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Study on properties of calcium sulfate whisker/basalt fiber modified asphalt mortar based on grey correlation analysis

Guanyu Li[a], Zhipeng Yang[b*], Haidong Gao[c]

College of Traffic Engineering, Gansu Forestry Technological College, Tianshui, Gansu, China
[a] 746977825@qq.com, [b] 1610389593@qq.com, [c] 365229062@qq.com
** Zhipeng Yang*

Abstract: *In order to analyze the relationship between the technical properties of asphalt and the content of calcium sulfate whisker basalt fiber, calcium sulfate whisker/basalt fiber composite modified asphalt was prepared by mechanical stirring method, and the technical properties of modified asphalt mortar were measured. The results showed that:Modifier content and the correlation between asphalt technical nature indicators, using grey relational analysis it is concluded that calcium sulphate whisker and basalt fiber adding amount on the asphalt performance influence degree for shear strength > softening point> Fmax > 25 ℃ Cone Penetration > 5 ℃ ductility, through comprehensive score method modifier dosage is: the best calcium sulphate whisker was 4%, 4% basalt fiber.*

Keywords: *calcium sulfate whisker, basalt fiber, ash correlation analysis, asphalt properties*

1. Introduction

Calcium sulphate whisker is a kind of wide application of inorganic filler, the rubber, epoxy resin, plastic, paper, and friction material is widely used in industries such as, through the past research has found that calcium sulphate whisker can be used to improve asphalt penetration, ductility, softening point and other technical indicators, basalt fiber is made up of basalt high-temperature wire drawing process of fiber materials, such as a,High strength, good corrosion resistance, good high temperature resistance, low cost.[1]-[2]Has been widely applied in improvement of fire protection textiles, building materials and other fields, is a new, green environmental protection, high performance to add material, this research will be basalt fiber and calcium sulfate whisker composite modification of asphalt mortar, using fiber reinforced properties of basalt fiber and calcium sulfate whisker both inorganic differential and chopped fiber performance,The basic properties of compound modified asphalt mortar were studied and the optimum modifier content was determined by comprehensive scoring method.[3]

2. Materials and methods

2.1 Technical specifications of raw materials

Anhydrous calcium sulfate whisker produced by Shanghai Tengmin Industrial Co., Ltd. is selected for calcium sulfate whisker. The main technical indexes provided by the manufacturer are shown in Table 1, basalt fiber technical indexes are shown in Table 2, and Petroleum asphalt technical indexes of Maoming Donghai Brand 90 are shown in Table 3.

Table 1. Technical specifications of calcium sulfate whisker

Technical indicators	Diameter (um)	Melting point (℃)	Tensile strength (GPa)	Loose density (%)	Length (um)	Whiteness (%)
Basalt fiber	3-4	1540	20.53	0.1-0.4	40-160.	96

Table 2. Technical indexes of basalt fiber

Technical indicators	Diameter (um)	Melting point (℃)	Tensile strength (MPa)	Elongation at break (%)	Length (mm)	appearance
Basalt fiber	12-14	760	2500	2.6 or higher	6	Dark grey

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Table 3. Technical specifications of asphalt

Technical indicators	90 # asphalt		Test method for
	The test results	Specification requirements	
25°C penetration /0.Imm	93	80-100.	T0604
Softening point / °C	49.1	45 °C or higher	T0606
10 °C degrees/cm	67	P 45	T0605
15 °C degrees/cm	147	P 100	T0605
Density (g/cm)	1.011	The measured records	T0603

2.2 Preparation of modified asphalt

The anhydrous calcium sulfate whisker to be used was mixed with basalt fiber 1%, 2%, 3% and 4% according to the mass fraction of base asphalt 2%, 4%, 6% and 8%. The base asphalt was heated in an oven at 150°C for 2h to make the base asphalt in a flowing state.Then, the standby calcium sulfate whisker and basalt fiber were heated at the same temperature, and were added into the asphalt according to the experimental design ratio, manually stirred for 3min, and then stirred for 30min with a booster electric mixer to prepare calcium sulfate whisker and basalt fiber modified asphalt.

