Optimum Asphalt Content of Hot Recycled Asphalt Mixture in Cold Area under Different Old Materials

Yanyu Meng¹,², Jiaqi Zhang², Zhan Luo¹, Liang Kong² and Yuanyuan Gu²
¹College of Civil Engineering and Transportation and, Beihua University, Jilin 132000, China
²Forestry College, Beihua University, Jilin 132000, China

*Corresponding author:707456092@qq.com
myygina@163.com

Abstract. In order to help the use of hot recycled asphalt mixture under different amount of used asphalt in cold areas of China. The optimum asphalt content of hot recycled asphalt mixture with different old materials was obtained by using Marshall Test method. By analyzing the material composition of hot recycled asphalt mixture in cold and cold areas, the optimum amount of asphalt with 70% old material in hot recycled asphalt mixture in cold area is 5.065%, the optimum amount of asphalt with 80% old material is 5.14%, and the optimum amount of asphalt with 80% old material is 5.2%. This study provides practical engineering for hot recycled asphalt mixture in cold area reference basis.

Keywords: Cold Region, Hot Recycled, Asphalt Mixture, Marshall Test

1 Introduction

According to the data of China's highway network, by 2018, the total mileage of China's highways has reached 4.8465 million kilometers, and the total mileage of expressways has reached 142600 kilometers. Compared with the previous year, the total mileage of expressways has increased by 6100 kilometers. In the built expressway, the proportion of asphalt pavement is more than 90%. Generally, the design service life of asphalt pavement of expressway is 15 years. Most of the asphalt pavement in our country has reached the service life; in this case, there will be a lot of waste materials, a lot of land resources. Therefore, as a new preventive maintenance measure, asphalt pavement geothermal regeneration technology has been widely used. Compared with the traditional high-grade asphalt pavement maintenance, the geothermal regeneration technology not only reduces the consumption of non-renewable resources such as asphalt and aggregate, but also solves the waste of land resources and environmental pollution caused by waste material accumulation [1].

As early as 1980 in the United States, the Ministry of transportation compiled the guide for recycling of used asphalt pavement, and published the technical manual for recycling asphalt pavement in 1981. By the 1990s, the recycling rate of used asphalt pavement in the United States had reached more than 90% [2]. Foreign countries have also made some research results on the aging,
regeneration process, regeneration mechanism and performance of recycled asphalt mixture with different content of used asphalt [3, 4]. Based on the reference of geothermal regeneration technology in foreign countries, the research on thermal regeneration asphalt pavement is carried out in China. According to Wang Chu and others, the different content of the old material in the recycled asphalt mixture has a great influence on the road performance [5]. Wang H thinks that under the condition of meeting the requirements of road performance, the grading requirements of recycled mixture should be considered in terms of local climate conditions, traffic conditions and other factors [6]. Because most of the mixtures used in geothermal regeneration are recycled old materials, their mineral properties, gradation and oil stone ratio are different from those of ordinary asphalt mixture, and this variability will lead to segregation, poor adhesion and non-compaction of recycled asphalt mixture [7, 8]. Kavussi A et al. studied that recycled concrete aggregate is a potential substitute for natural aggregate in asphalt mixtures [9]. Pasandin, A.R et al [10]. studied the effect of leachate on recycled asphalt mixture by indoor test. Qasrawi H et al. studied the performance of recycled asphalt mixture according to different grades of asphalt [11].

This paper mainly analyzes the material composition of the hot recycled asphalt mixture in the cold area, and gets the best asphalt content according to the different content of the old material in the hot recycled asphalt mixture in the cold area, which provides the corresponding basis for the actual project.

