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To cite this article: Zhaohui Sun *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **562** 012027

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# Emulsified Asphalt Dosage Determination Method of AC-13 Cold-Mixed Asphalt Mixture

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**Abstract.** At present, there is no test method specification for the optimum emulsified asphalt dosage of cold-mixed asphalt mixture. The current specifications are mainly for hot mix asphalt and cold recycled asphalt mixture. Based on the previous studies, this paper initially selected the AC-13 group as the best grading, discussed the mixing and health environment during the cold-mixed asphalt mixture test piece forming, the optimum emulsified asphalt dosage for the AC-13 cold-mixed asphalt mixture is determined by the Marshall test and the water-immersed Marshall test, it was verified by dry and wet splitting test and high temperature rutting test. The results show that the application of the Marshall test and the water-immersed Marshall test can determine the optimum amount of emulsified asphalt for cold-mixed asphalt mixture. It can provide reference for the determination of the best emulsified asphalt dosage for cold-mixed emulsified asphalt mixture.

## 1. Introduction

China's current regulations are mainly designed for hot-mixed and cold recycled asphalt mixture. There is still no method for determining the optimum amount of emulsified asphalt for cold-mixed asphalt mixture. This paper selects AC-13 grade based on the preliminary work of the research group. The design of cold mixed emulsified asphalt mixture was carried out by the Marshall test and the water immersion Marshall test at 25°C and 40°C water bath respectively, and verified by dry and wet split test and high temperature rutting test. The research results can provide reference for the determination of the best emulsified asphalt for cold-mixed emulsified asphalt mixture.

## 2. Raw Material Testing

Fuxin clay quarry gravel and stone chips are used in cold-mixed emulsified asphalt mixture, emulsified asphalt is produced by Xinmin Highway Asphalt Mixing Plant and 42.5 grade ordinary silicate cement is produced by Shenyang Hongxiang Cement Co., Ltd. The results of raw material testing are shown in Table 1 to Table 3. The properties of the tested raw materials meet the specifications.



**Table 1.** Asphalt test results

Test item		Unit	Quality Requirements	Test result
Demulsification speed			Slow split or split	Slow split
Particle charge			Cation(+)	Cation
Sieve residue (1.18mm sieve)		No greater than	%	0.1
Viscosity	Engela viscosity E25			2 ~ 30
	25°C Saybolt viscosity Va		s	7 ~ 100
evaporation the remains	Residue content	No less than	%	62
	Solubility	No less than	%	97.5
	Penetration(25°C)		0.1mm	50 ~ 300
	Ductility(15°C)	No less than	cm	40
Adhesion with coarse aggregate, wrapping area		No less than		2/3
Coarse and fine-grained aggregate mixing test				Uniform
Normal temperature storage stability	1d	No greater than	%	1
	5d	No greater than	%	5
				4.2

**Table 2.** Coarse aggregate test results

Test items	Technical requirements	Test results
Stone crush value (%)		
Loss of wear in Los Angeles	$\leq 30$	19.5
Apparent relative density		
Los Angeles wear loss	$\leq 35$	17.0
Apparent relative density	$\geq 2.45$	2.743
Water absorption (%)	$\leq 3.0$	0.69
Needle particle content(%)	$\leq 20$	6.2
Washing method < 0.075mm particle content(%)	$\leq 1$	0.1
Soft stone content(%)	$\leq 5$	2.6

**Table 3.** Fine aggregate test results

Test items	Technical requirements	Test results
Apparent relative density	$\geq 2.45$	2.743
Mud content (content less than 0.075mm) (%)	$\leq 5$	13.9
Sand equivalent(%)	$\geq 50$	75.6

### 3. Aggregate Gradation Design

Select the AC-13 gradation as shown in Table 4. Refer to Technical Specifications for Highway Asphalt Pavement Recycling(JTG F41-2008), the percentage of the dry mass of the remainder of the mixture after the emulsified asphalt of cold recycled mixture is converted into pure emulsified asphalt is generally 1.5%-3.5%, and the dosage of active filler such as cement generally does not exceed 1.5%. The amount of cement used in this paper refers to the cold regeneration specification, and the cement is mixed with a large value of 1.5%.