2.3 Preparation performance test of modified asphalt

Coning at 25°C, shear strength, softening point, force extension (5°C) and maximum force value Fmax were selected to evaluate the performance of modified asphalt glue.

(1) The viscosity was evaluated by coning degree, and the shear strength was calculated according to Formula 1.[4]

$$\tau = \frac{981Q\cos^2(\frac{\alpha}{2})}{\pi h^2 \tan(\frac{\alpha}{2})} \tag{1}$$

τ -- Shear strength (kPa);

Q -- is the penetration mass (according to the actual cone needle mass, this test is 195 g);

H - coning degree (0.1mm);

α - Indicates the Angle of the cone needle tip (30°).

(2) Asphalt elongation tester and "one word" mold were used to test the tensile elongation of composite modified asphalt. The test temperature was 5°C and the tensile rate was 5cm/min. The maximum tensile strength and tensile length (elongation) were used to evaluate the low temperature performance.

(3) Test the ductility and softening point of composite modified asphalt according to regulations.[5]

3. Results and discussion

3.1 Grey correlation analysis of the influence of calcium sulfate whisker and basalt fiber content on the performance of asphalt mortar.

Grey correlation analysis method[6]

(1) Set the grey system: $X_0 = \left[x_0(1), x_0(2), x_0(3), ..., x_0(n)\right]$ (2)

Is the system feature sequence;

$$X_i = \left[x_i(1), x_i(2), x_i(3), ..., x_i(n)\right] \tag{3}$$

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Is the sequence of related factors;

Where, $x_0(n)$ is the parent factor series, $x_m(n)$ Is the subfactor series.

(2) Dimensionless processing of the original data. In order to avoid the influence caused by the disunity of the reference series, this paper adopts the mean-value processing, and the calculation formula is shown in Equation (4).

$$Y_i = X_i / \overline{x} = \left[y_i(1), y_i(2), y_i(3), \ldots\ldots, y_1(n) \right] \quad (4)$$

$$i = (0,1,2,\ldots\ldots,m)$$

(3) Calculation of grey correlation coefficient and correlation degree

The parent series processed by mean value is denoted as, and the child series is denoted as, then, the correlation coefficient of and $\{x_0(t)\}$ $\{y_i(t)\}$ $t=k$ $\{x_0(t)\}$ $\{y_i(t)\}$ $\xi_{oi}(k)$

$$\xi_{oi}(k) = \frac{\Delta_{\min} + \rho\Delta_{\max}}{\Delta_{oi}(k) + \rho\Delta_{\max}} \quad (5)$$

Where, is the absolute difference between the two sequences at the moment,; $\Delta_{oi}(k)$ k $\Delta_{oi}(k) = \left| x_o(k) -_i (k) \right|$

$\Delta_{\min}$ and $\Delta_{\max}$ Are the minimum value and maximum value in the absolute value of time difference; ρ Is the discrimination coefficient, and 0.5 is taken here.

The correlation degree can be calculated by formula r_{oi}

$$r_{oi} = \frac{1}{N}\sum_{K=1}^{N} \xi_{oi}(k) \quad (6)$$

Where: r_{oi} is the correlation degree between the sub-series and the parent series, and N is the number of data.

Calcium sulphate whisker and basalt fiber composite modification, the modified asphalt mortar is multi-factor evaluation, selection of calcium sulphate whisker and basalt fiber content as the main influence factors, evaluation for the 25 ℃ cone into the degree, shear strength (), 5 ℃, ductility, softening point F (℃), the influence of avoiding the single index evaluation modification effect produced when conflicting,The test results are shown in Table 4, and the grey correlation calculation and analysis results are shown in Table 5. The results show that:The content of calcium sulfate whisker and basalt fiber has a significant effect on the performance of asphalt mortar, and the influence degree of the five indexes is different, including shear strength (21.7) %> softening point (20.7%) >Fmax (20.5%) >25℃ Cone Penetration (19.7%) > 5 ℃ ductility (17.4%).

