High Temperature Performance Prediction Model of GAC-20 Modified Asphalt Mixture

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Abstract. 25 groups of GAC-20 modified asphalt mixture are designed by referencing the orthogonal design method, the high temperature rutting test are carried out , the related model of the fractal dimension and the high temperature performance evaluation index dynamic stability is established by using fractal theory. The high temperature performance of GAC-20 asphalt mixture can be predicted according to the gradation designed. This can reduce the test workload, improve work efficiency, and offer the reference for engineering design.

Introduction

The design of asphalt mixture has an important influence on asphalt pavement. There are a certain correlation between the distribution of asphalt mixture gradation and fractal theory. The correlation analysis can be carried out between the fractal dimension and the road performance. In this paper, we analyze the correlation between the fractal dimension and the high temperature performance evaluation index of asphalt mixture, and establish the correlation model between the fractal dimension and the pavement high temperature performance evaluation index. The road high temperature performance prediction model can be obtained.

The Raw Material Performance Test

Liaohe petroleum asphalt grade A No.90, which is widely used in the northeast of China and the basic performance test results are shown in Table 1, the basic performance test results of SBS modified asphalt are shown in Table 2. [1]

Table 1 Matrix 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

Table 2 SBS Modified asphalt technical index

Detection index	Unit	Test value	Specification requirements Conclusion
Penetration(25°C, 5s, 100g)	0.1mm	83.6	80~100
Softening Point(R&B)	°C	52.0	≥50
Ductility(5°C, 5cm/min)	cm	>100	≥40
Kinematic viscosity(135°C)	Pa·s	2.7	≤3
Elastic recovery (25°C)	%	91.2	≥90

The coarse and fine aggregate of GAC-20 mixture use limestone gravel produced by Liaoyang Xiaotun victory quarry. The basic performance test results are shown in table 3.[3]

HIGH TEMPERATURE Performance Test

Using the orthogonal test method for reference to design 25 groups of GAC-20 modified asphalt mixture, the rutting test and water stability test were carried out under the wheel pressure is 0.84MPa.

Table 3 Technical index of limestone coarse aggregate

Material specification(mm)		**26.5-31.5**	**19-26.5**	**16-19**	**13.2-16**	**9.5-13.2**	**4.75-9.5**
Technical index	Standard value	Test value					
Crushing value(%)	≤24	15					
Apparent relative density(T/m^3)	≥2.5	2.729	2.726	2.73	2.718	2.729	2.732
Water absorption rate(%)	≤2.0	0.12	1.18	0.26	0.28	0.38	0.62
Adhesion with asphalt(Grade)	≥4	4					
Consistency(%)	≤8	8					
Content of needle and sheet granular(%)	≤12	12					
<0.075Particle content(%)	≤ 1	0.3		0.3	0.3	0.3	0.3

Grade A No.90 road petroleum asphalt, SBS modified additives and limestone were tested in accordance with the requirements of the road usage.
Test results are shown in table 4.

The technical requirements for the dynamic stability of asphalt mixture rutting test are different according to different climate zones and the type of asphalt and mixture in the current specification, Climate zoning in the Northeast of China is belonging to the 2-1 (hot in summer and severe cold in winter) area and 2-2 (hot in summer and cold in winter) area, due to the wheel pressure 0.84 MPa was adopted in rutting test, dynamic stability should be reduced from relevant literature to meet greater than or equal to 2000 times / mm. Therefore, the high temperature stability of GAC-20 mixture with the grading number of 3, 8, 11, 13, 9, 17 and 24 can meet the requirements.

Table 4 The results of GAC-20 Rutting test(times/mm)

Gradation	**The optimum asphalt aggregate ratio /%**	DS_0
GAC-20-1	4.26	1182
GAC-20-2	4.26	1432
GAC-20-3	4.40	3103
GAC-20-4	4.27	1892
GAC-20-5	4.27	593
GAC-20-6	4.29	1869
GAC-20-7	4.30	712
GAC-20-8	4.30	2192
GAC-20-9	4.21	2042
GAC-20-10	4.26	4733
GAC-20-11	4.24	2413
GAC-20-12	4.32	1645
GAC-20-13	4.30	3124
GAC-20-14	4.26	1079

Gradation	The optimum asphalt aggregate ratio /%	DS_0
GAC-20-15	4.26	1207
GAC-20-16	4.26	602
GAC-20-17	4.27	4827
GAC-20-18	4.27	1261
GAC-20-19	4.29	—
GAC-20-20	4.30	1690
GAC-20-21	4.23	—
GAC-20-22	4.21	805
GAC-20-23	4.26	905
GAC-20-24	4.24	3745
GAC-20-25	4.32	595

Note:”-”indicate the test data is not listed in the table, it needs further verification.

