

Application and Research on Plant-Mixed Thermal Regeneration Technology of RAP Asphalt Mixtures

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Abstract: When the plant-mixed thermal regeneration technology is adopted for the waste asphalt pavement mixtures, its performance can basically reach the level of freshly-mixed asphalt concrete, which can be used for paving the middle and lower layers of road pavements of various grades. Through the research and application of plant-mixed thermal regeneration technology based on China's Kunming-Yuxi Expressway Pavement Overhaul Project, this paper summarizes relevant technical points and effectively advocates the promotion and application of this technology in highway maintenance.

Keywords: Plant-mixed hot recycling; Asphalt mixture; Asphalt pavement

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1 Overview

In 2008, the Ministry of Communications of China promulgated and implemented the "Technical Specifications for Asphalt Pavement Recycling." The national "12th Five-Year Plan" clearly proposed the implementation of circular production methods and demanded "to promote the recycling of bulk industrial solid waste, construction and road waste, and agricultural and forestry waste, with the comprehensive utilization rate of industrial solid waste reaching 72%". The "13th Five-Year Plan" put forward higher requirements for environmental protection. The plant-mixed thermal regeneration technology uses old asphalt pavement milling waste to produce the recycled mixture with the

advantages of stable gradation and controllable quality, with performance basically matching the standard of new mixtures. It is a green, economical and environmentally friendly highway maintenance technology.

2 Project Overview

The Kunming-Yuxi Expressway in China was completed and opened to traffic in 1999. It is a bidirectional 6-lane asphalt concrete pavement. This project will start overhauling the 24km road surface 13 years after its completion. The road overhaul plan is to mill the original asphalt pavement down 13cm, and then pave back an 18cm thick asphalt pavement surface. The structure of the overhaul road surface (from top to bottom) is: 4cm thick AC-13 modified asphalt concrete + 6cm thick AC-20 recycled asphalt concrete + 8cm thick AC-25 recycled asphalt concrete. In order to make the overhaul road match the standards of the freshly mixed asphalt pavement, 3% anti-rutting agent needs to be added to the 6cm recycled asphalt concrete layer.

3 Implementation Plan for Plant-mixed Thermal Regeneration

The recycled asphalt concrete used in this project is planned to adopt the plant-mixed thermal regeneration technology. Firstly, the recycled materials from asphalt pavement (RAP) of the milled old asphalt pavement were sampled, and the asphalt and aggregate components in the RAP material were tested. According to the test results, the content of the new asphalt, aggregates and admixtures was determined through tests, and the plant-mixed thermal regeneration equipment was selected according to the

scale of the project.

3.1 RAP Materials

A milling machine was used to sample the RAP materials from old pavements in layers and full

thickness, and the asphalt and aggregates in the RAP material were extracted for tests. The test results are shown in Table 1.

Table 1. Technical Test Indicators Table of the Main Components of the RAP Materials

Sampling Method	Asphalt Content] (%)	Asphalt Indicators of RAP Materials			Aggregate Indicators of RAP Materials	
		Penetration (1/10mm)	Softening Point(°C)	Ductility (cm)	Maximum Particle Size (mm)	Sand Equivalent (%)
Upper Layer (milled to 3cm)	4.2	19.7	64.0	0.6	13	67
Lower Layer (milled from 3cm~13cm section)	3.5	27.1	62.7	19.8	20	57
Full Thickness(milled to 13cm)	4.0	24.3	63.5	17.3	20	63

The data in Table 1 shows that the asphalt content in the RAP materials is relatively high. Except for the softening point, the three major asphalt indicators do not meet the requirements, indicating that the degree of asphalt aging is severe. However, the maximum particle size and sand equivalent meet the requirements. Therefore, in order to effectively utilize the RAP materials, they must be crushed and screened before undergoing plant-mixed thermal regeneration when the full-thickness milling method is used to recover the RAP materials.

3.2 New Asphalt

As the asphalt in the RAP materials aged more severely, the new asphalt added should be high-grade asphalt. Combined with the characteristics of the overhaul project, the new asphalt should be Grade A 90# asphalt. Through the test on the mixing ratio of new and old asphalt, when new asphalt accounts for

20% to 28% of the total amount of mixed asphalt, the mixed asphalt can meet the indicator requirements of Grade A 70# asphalt.

3.3 New Aggregates

Since the stones in the RAP materials can no longer meet the grading requirements after milling and crushing, it is necessary to add new aggregates to adjust the mixture gradation. As the RAP material is recycled by full-thickness milling and it contains a lot of limestone, the recycled asphalt mixture cannot be used as a pavement wear layer.

3.4 Regenerant

With reference to the requirements for the technical indicators of regenerants in the Chinese regulations, the FENICE-9 type regenerant was selected for this project. The technical indicators are shown in Table 2.

Table 2. Technical Indicators Table of FENICE-9 Type Regenerant

Test Parameter	Requirements	Measured Value	Test Methods
Viscosity at 60°C cSt	50~175	60.7	T 0619
Flash Point (°C)	≥220	228	T 0633
Ignition Point (°C)	—	295	T 0633
Viscosity Ratio before and after Thin-Film Oven Test	≤3	1.02	T 0619
Quality Change before and after Thin-Film Oven Test (%)	≤4, ≥-4	-3.559	T 0609
Density at 15°C (g/cm3)	Measured Record	1.001	T 0603

3.5 Plant-Mixed Thermal Regeneration Equipment

There are generally three types of commonly used plant-mixed asphalt pavement recycling equipment, namely continuous mixing, indirect heat-mixing and parallel heat-mixing. Due to the large scale of the project, ACP-4000 parallel heating mixing equipment was selected in order to ensure production efficiency and project quality.