3.2 Determination of the optimal dosage

In order to comprehensively evaluate the influence of the dosage of compound modifier on the performance indexes of asphalt mortar, a comprehensive scoring method was selected. According to the grey correlation analysis method, the proportion of each evaluation index in the evaluation of modification effect was calculated, and then the multiple indexes of each sample were comprehensively scored by weighting, and the multiple indexes were converted into a single index. The single index after transformation was expressed by Y_1[7],where:

$$Y_i = \sum_{j=1}^{5} b_{ij} \times (\textbf{each index}) \quad (i=1,2,3,\ldots..,10) \quad (7)$$

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$$b_{ij} = \frac{Percentag}{\mathbf{x_{max}} - \mathbf{x_{min}}}$$

According to Formula (7), the calculation results are shown in Table 4-15. By calculating the comprehensive score, it is found that when the content of calcium sulfate whisker is 4% and that of basalt fiber is 4%, the comprehensive score 263.34 is the highest among all combinations. After comprehensive consideration, the optimal content of calcium sulfate whisker is 4% and that of basalt fiber is 4%.

4. Conclusion

(1) Calcium sulfate whisker and basalt fiber have significant influence on the performance of asphalt mortar. The modification effect of composite modified asphalt mortar is characterized by multiple indexes. By using grey correlation analysis method, it can be analyzed that the influence degree of composite modifier dosage on the performance of asphalt mortar is as follows:Shear strength (21.7) %> softening point (20.7%) >Fmax (20.5%) >25℃ Cone Penetration (19.7%) > 5 ℃ ductility (17.4%).

(2) The dosage of modifier can be determined by using grey correlation analysis results through comprehensive evaluation method. When the dosage of calcium sulfate whisker is 4% and that of basalt fiber is 4%, each performance can be taken into account well, avoiding the single factor evaluation index contradiction.

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Table 4 Test results of coning penetration of CSW/ basalt fiber composite modified asphalt

CSW content (%)		2				4 6				6			
Basalt fiber content (%)		1	2	3	4	1	2	3	4	1	2	3	4
25℃ taper /0.1mm 25 ℃		75.2	69.2	66.3	61.3	70.3	65.2	61.5	56.3	66.2	63.2	59.0	50.3
τ		38	44	48	56	43	50	56	67	48	53	61	84
5℃ force extension	ductility (mm)	381	288	230	215	290	255	230	198	190	170	160	143
	F_{Max} (N)	80	83.2	105.0	94.0	84	96.0	101.2	100.3	97.0	93.2	92.1	90.7
Softening point (℃)		49.2	53.0	57.3	59.4	50.1	55.4	60.2	62.1	52.2	54.3	61.3	63.4

Table 5. Calculation table of correlation degree and correlation coefficient of each index

Correlation coefficient		ξ_{oi} 1	ξ_{oi} 2	ξ_{oi} 3	ξ_{oi} 4	ξ_{oi} 5	ξ_{oi} 6	ξ_{oi} 7	ξ_{oi} 8	ξ_{oi} 9	ξ_{oi} 10	ξ_{oi} 11	ξ_{oi} 12	correl ation	Percenta ge (%))
25℃ taper /0.1mm 25 ℃		0.366	0.402	0.423	0.463	0.825	1.000	0.974	0.805	0.465	0.439	0.408	0.356	0.577	19.7
τ		0.678	0.566	0.509	0.425	0.678	0.883	0.967	0.636	0.392	0.434	0.522	0.923	0.635	21.7
The force ductility	ductility (mm)	0.250	0.341	0.441	0.478	0.611	0.810	1.057	0.772	0.369	0.340	0.328	0.308	0.509	17.4
	F_{Max} (N)	0.530	0.506	0.385	0.438	0.838	0.980	0.857	0.876	0.466	0.444	0.438	0.431	0.599	20.5
Softening point (℃)		0.522	0.478	0.436	0.418	0.810	1.012	0.901	0.834	0.407	0.424	0.492	0.517	0.604	20.7

Table 6. Calculation table of comprehensive evaluation index results

CSW (%)	2				4 6				6			
Basalt fiber (%)	1	2	3	4	1	2	3	4	1	2	3	4
The comprehensive score	242.58	242.01	261.49	254.24	239.03	253.27	262.59	263.34	244.52	242.98	251.98	256.60