**Table 4.** AC-13 cold-mixed asphalt mixture grading

Gradation	Percentage of each mesh pass /%										
	19	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
AC-13	--	100	95	70	41.5	30	22.5	16.5	12.5	8.5	6

#### 4. Determination of Optimum Moisture Content and Maximum Dry Density

The compaction test of the synthetic minerals is carried out according to the current method of Highway Geotechnical Test Procedures (JTG E40) T0131 to determine the optimum water content. When determining the optimal water consumption, the test amount of emulsified asphalt is set to 4%, and the water content is tested for compaction test. When the maximum dry density is obtained, the water content of the mixture at this time is the optimum water content OWC. The test results are shown in Table 5.

**Table 5.** AC-13 grade with heavy-duty compaction test results

Water content(%)	Dry density(g/cm <sup>3</sup> )	Optimal mixing water consumption(%)	Maximum dry density(g/cm <sup>3</sup> )
4	2.125		
5	2.163		
5.5	2.197	5.5	2.197
6	2.134		
7	2.102		

As can be seen from Table 5, it is preliminarily concluded that the optimum water content of AC-13 grade is 5.5%, and the maximum dry density is obtained at this time.

#### 5. Determination of the Amount of Emulsified Asphalt

According to the empirical formula of the optimum fluid volume of asphalt mixture obtained from the research of emulsified asphalt, the cation emulsified asphalt research group of the Ministry of Communications calculated the addition amount of emulsified asphalt. This addition amount is only the initial dosage of the emulsion.

The formula is as follows:

$$P = 0.06A + 0.12B + 0.2C$$

In the middle: P—The percentage of emulsion quality and dry mass of all minerals (%);

A—Mineral content of mineral material larger than 2.5mm (%);

B—Content of mineral material with a particle size between 2.5mm and 0.074mm in mineral material (%);

C—The content of mineral material with particle size less than 0.074mm in mineral material (%).

Referring to the above calculation formula, the mixing test of the mixture is carried out after the initial addition of the emulsified asphalt. The mixing amount of the mixed material is gradually increased from 0.3% of the mass of the mineral material without adding water, and the mixing state of the mixture is observed during the mixing of the mixture. The emulsion can be evenly wrapped on the surface of the aggregate. The amount of the additive is based on the optimal amount of water. When the actual mixture shows no agglomeration, no segregation, etc., the optimum amount is calculated and the water content in the emulsion is calculated. The optimum moisture content of the feed, which is the total amount of water in the emulsion as well as the added water.

The molding of emulsified asphalt cold-mixed has certain uniqueness, according to formula calculation and mixing test to determine the amount of emulsified asphalt added, control the water content unchanged, adjust the amount of emulsion, make test pieces, carry out Marshall test, and get the best emulsion dosage.

After determining the optimum moisture content, mixtures of 4%, 4.5%, 5%, 5.5% and 6% different ratio of emulsified asphalt to stone were prepared. Under the condition of guaranteeing the total moisture content unchanged, samples were formed through Marshall test and the optimum ratio of emulsified asphalt to stone was determined according to the specifications. The test results are shown in Table 6.

**Table 6.** Test results of mechanical index of AC-13 emulsified asphalt mixture at room temperature

Ratio of emulsified asphalt to stone(%)	Gross volume density( $g/cm^3$ )	stability(K N)	Flow value(0.1mm)
4	2.210	7.58	1.70
4.5	2.232	10.36	2.13
5	2.318	11.57	2.86
5.5	2.271	9.89	3.01
6	2.262	8.04	3.50

**Table 7.** Test results of mechanical index of 40 °C water bath of AC-13 emulsified asphalt mixture

Ratio of emulsified asphalt to stone(%)	Gross volume density( $g/cm^3$ )	stability(K N)	Flow value(0.1mm)
4	2.510	6.37	1.64
4.5	2.532	7.57	2.03
5	2.618	8.69	2.89
5.5	2.571	7.89	3.21
6	2.562	5.64	3.79

Emulsified asphalt also contains a certain amount of water. If this part of water is not considered, the water content of the mixture is different when the amount of emulsified asphalt is different, that is, the mixture is not formed at the optimum water content, so the amount of emulsified asphalt is tested. At the same time, the amount of water added should be changed accordingly to ensure the best water consumption is accurate. Marshall and water-immersed Marshall test results are shown in the table 6 and 7. As can be seen from Table 6 and Table 7, the optimum ratio of emulsified asphalt to stone is 5%.

