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The High Temperature Performance Prediction Model of AC-13 Asphalt Mixture

Zhaohui Sun¹, Huaizhi Wang¹, Gang Chen² and Guangpeng Zhang¹

1. The Traffic Engineering School of Shenyang Jianzhu University, China

2. Science and Technology Research Institute of Shenyang Railway Bureau, China
happyforevernicety@126.com

Abstract. 12 sets of AC-13 asphalt mixture were designed and tested for high temperature stability. According to fractal theory and dynamic stability test results, the correlation equations of fractal dimension and dynamic stability index were established. Using this equation to predict high temperature stability of AC-13 asphalt mixture, it is expected reducing the amount of test, it can provide a reference for engineering design.

1. Introduction

In the hot northern regions of summer, the high temperature stability of asphalt mixtures has always been an important reference for judging the performance of roads. The design of asphalt mixture has a great influence on the performance of asphalt pavement. The gradation distribution of asphalt mixture is closely related to the road performance. This paper applies the fractal theory to analyze the internal relationship between the two, through multiple groups of AC-13 asphalt mixture rutting test, the high temperature performance prediction model of AC-13 asphalt mixture was established for design reference.

2. The Raw Material Performance Test

Liaohe Class A No. 90 road petroleum asphalt, limestone mineral powder produced by Liaoyang Xiaotun Wang Bao Fulong Quarry, Grade 42.5 ordinary portland cement produced by Shenyang Hongxiang Cement Co., Ltd. are selected to apply in AC-16 mixture. Emulsified asphalt is produced by Xinmin Highway Asphalt Mixing Plant, The aggregate of AC-16 asphalt mixture use limestone gravel produced by Liaoyang Xiaotun victory quarry. 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 technical index

Detection index	Unit	Test value	Specification requirements
Penetration (25°C, 100g, 5s)	0.1mm	86.3	80-100
Ductility (15°C)	cm	>100	≥50
Softening Point (R&B)	°C	45.9	≥45

Grade A No.90 road petroleum asphalt and limestone were tested in accordance with the requirements of the road usage.



Table 2. Coarse aggregate test results

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

Table 3. Fine aggregate test results

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

3. AC-13 Asphalt Mixture Design

The design scheme of AC-13 asphalt mixture aggregate gradation is shown in the table 4.

Table 4. The design scheme of AC-13 asphalt mixture aggregate gradation

Grading number	Percentage of quality pass (%)										Optimal asphalt dosages/%
	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075	
AC-13-1	100	95	76.5	53	37	26.5	19	13.5	10	6	4.39
AC-13-2	100	95	76.5	45.5	30.5	20.75	14.5	10.25	7.5	5	4.39
AC-13-3	100	95	76.5	60.5	43.5	32.25	23.5	16.75	12.5	7	4.39
AC-13-4	100	92.5	72.25	53	37	20.75	14.5	10.25	8.5	7	4.40
AC-13-5	100	92.5	72.25	45.5	30.5	26.5	23.5	16.75	10	6	4.38
AC-13-6	100	92.5	72.25	60.5	43.5	26.5	19	13.5	7.5	5	4.39
AC-13-7	100	97.5	80.75	53	37	32.25	23.5	16.75	7.5	5	4.38
AC-13-8	100	97.5	80.75	45.5	30.5	26.5	19	13.5	12.5	7	4.38
AC-13-9	100	97.5	80.75	60.5	43.5	20.75	14.5	10.25	10	6	4.40
AC-13-10	100	96	76	42	28	21	14	11	9	6	4.39
AC-13-11	100	95	70	41.5	30	22.5	16.5	12.5	8.5	6	4.39
AC-13-12	100	97.5	71	46	35	27	20	14	8.5	6	4.39

4. High Temperature Performance Test

Rut specimens cured at room temperature are put into the curing box at 60°C. The curing time is not less than 5 hours and should not exceed 12 hours. The contact pressure of rut test tires is 0.7 MPa. The experimental results are shown in Table 5.