2 Climate division of asphalt pavement performance

In this paper, the selected area of hot recycled asphalt pavement is a street section in Jilin Province, with a total width of 21m and a thickness of 5cm. According to the climate division of asphalt pavement performance in the technical code for construction of highway asphalt pavement (see Table 1) and the statistical data of extreme and extremely high temperature of Jilin Meteorological Observatory (see Fig.2), the study defines the asphalt pavement performance.

| Low temperature climate zoning       | Extreme minimum temperature (℃) |
|--------------------------------------|---------------------------------|
| Winter severe cold region            | <37                             |
| Winter cold area                     | -21.5~37                        |
| Winter cold area                     | -9~21.5                         |
| Winter temperature area              | >9                              |

![Table 1. Low temperature climate zoning of asphalt pavement performance](image)

**Fig.1** Extreme and very high temperature of Jilin Provincial Meteorological Station

It can be seen from Figure 1 that the extreme temperature in Jilin Province is between -27 ℃ and -34 ℃, and it can be seen from table 1 that the asphalt pavement in Jilin Province is located in the winter cold area, so the service performance of the hot recycled asphalt pavement in Jilin Province
must meet the requirements of the specification for the service performance of the asphalt pavement in the winter cold area.

3 Composition and analysis of materials
Hot recycled asphalt mixture is a general term of mixture which is re-heated and mixed with recycled agent, new asphalt material and new aggregate in a certain proportion after the old asphalt pavement is excavated, recovered, broken and screened. When the asphalt pavement is recycled, the old asphalt and old mineral aggregate of the original pavement shall be detected and analyzed first. If one of them cannot be recycled, the whole old asphalt mixture cannot be recycled. Therefore, the quality of the old asphalt mixture has a great influence on the performance of the hot recycled asphalt mixture. This study mainly tests and analyzes the basic performance of the old asphalt mixture and the new asphalt mixture of the hot recycled asphalt pavement in a street section of Jilin Province.

3.1 Performance analysis of old asphalt mixture
First of all, according to the test code for asphalt and asphalt mixture of highway engineering, the asphalt content of old asphalt mixture (see Tab.2) and three major indexes (see Tab. 3) are measured, and the changes of three major indexes (see Tab.4) of adding old asphalt as regenerate are analyzed and evaluated. Then, the old aggregate shall be screened (see Tab.5) and evaluated according to the screening method of mineral aggregate grading in the code for aggregate test of highway engineering. Finally, determine whether the old asphalt mixture meets the regeneration requirements.

| Table 2. Content of asphalt in old asphalt mixture |
|--------------------------------------------------|
| Number                                           | 1   | 2   | 3   |
| RAP drying total mass m/g.                       | 1500| 1500| 1500|
| Drying aggregate quality m/g²                    | 1393.2| 1394.9| 1397.5|
| Weight gain after drying of filter paper m²/g   | 0.5 | 0.3 | 0.6 |
| A mineral powder precipitated in a solution. m³/g| 40.8| 38.5| 36.2|
| Bitumen content P/ %                             | 4.37| 4.42| 4.38|
| Bitumen content average value %                 | 4.39|

The test results show that the average value of the three recovery test results is 4.39% of the asphalt content in the old asphalt mixture, which is low. The main reason is that the asphalt of the old asphalt mixture is oxidized in contact with the air under the influence of various factors such as sunlight, air, water, vehicle load, etc. for a long time in the use of the original road surface, and the sun and water accelerate the oxidation process, resulting in The asphalt content of the pavement is reduced; in cold areas, the asphalt pavement is alternately affected by the climate in four seasons, so that the adhesion between the asphalt and aggregate in the asphalt pavement is reduced, the water peeling off of the asphalt is strengthened, and the asphalt content in the original asphalt pavement is reduced.

| Table 3. Determination results of three Indexes of Asphalt in Old Asphalt mixture |
|--------------------------------------------------|
| Test specification                               | Penetration 25 °C | Delay 15 °C (cm) | Soften point °C |
| Old asphalt                                      | 29              | 9.8              | 62.5            |
| 90#Asphalt technical index                       | 80-100          | ≥100             | 44-45           |

| Table 4. Determination results of three Indexes of Asphalt mixed with Recycling Agent |
|--------------------------------------------------|
| Amount of regenerated agent (%)                  | 5     | 7     | 9     |
| Penetration 25 °C (0.1mm)                        | 43    | 59    | 69    |
| Delay 15 °C (cm)                                 | 39.8  | 49.9  | 44.5  |
| Soften point °C                                  | 54    | 49.5  | 55.5  |