4 Key Technology Research

4.1 Extraction Methods for Aged Asphalt

In order to obtain the asphalt in the RAP materials, the centrifugal separation method (T 0727-2011) was initially used, but the concentration of the extracts obtained by this test method was quite low. After optimizations, the reflux extraction method (T 0727-

1993) was used to obtain higher concentration of extracts. The minerals in the extracts were removed using centrifuge, and the rotary evaporation method (T 0727-1993) was applied to remove the solvent (trichloroethylene) to obtain the aged asphalt.

4.2 Dosage of Regenerant

According to the penetration of the aged asphalt, a certain amount of regenerant was added to the aged asphalt and the penetration of the asphalt was measured. Then, the suitable dosage of regenerant was calculated according to the “regenerant dosage-

penetration semi-logarithmic relationship table”, and then increase or decrease of dosage was made based on the calculation. Afterwards, the penetration, ductility, and softening point indicators of the recycled asphalt were repeatedly tested to make all indicators meet the requirements of the specification. The recycled asphalt mixture of this project adopts Grade-A 70# asphalt, and the penetration of recycled asphalt needs to be adjusted to around 70 (+0.1mm). See Table 3 for comparison data.

Table 3. Comparison Table of Aged Asphalt Indicators before and after Regeneration

Site	Measured Indicator Values of Aged Asphalt in RAP Materials			Regenerant Dosage (%)	Measured Indicator Values of Regenerated Asphalt		
	Penetration (1/10mm)	Melting Point (°C)	Ductility at 15°C (cm)		Penetration (1/10mm)	Melting Point (°C)	Ductility at 15°C (cm)
Full-thickness	24.3	63.5	17.3	6.1	71.1	57.7	105
Upper Layer	19.7	64.0	0.6	7.3	70.2	58.2	84
Lower Layer	27.1	62.7	19.8	5.0	71.6	57.3	127

4.3 Analysis of Regenerated RAP Mixtures

The key indicators for the mix ratio design of regenerated RAP mixtures are asphalt content, mineral gradation and theoretical maximum relative density. The theoretical maximum relative density was determined by the vacuum method (T 0711-2011). Asphalt content and mineral grading were carried out according to the centrifugal separation method (T 0722-1993). However, considering that the recovery of mineral powder is difficult in the actual operation process, the combustion furnace method was used for measurement. After many tests, it was found that the deviation of the mineral grading is about 1% to 3%, and the relative error of the asphalt content fluctuates in the interval of 0.05% to 0.03%. In order to improve the test accuracy, the burning

furnace method was changed to the lipid extraction method (T 0724-1993), and the absolute error of the test results was controlled within 0.3%.

4.4 The Mix Ratio Design of Regenerated RAP Mixtures

After the RAP mixture aggregate grading test was carried out, the target mix ratio design and Marshall test can be used to determine the standard mix ratio of the regenerated mixture, the best oil-to-stone ratio, and the production mixture ratio. The amount of asphalt should be the total amount of new asphalt, old asphalt, and regenerant.

Through multiple sets of indoor trial matching tests in this project, two regeneration rate mix ratios were finally determined, which were 20% and 50% respectively. The test data are shown in Table 4.

Table 4. Table of Key Indicators for Indoor Tests with Different Regeneration Rates

Regeneration Rate	Raw Material Mix Ratio (%)				Penetration of Mixed Asphalt (1/10mm)	Marshall Test		
	New Aggregates	RAP	New Asphalt	Regenerant		Stability (kN)	Flow Value (mm)	Freeze-thaw Splitting Strength (kN)
20%	80	20	3.26	0	60.3	11~13	3.5~4	0.7~0.8
30%	70	30	2.89	0	54.5	14~15	3.5~4	0.65~0.75
40%	60	40	2.52	0	47.1	16~17	3.5~4.2	0.45~0.55
50%	50	50	2.15	0	44.3	18~19	3.3~4.8	0.4~0.45
50%	50	50	2.0	0.17	69.3	11~12	3.5~4	0.8~0.9

The test data shows that the penetration of the mixed asphalt with new asphalt but without regenerant dropped significantly. After the addition of regenerant, the penetration of the mixed asphalt can be maintained at around 70 (1/10mm). The Marshall index of RAP mixture added with regenerant is basically the same as that of new material. Although the Marshall stability of the RAP mixture without regenerating agent was improved, the freeze-thaw splitting strength was greatly reduced, and the water stability was too low, so it is not suitable for use as a pavement material for high-grade highways.

5 Conclusion

The plant-mixed thermal regeneration technology is a green, economical and environmental-friendly highway maintenance technology. The regenerated RAP materials produced by scientific technology can meet the technical requirements of freshly mixed asphalt materials. (1) The reflux extraction method (T 0723-1993) is recommended for analyzing old

asphalt in RAP materials. (2) For RAP materials with the penetration of the old asphalt below 20 (0.1mm), although it can be modified by adding a regenerating agent after the old asphalt has severely aged, the recycled asphalt can still barely meet the specifications for the required ductility of heavy duty Grade A asphalt, so these RAP materials are not recommended to be used for plant-mixed thermal regeneration. (3) In order to conduct simple, fast and accurate asphalt content and aggregate tests on RAP materials, it is recommended to use lipid extraction method for indicator testings.

References

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