Table 5. The results of AC-13 asphalt mixture rutting test and gradation fractal dimension(times/mm)

Grading number	Grading fractal dimension D	Coarse aggregate fractal dimension D _c	Fine aggregate fractal dimension D _f	Dynamic stability DS (times/mm)
AC-13-1	2.4878	2.4683	2.4762	1182
AC-13-2	2.4369	2.3523	2.4918	1955
AC-13-4	2.4729	2.4801	2.6078	3230
AC-13-6	2.4494	2.5781	2.3815	1586
AC-13-7	2.4643	2.4569	2.2936	913
AC-13-8	2.5206	2.3409	2.5533	2587
AC-13-9	2.4537	2.5549	2.5865	946
AC-13-10	2.4723	2.2969	2.5729	1200
AC-13-11	2.4843	2.337	2.5205	1462
AC-13-12	2.4881	2.4188	2.4397	1023

Note: The coefficient of variation of rutting data in the table is less than 20%.

5. Road Performance Model

The rutting test results of meeting high temperature stability requirements in the Northeast of China and the corresponding fractal dimension are summarized in Table 5.

As can be seen from table 5, the fractal dimension range of meeting the requirement of dynamic stability is $D=[2.4369, 2.5206]$, $D_c=[2.2969, 2.5781]$, $D_f=[2.2936, 2.6078]$. There is a correlation between the high temperature performance of asphalt mixture and fractal dimension. The regression analysis is done after the abnormal point (AC-13-4, 7, 8, 9, 12 is eliminated to get more accurate regression model. The ternary linear regression model is shown in formula (1).

$$DS=54278.8-4524.2D-6250.3D_c-10690.1D_f \quad (1)$$

The regression coefficient $R^2=0.980$

This can be shown that the three element linear regression model can be established between dynamic stability and fractal dimension, and the regression coefficient is higher, the correlation analysis is done by data in Table 5, the correlation analysis results are shown in Table 6.

Table 6. The correlation of dynamic stability and fractal dimension

	DS	D	D _c	D _f
DS	1.000	-0.856	0.041	-0.339
D	-0.856	1.000	-0.184	0.405
D _c	0.041	-0.184	1.000	-0.951
D _f	0.339	0.405	-0.951	1.000

It can be seen from table 6, the correlation between the fractal dimension and DS ordered from the big to small is $D>D_f>D_c$. The influence of fine aggregate fractal dimension on dynamic stability of AC-13 asphalt mixture is relatively large, but that of the coarse aggregate fractal dimension is relatively small. The correlation model between the fractal dimension and the dynamic stability can be established. The related model is shown in formula (2) and (3).

$$DS=31889-15011D+2689D_f \quad (2)$$

The regression coefficient $R^2=0.961$

$$DS=35190.5-13680.9D \quad (3)$$

The regression coefficient $R^2=0.771$

6. Model Selection

The correlation model of dynamic stability and fractal dimension established is included in Table 7. It can be seen from table 7 that the prediction accuracy of the model 1 and 2 are higher, Thus, the model 1 and 2 are recommended to predict the dynamic stability.

Table 7. Prediction model of dynamic stability

No.	Model expression	Regression coefficient R^2
1	$DS=54278.8-4524.2D-6250.3D_c-10690.1D_f$	0.980
2	$DS=31889-15011D+2689D_f$	0.961
3	$DS=35190.5-13680.9D$	0.771

7. Model Validation

AC-13 asphalt mixture test scheme is shown in table 8.

Table 8. AC-13 asphalt mixture test scheme

Screen size (mm)	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
Percentage of quality pass(%)	100	95	71	42	32	21.5	15.9	10.3	8.5	6

The gradation fractal dimension is calculated. $D = 2.471$, $D_c = 2.367$, $D_f = 2.539$ can be get, the $DS = 1156$ times / mm was obtained by substituting them into the high temperature performance prediction model 1, the $DS = 1619$ times / mm was obtained by substituting them into the high temperature performance prediction model 2. The test value is 1426 times / mm, relative errors are all within 20%. It can be seen that the prediction of model 1 is underestimated and safe.

8. Conclusions

By the results of the above experiments and the model, the prediction model of high temperature performance of AC-13 mixture is recommended, it can reduce the amount of testing, improve the working efficiency, and it can offer reference for engineering design.

9. Acknowledgements

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