Low Temperature Performance Prediction Model of AC-25 Asphalt Mixture
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ABSTRACT

25 sets of AC-25 asphalt mixture were designed by means of orthogonal design method. The bending and low temperature creep tests of the AC-25 were carried out. The related models of the fractal dimension and the road performance evaluation index including low temperature bending failure strain εB and bending strength RB are established by using fractal theory. The model can be used to predict the low temperature performance of AC-25 asphalt mixture according to the design gradation, which can reduce the test workload and improve the working efficiency, so as to provide the reference for engineering design.

PREFACE

Asphalt mixture low-temperature performance is an important component of road performance, especially for the northeastern region. If the correlation model between asphalt mixture fractal dimension and low temperature performance evaluation index can be established, the low temperature performance of asphalt mixture can be predicted through the gradation fractal dimension to reduce the amount of test work. Based on the correlation analysis between the fractal dimension and the evaluation index of low temperature performance, the low temperature performance prediction model is established and the low temperature performance prediction model of asphalt mixture is recommended through the comparison of multiple models.

THE RAW MATERIAL PERFORMANCE TEST

Asphalt mixture use limestone gravel produced by Liaoyang Xiaotun victory quarry. The basic performance test results are shown in table 1.[1] The coarse aggregate of AC-25 asphalt mixture use limestone gravel produced by Liaoyang Xiaotun victory quarry. The basic performance test results are shown in Table 2.[3]
### Table 1. Asphalt technical index.

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

### Table 2. 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/m³) | ≥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 | 0.3 |

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

**MODEL BUILDING**

The experimental results and the corresponding fractal dimensions of the low temperature stability requirements in Northeast China are summarized in Table 3.

It can be seen from Table 3 that the range of fractal dimension satisfying the low-temperature bending strain is D=2.3638~2.5767, Dc=2.3852~2.6701, Df=2.4208~2.5809.

The ternary linear regression model is established through taking εB as the dependent variable, taking D, Dc, Df as the independent variables, the abnormal point in the data is found by the analysis of residual error. The regression residual error chart of the low temperature bending strain and fractal dimension are obtained by regression analysis of low-temperature bending strain and fractal dimension by MATLAB program, as is shown in Fig.1.
Table 3. The fractal dimension of AC-25 asphalt mixture and the low temperature test data.

| Gradation number | Average maximum load (N) | Average span deflection (mm) | Bending strain ε₉ (με) | Bending strength Mpa | D   | Dc  | Df  |
|------------------|--------------------------|-----------------------------|-----------------------|---------------------|------|------|------|
| AC-25-6          | 615                      | 1.30                        | 3352                  | 5.84                | 2.5492| 2.5639| 2.5367|
| AC-25-9          | 599                      | 1.20                        | 4838                  | 6.12                | 2.5767| 2.3998| 2.5259|
| AC-25-13         | 315                      | 0.59                        | 2427                  | 4.51                | 2.4917| 2.5823| 2.4256|
| AC-25-15         | 689                      | 1.18                        | 5261                  | 6.22                | 2.3638| 2.6517| 2.4208|
| AC-25-18         | 908                      | 1.04                        | 3762                  | 7.80                | 2.5607| 2.5098| 2.5809|
| AC-25-20         | 321                      | 0.76                        | 2526                  | 3.36                | 2.4900| 2.6701| 2.5583|
| AC-25-22         | 892                      | 0.51                        | 2376                  | 7.88                | 2.4382| 2.6100| 2.5414|
| AC25-GC          | 735                      | 0.73                        | 2539                  | 6.57                | 2.4853| 2.3852| 2.5754|

Figure 1. The residual diagram of low temperature bending strain and fractal dimension for AC-25 asphalt mixture.

It can be seen from Figure 1 that the data 3 and data 4 are abnormal data, the correlation model of the bending strain and the fractal dimension is established by the regression analysis, as is shown in formula (1).

ε₉ = 4795.6 + 13656.5D - 1789.2Dc - 12305.8Df  
(1)

Regression coefficient R² = 0.907

The ternary linear correlation models of bending strain and three fractal dimensions are established, the correlations of data in Table 4 are analyzed by using SPSS software to obtain the correlation between the bending strain and fractal dimension, as is shown in Table 4.