HIGH TEMPERATURE Performance Model

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

Table 5 GAC-20 grading fractal dimension and dynamic stability data

Grading	Grading fractal dimension D	Coarse aggregate fractal dimension D_c	Fine aggregate fractal dimension D_f	Dynamic stability DS (times/mm)
GAC-20-3	2.5665	2.4692	2.4484	3103
GAC-20-8	2.5739	2.5044	2.4017	2192
GAC-20-9	2.5367	2.4487	2.5468	2042
GAC-20-10	2.5369	2.6229	2.3127	4733
GAC-20-11	2.5026	2.3988	2.4749	2413
GAC-20-13	2.4535	2.5041	2.3420	3124
GAC-20-17	2.5394	2.4417	2.3571	4827
GAC-20-24	2.5835	2.5044	2.4632	3745

As can be seen from table 5, the fractal dimension range of meeting the requirement of dynamic stability is D=[2.4535,2.5835], Dc=[2.3988,2.6229], Df=[2.3127,2.5468].There is a correlation between the high temperature performance of asphalt mixture and fractal dimension. First of all, three element linear regression is analyzed between the fractal dimension Dree element linear regression model of dynamic stability and fractal dimension is established. The residual chart of dynamic stability and fractal dimension is drawn by the software MATLAB in Figure 2 to check out the abnormal data. The regression analysis is done after the abnormal point is eliminated to get more accurate regression model.

It can be seen From Figure 2, except for the second data, the residual of the rest data is close to the zero point, and the confidence interval of the residuals contains zero. The confidence interval contains zero point, which shows that the regression model can meet the original data. The second data can be regarded as abnormal points in the data analysis, it should be removed when the regression analysis is done again.That is excluding the second data, three element linear regression analysis is done to obtain the correlation model of dynamic stability. The regression coefficient R^2=0.937, As can be seen in formula (2).

$$DS=3206.5+16056.8D-2605.5Dc-14025.4Df \tag{2}$$

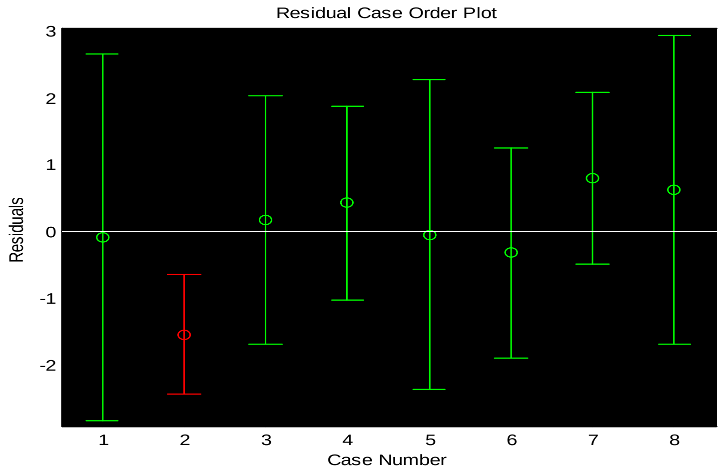

Figure 2The residual chart of dynamic stability and fractal dimension

Table 6 The correlation of dynamic stability and fractal dimension

	DS	D	D_c	D_f
DS	1.000	0.123	0.283	0.072
D	0.123	1.000	-0.621	0.477
D_c	0.283	-0.621	1.000	-0.685
D_f	0.072	0.477	-0.685	1.000

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, so there are the correlation between dynamic stability and the fractal dimension, the correlation analysis is done by data in Table 5, the correlation analysis results are shown in Table 6.

It can be seen from table 6, the correlation between the fractal dimension and DS ordered from the big to small is $D_C > D > D_{f,}$. The influence of coarse aggregate fractal dimension on dynamic stability is relatively large, but the correlation coefficient of DS and the coarse aggregate fractal dimension is relatively small. The correlation between D_f and DS is lower, the correlation between the stability and the coarse aggregate is the largest through the analysis of the correlation between the dynamic stability and the fractal dimension, so the correlation model between the fractal dimension of the coarse aggregate and the dynamic stability can be established. The related model of dynamic stability DS and D_c is shown in formula (3).

$$DS=42052D_c^2-203689D_c+249584 \quad (3)$$

The regression coefficient R^2=0.2639

The correlation among dynamic stability and fractal dimension D, Dc is relatively larger than that of dynamic stability and Df. The correlation model of dynamic stability and two fractal dimensions D,Dc is established. As is shown in formula (4).

$$DS=-22878.3-862.6D+11277.1D_c \quad (4)$$

The regression coefficient R^2=0.6575

The correlation model of dynamic stability and two fractal dimensions D_c,D_f is established. As is shown in formula (5).

$$DS=20934.2+1360.2D_c-8702.0D_f \quad (5)$$

The regression coefficient R^2=0.4733

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 three element linear model is higher than the others. Thus, the model 1 is recommended to predict the dynamic stability by model selection.

Table 7 Prediction model of dynamic stability

No.	Model expression	Regression coefficient R^2	Characteristics
1	$DS=3206.5+16056.8D-2605.5D_c-14025.4D_f$	0.937	The regression coefficient is higher and the analysis of the factors is more comprehensive
2	$DS=42052D_c^2-203689D_c+249584$	0.2639	The regression coefficient is low and the analysis of the influence factors is relatively simple
3	$DS=-22878.3-862.6D+11277.1D_c$	0.6575	The regression coefficient is lower
4	$DS=20934.2+1360.2D_c-8702.0D_f$	0.4733	The regression coefficient is lower

Conclusions

By the results of the above experiments and the model, the prediction model of high temperature performance of GAC-20 mixture is $DS=3206.5+16056.8D-2605.5D_c-14025.4D_f$;
The water stability prediction model is $DSR=-1.2919+0.3012D+0.3414D_c+0.2462D_f$ or $DSR=-1.0483+0.4426Dc+0.3553Df$.
These models are used to predict the performance of GAC-20 mixture, it can reduce the amount of testing, improve the working efficiency, and can be used for engineering design.

Acknowledgements

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