## 6. Test Verification

Dry and wet splitting strength test

Dry and wet splitting strength test was done according to Technical Specifications Highway Asphalt Pavement Recycling, the test results are shown in the table 8.

**Table 8.** The results of dry and wet splitting strength test

Ratio of emulsified asphalt to stone(%)	Health age	splitting strength	Wet splitting strength	Dry and wet splitting strength ratio
5	2d	0.62	0.49	77.8

## 7. Rutting Test

The rutting test method is used to evaluate the high temperature stability of emulsified asphalt mixture. The rutting test was developed by the British Institute of Transport and Roads. The test piece is subjected to a specified number of round-trip rolling under certain temperature and load conditions, the mixture is deformed and the deformation amount is analyzed to evaluate the high temperature deformation resistance of the mixture. The biggest feature of the test method is that it directly reflects the driving condition of the wheel on the asphalt road. The test process can change the temperature, load, size and thickness of the test piece. The test result is relatively intuitive and can simulate the actual situation of the road.

At present, there is no standard specification for the rutting test of emulsified asphalt mixture in China. In particular, there is no uniform regulation on the molding of test pieces. Using the current hot mix asphalt mixture rutting test method, the test piece is easily destroyed in the test, and a qualified test piece is not obtained, and the obtained test result cannot accurately reflect the anti-deformation ability of the emulsified asphalt mixture. In this paper, correct on the test method of ordinary hot mix asphalt mixture rutting according to the characteristics of emulsified asphalt mixture by consulting the papers and materials related to emulsified asphalt mixture at home and abroad, The specific steps are as follows:

(1) According to the method in the test procedure, calculate the amount of emulsified asphalt mixture required for forming the slab, and mix the mixture according to the design grade and load the test mold.

(2) Rolling is carried out on a wheel mill, and it is rolled and formed twice. For the first time, 14 round trips were crushed, and the direction of rolling was recorded. After 2 hours, the second rolling was carried out, and 7 round trips were rolled.

(3) After the crushing is completed, the test piece is placed in a blast oven at 60 °C for 48 hours, and taken out from the oven for 2 days at room temperature.

(4) The test piece that has been cured is placed in a constant temperature oven at 60 °C for 5 to 6 hours, and then the rutting test is carried out at 60 °C.

The test results are shown in the table 9.

**Table 9.** The test results of dynamic stability of AC-13 emulsified asphalt mixture

Ratio of emulsified asphalt to stone (%)	Dynamic stability	Standard requirements for dynamic stability of hot mix asphalt mixture
5	968	800

It can be seen from Table 9 that the dynamic stability of the AC-13 cold mix cold asphalt mixture meets the AC-13 hot mix asphalt standard when the optimum ratio of of emulsified asphalt to stone is 5.0%.

## 8. Conclusion

The results show that the application of Marshall test and water-immersed Marshall test can determine the optimum amount of emulsified asphalt for cold- mixed asphalt mixture, and recommend the best ratio of emulsified asphalt to stone of AC-13 cold-mixed emulsified asphalt mixture to 5.0%, cement dosage is 1.5%, the optimum water content is 5.5%. It can provide reference for the determination of the best emulsified asphalt for AC-13 cold-mixed emulsified asphalt mixture. The paper clarifies a link that is not clear in the specification. In the process of determining the optimal emulsified asphalt, the calculation method of adding water is: keep the total water consumption unchanged, and the water in the emulsified asphalt should be deducted when calculating the added water amount.

## 9. References

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