Table 4. Correlation between low temperature bending failure strain and fractal dimension of AC-25 asphalt mixture.

|         | ε₉   | D   | Dc  | Df  |
|---------|------|-----|-----|-----|
| ε₉      | 1.000| 0.919| -0.208| 0.398|
| D       | 0.919| 1.000| -0.206| 0.196|
| Dc      | -0.208| -0.206| 1.000| -0.317|
| Df      | 0.398| 0.196| -0.317| 1.000|
It can be seen from table 4, the correlation sequence of low temperature bending strain $\varepsilon_B$ and the fractal dimension $D$, $D_C$, $D_f$ from large to small is $D > D_f > D_C$, indicating that the relation between the aggregate fractal dimension and bending strain is relatively large, the correlation between $\varepsilon_B$ and $D_C$ is relatively small.

The correlation model of $\varepsilon_B$ and $D$ is established, as is shown in the formula (2).

$$\varepsilon_B = 126061D^2 - 619425D + 763267 \quad (2)$$

Regression coefficient $R^2 = 0.9874$

The correlation model of $\varepsilon_B$ and $D, D_f$ is established, as is shown in the formula (3).

$$\varepsilon_B = -31074.0 + 11208.0D + 2309D_f \quad (3)$$

Regression coefficient $R^2 = 0.894$

Similarly, the ternary linear regression models of bending strength is established, as is shown in the formula (4).

$$R_B = -37.8719 - 7.0199D + 4.1322D_C + 20.4183D_f \quad (4)$$

Regression coefficient $R^2 = 0.7758$

For the correlation between the bending failure strength and the fractal dimension, the data in Table 3 are analyzed by SPSS software. The relationship between the bending failure strength $R_B$ and the fractal dimension is shown in Table 5.

Table 5. Correlation between low temperature bending strength and fractal dimension of AC-25 asphalt mixture.

|      | $R_B$ | $D$ | $D_C$ | $D_f$ |
|------|------|-----|-------|-------|
| $R_B$ | 1.000| -0.032| -0.052| 0.676 |
| $D$   | -0.032| 1.000| -0.629| 0.565 |
| $D_C$ | -0.052| -0.629| 1.000| -0.609 |
| $D_f$ | 0.676| 0.565| -0.609| 1.000 |

It can be seen from Table 5 that the correlation between the bending strength $R_B$ and the fractal dimension $D_f$ of the fine aggregate gradation is relatively large. Therefore, a correlation model between the bending strength and the fractal dimension $D_f$ of the fine aggregate gradation can be established. As is shown in the formula (5) and (6).

$$R_B = 55.2D_f^2 - 264.2D_f + 321.5 \quad (5)$$

Regression coefficient $R^2 = 0.4307$

$$R_B = -23.6249 + 11.9451D_f \quad (6)$$

Regression coefficient $R^2 = 0.4564$. The regression coefficient is low.

**MODEL SELECTION**

As described above, a correlation model of low-temperature bending strain, bending strength and fractal dimension is established, and the results are summarized in Table 6. It can be seen from Table 7 that the prediction accuracy of model 1 and 2 is relatively high, and the model 1 and 2 are recommended as the prediction model of low temperature bending strain and the model 4 is recommended as the prediction model of low temperature bending strength through multi-model comparison.
Table 6. The prediction model comparison of bending strain and bending strength for AC-25 asphalt mixture.

| Model No. | Model expression | Regression coefficient R² | Advantages and disadvantages |
|-----------|------------------|----------------------------|-----------------------------|
| 1         | εB=4795.6+13656.5D-1789.2Dc-12305.8Df | 0.907                      | Higher regression coefficient, Factor analysis is more comprehensive |
| 2         | εB=126061D²-619425D+763267 | 0.9874                     | Higher regression coefficient, Factor analysis is single |
| 3         | εB=-31074.0+11208.0D+2309Df | 0.894                      | Higher regression coefficient |
| 4         | R_B=-37.9+7.0D-3.6D+20.4Df | 0.7758                     | Lower regression coefficient |
| 5         | R_B=55.2D²-264.2D+321.5 | 0.4307                     | Low regression coefficient |
| 6         | R_B=-23.6249+11.9451Df | 0.4564                     | Low regression coefficient |

CONCLUSION

The correlation model recommended between the fractal dimension and the evaluation index of low temperature performance can be used to predict the low temperature performance of AC-25 modified asphalt mixture according to the design gradation, which can reduce the test workload and improve the working efficiency

ACKNOWLEDGEMENT

This research was financially supported by the Natural Science Foundation of China (51178278)

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