It can be seen from table 3 that the penetration of old asphalt is reduced by 51-71 °C, the softening point is increased by 17.5-18.5 °C, and the ductility is reduced to 9.8cm, indicating that the old
asphalt is aging. For cold areas, asphalt with large penetration index and large ductility should be selected. Although the old asphalt cannot reach the standard index, its performance can be restored by adding regenerative. According to the data in Table 4, the penetration of 9% regenerative larger than that of 7% and 5%, the ductility of 7%regenerative is larger than that of 5% and 9%, and the opposite softening point is the lowest. The results show that the performance of old asphalt can be restored by adding regenerative, but a reasonable amount of 5%, 7% and 9% regenerative should be selected according to the aging degree of asphalt. The addition of 7% regenerative can improve the penetration and ductility of old asphalt and reduce the softening point at the same time.

![Fig.2](image)

**Fig.2** Comparison diagram of upper and lower limits of gradation between old aggregate and AC-13 mixture

According to the analysis in Fig.2, the old aggregate may be refined in the use or recovery process. Although the old aggregate is within the range of reasonable grading of upper and lower curves of AC-13 aggregate grading, it deviates from the target grading curve. In order to improve the road performance of recycled asphalt mixture, a certain amount of new mineral materials should be added in the mix proportion of recycled asphalt mixture.

3.2. Selection and performance test of new asphalt

Firstly, according to the climate division and technical requirements in the technical specifications for construction of highway asphalt pavement (see Table 5), the new asphalt grade is selected to be suitable for asphalt pavement in cold area, and then the performance of the new asphalt selected is tested (see Table 6).

**Table 5.** Asphalt marking and technical requirements for climate zoning

| Asphalt label | 110# | 90# | 70# |
|---------------|------|-----|-----|
| Climate zoning | 2-1, 2-2, 3-2 | 1-1, 1-2, 1-3, 2-2, 2-3 | 1-3, 1-4, 2-2, 2-3, 2-4 |
| Penetration 25 °C | 100-120 | 80-100 | 60-80 |
| Soften point °C | ≥43 | 44-45 | 45-46 |
| Delay 15 °C (cm) | ≥100 | | |

According to Table 5 technical requirements of winter temperature on asphalt grade in cold area, No. 90 asphalt is selected as the newly added asphalt in hot recycled asphalt mixture in cold area.

**Table 6.** Three indexes of 90 # new asphalt

| Test specification | Penetration 25 °C | Delay 15 °C (cm) | Soften point °C |
|--------------------|------------------|------------------|----------------|
| New asphalt        | 86.5             | 1350             | 44.5           |
| Qualification      | 80-100           | ≥100             | 44-45          |
According to the comparison between the test results in Table 6 and the technical index range of 90 asphalt in the specification, the selected 90 asphalt meets the basic requirements of the technical specification.

4 Optimum asphalt content and Marshall test
First of all, according to the determination of mineral aggregate in the old asphalt mixture and the influence of climate conditions in cold areas, this paper selects the mineral aggregate composition grading of hot recycled asphalt mixture as dense mix AC-13 (see Table 7). Then, according to the asphalt content of the old asphalt mixture 4.39%. By adding 70%, 80% and 90% old materials for testing, we can get the best asphalt content of hot recycled asphalt mixture under different old material content as shown in Table 7.

Table 7. Optimal asphalt dosage of hot recycled asphalt mixtures with different used materials

| Quantity of used material | 70%  | 80%  | 90%  |
|---------------------------|------|------|------|
| Optimum asphalt content   | 5.065| 5.14 | 5.2  |

In order to test the road performance of hot recycled asphalt mixture with different content of old material, the Marshall test piece made of hot recycled asphalt mixture with the best content of old material of 70%, 80% and 90% is tested, and the test data is shown in Table 8.

