The Gradation Test Prediction Model of AC-25 Asphalt Mixture

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Abstract. Correlation models of fractal volume parameters and fractal dimension of AC-25 asphalt mixture are established.The volume parameters of AC-25 asphalt mixture can be predicted by the known fractal dimension, which is advantageous to test the grading and determine the structure type of asphalt mixture. Thereby the workload can be reduced and the design can be optimized.

1. Derivation and calculation of fractal volume index

The coarse aggregate fractal volume V_c, coarse aggregate fractal voidage V_{co} and the fractal volume V_f offine aggregate in the coarse aggregateare analyzed according to the early research results of the gradation test method of asphalt mixture based on fractal theory. The fractal volume index is shown in formula [5] (1), (2) and (3).

The fractal volume of coarse aggregate in the whole V_C

$$V_C = -\frac{M_O}{\rho}\int_{4.75}^{x_{\max}} \frac{(3-D_c)}{x_{\max}^{3-D_C}}dx = \frac{x_{\max}^{3-D_c} - 4.75^{3-D_c}}{\rho x_{\max}^{3-D_C}} M_O \tag{1}$$

Type: xmax is maximum particle sieve size; D_C is coarse aggregate fractal dimension; Mo is the overall quality percentage; R is coarse aggregate tamping compaction density; The coarse aggregate fractal voidage Vco :

$$V_{CO} = \frac{V_C - M_C / \rho_c}{V_c} \tag{2}$$

Type: Mc is mass percentage of coarse aggregate; ρc is synthetic density of coarse aggregate, V_f: is fractal volume of fine aggregate in coarse aggregate.

The fractal volume V_f of fine aggregate in the coarse aggregate

$$V_f = -V_C\int_{0.075}^{4.75} \frac{(3-D_x)x^{2-D_f}}{26.5^{3-D_C} - 4.75^{3-D_c}}dx = \frac{4.75^{3-D_f} - 0.075^{3-D_f}}{26.5^{3-Dc} - 4.75^{3-Dc}} V_c \tag{3}$$

Prediction model of grading test for AC-25 mixture

Model establishment

Table 1. AC-25 physical index data

Gradation	Coarse aggregate mass fraction (%)	Fine aggregate mass fraction (%)	Filler quality (%)	Gross bulk density of coarse aggregate(g/cm^3)	Gross bulk density of fine aggregate (g/cm^3)	Bulk density of asphalt mixture (g/cm^3)	The fractal dimension of gradationD	The fractal dimension of coarse aggregateD_c	The fractal dimension of fine aggregateD_f
1	50	43	7	2.728	2.738	2.433	2.5872	2.6241	2.5518
2	54	40	6	2.728	2.737	2.433	2.5492	2.5639	2.5367
3	58	37	5	2.728	2.736	2.432	2.4984	2.4821	2.5057
4	62	34	4	2.728	2.735	2.455	2.4495	2.3906	2.4877
5	66	31	3	2.728	2.730	2.430	2.3928	2.2871	2.4745
6	54	42	4	2.729	2.740	2.433	2.4264	2.6333	2.4352
7	58	39	3	2.729	2.730	2.429	2.3687	2.5731	2.4745
8	62	32	6	2.728	2.734	2.432	2.5922	2.4913	2.5689
9	50	45	5	2.727	2.741	2.436	2.5767	2.3998	2.5259
10	66	27	7	2.728	2.729	2.461	2.5185	2.2963	2.5583
11	58	38	4	2.729	2.732	2.453	2.5564	2.6425	2.6060
12	62	32	6	2.728	2.743	2.452	2.4917	2.5823	2.4256
13	66	29	5	2.729	2.743	2.433	2.4441	2.5005	2.5130
14	72	47	3	2.728	2.724	2.428	2.3085	2.4090	2.4492
15	54	39	7	2.727	2.734	2.420	2.6117	2.3046	2.5689
16	62	35	3	2.730	2.740	2.432	2.3638	2.6517	2.4208
17	66	30	4	2.728	2.738	2.450	2.5973	2.5915	2.5581
18	50	43	7	2.728	2.732	2.420	2.5607	2.5098	2.5809
19	54	40	6	2.728	2.723	2.429	2.508	2.4182	2.6248
20	58	37	5	2.727	2.740	2.451	2.4641	2.3147	2.3781
21	66	29	5	2.730	2.729	2.429	2.4900	2.6701	2.5583
22	50	46	4	2.729	2.723	2.428	2.4382	2.6100	2.5414
23	54	43	3	2.727	2.750	2.440	2.3761	2.5282	2.2882
24	58	36	6	2.727	2.734	2.433	2.6156	2.4366	2.5940
25	62	31	7	2.727	2.732	2.380	2.5798	2.3332	2.5809

The physical parameters were measured and calculated for the coarse and fine aggregate of AC-25 graded. The basic data were showed in table 1.

Vc, Vco and Vf are calculated according to formula (1), (2) and (3).The coarse aggregate can form an effective framework when the fractal voidage Vco of coarse aggregate is larger than the fractal volume V_f of the fine aggregate in the coarse aggregate, the skeleton of coarse aggregate can be formed. The Vco and V_f value are obtained from the 25 groups of AC-25 mixture, and the gradation data of the skeleton formed can be shown in table 2.

First, the three elements linear regression model is established between the coarse aggregate fractal void rate Vco and the fractal dimension D, Dc and D_f by using MATLAB programming.

