C has the greatest influence on the shear strength of EME mixtures, and indicating that the shear strength of EME mixtures is mainly from cohesion C. By comparing the C and the phi values of the EME continuous and discontinuous gradations, it is found that the internal friction angle of the EME discontinuous gradation is relatively large. Although the EME mixture gradation structure does not have a large degree of discontinuous SMA mixture, we may conclude that in the case of increasing C value, by optimizing the grading structure of EME mixture and make it has better shear performance.

3.3. Triaxle Shear Test of Asphalt Mixture

In this experiment, three different gradations of AC-13, SMA-13 and EME-14II were selected. Three kinds of gradation were made respectively by 70 ordinary asphalt, SBS modified asphalt and 30 hard bitumen. Triaxle shear test was done under optimum asphalt content. The results of the test are shown in Table3.3.

Table 3.3. The data of three axis test results for different gradation of asphalt mixture

Gradation	NO.	Confining Pressure (Kpa)	σ_1 (Kpa)	σ_3 (Kpa)	Shear Index		
					C (Kpa)	ϕ (°)	R ²
AC-13	1	0	630	0	162.7	32.3	0.991
		138	1100.6	138			
		276	1662.3	276			
	2	0	732	0			
		138	1159.8	138			
		276	1686.2	276			
SMA-13	1	0	654	0	171.4	38.7	0.990
		138	1264	138			
		276	1578	276			
	2	0	628.8	0			
		138	1358	138			
		276	1654	276			
EME-14	1	0	634	0	189.7	35.2	0.993
		138	1258.4	138			
		276	1767	276			
	2	0	651.8	0			
		138	1225	138			
		276	1674.8	276			

From Table 3.3, we can see the size of the cohesion C and the internal friction angle are the two main factors affecting the shear properties of the asphalt mixtures. The cohesion C of the EME-14 asphalt mixture is the largest. It is 16.5% and 10.6% larger than the AC-13 and SMA-13 asphalt mixtures respectively. From the analysis data, it can be clearly concluded that the use of low grade 30 asphalt mixture has greater contribution to asphalt mixture strength than that of matrix asphalt 70 or SBS modified asphalt. Low grade asphalt can effectively improve cohesion C value and improve the strength and shear resistance of asphalt mixture. At the same time, it can be seen from the table that the internal friction angle of SMA-13 asphalt mixture is maximum, which is 19.8% and 10% higher respectively than that of AC-13 and EME-14 asphalt mixtures respectively. It shows that the embedded and squeezed structure of the broken gradation of SMA-13 plays a major role. Therefore, we can conclude that the more the grading structure is embedded, the greater the internal friction angle of the aggregate is, the stronger the strength of the asphalt mixture is, and the stronger the shearing resistance is.

4. Hamburg Test

The hamburger test [10] was carried out for the three types of mixture to verify the high temperature resistance performance of the asphalt mixture. The results of the test are shown in Table 4.1.

Table 4.1. The results of the Hamburg test

Mixture Type	Temperature	No.	20000 Rutting Depth /mm
AC-13	60°C	1	5.59
	60°C	2	5.49
SMA-13	60°C	1	4.64
	60°C	2	4.52
EME-14	60°C	1	4.37
	60°C	2	4.41

The experimental results show that the high temperature rutting performance of EME-14 asphalt mixture is better because of the low grade asphalt 30 improving cohesion C and the formation of the skeleton structure. It promotes the strength of asphalt mixture when the cohesive force C and internal friction angle increase simultaneously, and the EME-14 asphalt mixture has a good performance of high temperature resistance to rutting.

5. Conclusion

1. It is scientific and feasible to study the influence of the friction angle of the aggregate on the strength of the mixture as the medium of glycerol instead of the asphalt.
2. There are two ways to improve the strength of asphalt mixture, one is to enhance cohesion C by using low grade asphalt to improve the performance of asphalt binder, the other is to increase the internal friction angle, to enhance the embedment of asphalt mixture grading structure for optimizing the grading structure.
3. Through the study on the gradation structure of the high modulus EME-14 continuous and discontinuous mixture, it is found that the shear performance of the discontinuous graded mixture is better than the continuous gradation. So we can take the optimization of continuous gradation, which is the broken gradation between 6.3mm and 4mm of the sieve to enhance the internal friction angle. At the same time, the relative bituminous binder is used to make the asphalt mixture have high shear strength, and the advantages of water permeable, easy compaction and so on.

6. Reference

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