Excluding the abnormal data points 8, the three element linear regression model of Vco and the fractal dimension is obtained in the formula (4).

$$V_{co}=0.065+0.939D-0.196D_c-0.684D_f \quad (4)$$

The regression coefficient$R^2=0.561$

Table 2. The fractal volume and fractal dimension

Gradation	Gradation fractal dimensionD	Coarse aggregate fractal dimensionD_c	Fine aggregate fractal dimensionD_f	V_c	V_{co}	V_f
AC-25-3	2.4984	2.4821	2.5057	0.257	0.172	0.130
AC-25-4	2.4495	2.3906	2.4877	0.279	0.185	0.097
AC-25-5	2.3928	2.2871	2.4745	0.305	0.206	0.071
AC-25-9	2.5767	2.3998	2.5259	0.279	0.342	0.093
AC-25-10	2.5185	2.2963	2.5583	0.299	0.191	0.060
AC-25-15	2.6117	2.3046	2.5689	0.302	0.345	0.061
AC-25-18	2.5607	2.5098	2.5809	0.250	0.266	0.121
AC-25-19	2.508	2.4182	2.6248	0.275	0.280	0.078
AC-25-20	2.4641	2.3147	2.3781	0.296	0.282	0.093
AC-25-24	2.6156	2.4366	2.594	0.269	0.211	0.090
AC-25-25	2.5798	2.3332	2.5809	0.301	0.245	0.067

The regression coefficients of the three elements linear correlation model are lower, then, the correlation between Vco and D, Vco and Dc, Vco and D_f can be analyzed by software SPSS . The analysis results are shown in Table 3.

Table 3. Correlation between fractal voidage of coarse aggregate and fractal dimension

	D	D_c	D_f	V_{co}
D	1.000	0.259	0.647	0.474
D_c	0.259	1.000	0.337	-0.124
D_f	0.647	0.337	1.000	0.115
Vco	0.474	-0.124	0.115	1.000

From Table 3, it can be seen that the fractal volume void fraction of coarse aggregate Vco has a relatively high correlation with D, and fractal void fraction Vco and fractal dimension residuals of coarse aggregate are plotted by MATLAB software to test abnormal data points and regressed after removing the 10^{th} abnormal data points, we can establish the relevant models of Vco and D, as shown in Equation (5).

$$V_{co} = 4.177D^2-20.353D+24.999 \quad (5)$$

The regression coefficientR^2=0.487

Similarly, the fractal volume V_f prediction model of fine aggregate in coarse aggregate is established. Taking V_f as the dependent variable and D, Dc and D_f as the independent variables, the linear regression was performed to get the correlation model between V_f and the fractal dimension, as can be shown in Equation (6).

$$V_f = -0.184+0.002D+0.306D_c-0.182D_f \quad (6)$$

The regression coefficient R^2=0.978

According to the ternary linear correlation model, the overall correlation between V_f and D, Dc and D_f is high. The correlation between V_f and D, V_f and Dc, V_f and D_f can be analyzed by SPSS software. The analysis results are shown in Table 4.

Table 4. The correlation between V_f and D, D_c, D_f

	D	D_c	D_f	V_f
D	1.000	0.259	0.647	-0.084
D_c	0.259	1.000	0.337	0.844
D_f	0.647	0.337	1.000	-0.202
V_f	-0.084	0.844	-0.202	1.000

From Table 4, it can be seen that the correlation between the fractal volume V_f of the fine aggregate in the coarse aggregate and Dc is high, and the correlation model between V_f and Dc can be established. The residual figure of V_f and Dc are plotted by MATLAB software to make data abnormal point test, excluding the 9th abnormal point data before regression, as shown in formula (7).

$$V_f = 0.732D_c^2-3.220D_c+3.601 \quad (7)$$

The regression coefficient $R^2=0.840$

Because the gradation is composed of coarse and fine aggregate, the correlation model between the fractal volume V_f of the fine aggregate in the coarse aggregate and coarse aggregate fractal dimension Dc, fine aggregate fractal dimension D_f was established. There is no abnormalities were found after the residual analysis. The correlation model after regression is shown in formula (8).

$$V_f = -0.182+0.306D_c-0.181D_f \quad (8)$$

The regression coefficient$R^2=0.978$

2. Model comparison

The correlation model of fractal volume parameters and fractal dimensions is established and summarized in Table5. As can be seen from Table 5, the regression coefficients of Models 1 and 2 are low. Due to the limited number and time of experiments, the prediction model of fractal void fraction Vco of coarse aggregate needs to be further established. The regression coefficients of Models 3 and 5 are higher, so models 3 and 5 can be used as fractal volume prediction models for fine aggregates in coarse aggregates. In order to simplify the model and facilitate the application, the model 5 is recommended as the fractal volume prediction model of fine aggregate in coarse aggregate.

3. Conclusion

The correlation model of fractal volume parameters and fractal dimension of AC-25 gradation is established in the research.

The prediction model of coarse aggregate fractal voidage of AC-25 gradation is established, that is $0.065+0.939D-0.196D_c-0.684\ D_f$

The prediction model of the fractal volume of fine aggregate in coarse aggregate for AC-25 gradation is established, that is $V_f = -0.184+0.002D+0.306D_c-0.182\ D_f$

The paper focuses on the modeling method of the AC-25 asphalt mixture grading test prediction model. Because the selected grading quantity and test quantity are limited, the obtained model still needs further verification.

4. Acknowledgments

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

5. References

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