Table 8. AC-13 thermal recycling asphalt mixture marshall test

| Quantity of used material (%) | 70%  | 80%  | 90%  |
|-------------------------------|------|------|------|
| Optimum asphalt content       | 5.065| 5.14 | 5.2  |
| Relative density of gross volume | 2.341| 2.343| 2.333|
| Stability (KN)                | 9.02 | 9.07 | 9.18 |
| Void volume (%)               | 4.45 | 4.43 | 4.40 |
| Flow value (0.1 mm)           | 33.2 | 32.8 | 32.6 |
| Saturation level (%)          | 70.70| 70.91| 71.57|
| Material clearance rate (%)   | 15.19| 15.23| 15.47|

From the summary of test data in Table 8, it can be seen that the optimal asphalt content of 70%, 80% and 90% old materials in the hot recycled asphalt mixture meets the requirements of various indicators in the technical code for hot recycling of highway asphalt pavement. It can be seen that with the increase of the content of old materials, the stability is improved and the flow value is decreasing. Marshall Test shows that 70%, 80% and 90% of the recycled asphalt mixture can meet the requirements of the specifications.

5 Conclusions
(1) In the cold area, the aggregate refinement of the recycled old asphalt mixture is more serious. The new aggregate gradation is improved by adding the new aggregate. According to the requirements of the code, the new asphalt mixture is less than 30%, so 70%, 80%, 90% of the old asphalt mixture is selected. In order to meet the requirements of high temperature rutting and low temperature cracking performance at the same time, the amount of coarse aggregate near the nominal maximum particle size should be properly reduced in the mix design of hot recycled asphalt mixture.

(2) The best asphalt content is 5.065% when 70% old material is added into the hot recycled asphalt mixture, 5.14% when 80% old material is added, and 5.2% when 90% old material is added.

(3) The Marshall test shows that 70%, 80% and 90% of the recycled asphalt mixture meet the requirements of the specifications.

Acknowledgements
This research was funded by the Graduate Innovation Training Project (Grant No. 2018051), Key laboratory open fund project of Bridge Nondestructive Testing and Engineering Calculation of Sichuan province (Grant No. 2017QYJ05), Jilin Province Teaches Hall "13th Five-Year" Science and
Technology Research Project (Grant No. JJKH20190648KJ) and Jilin Outstanding Youth Talent Training Project (Grant No. 201831767).

References
[1] Wu F., and Wu G.(2018). Mix proportion design of geothermal recycled asphalt mixture for asphalt pavement. Highway Traffic Science and Technology (Applied Technology Edition), 14 (11): 143-145. (in Chinese)
[2] Christiane R., Ingrid C., and Manfred N.(2017). Ageing and performance of warm mix asphalt pavements. Journal of Traffic and Transportation Engineering (English Edition), 4(04), 388-394.
[3] Giorgia. M., Edoardo B., and Francesco C.J.(2018). Influence of rejuvenators on bitumen ageing in hot recycled asphalt mixtures. Journal of Traffic and Transportation Engineering (English Edition), 157-168.
[4] Wang H.F., and MA B.(2017) The Characteristics of Asphalt Mixture in the System of Full Thickness Cold In-place Recycling, Journal of Wuhan University of Technology, Materials Science, 32(06): 1402-1407.
[5] Wang X, and Ma R.(2018) The effect of RAP content and regenerant on the design of the mix ratio of the recycled asphalt mixture is (NHTSA), 14 (10): 88-90. (in Chinese)
[6] Wang H. (2018). Application and Research of Local Thermal Recycling in Asphalt pavement maintenance. Changchun: Jilin University, 20-30. (in Chinese)
[7] Zhang X.Y(2018). Application of Geothermal Regeneration Technology on ECA overlay in Expressway. Scientific and technological Innovation and Application. 158-159. (in Chinese)
[8] Cheng P.F., Kou H., and Li J. (2018). Effect of Old material content on compacting temperature and performance of Hot recycled Asphalt mixture. Chinese and Foreign Highway, 193-198. (in Chinese)
[9] Kavussi A, Hassani A, Kazemian F, et al. Laboratory evaluation of treated recycled concrete aggregate in asphalt mixtures[J]. International Journal of Pavement Research and Technology, 2019, 12(1):26-32.
[10] Pasandin, A.R, Pérez, I. Effect of ageing time on properties of hot-mix asphalt containing recycled concrete aggregates[J]. Construction and Building Materials, 2014, 52:284-293.
[11] Qasrawi H, Asi I. Effect of bitumen grade on hot asphalt mixes properties prepared using recycled coarse concrete aggregate[J]. Construction and Building Materials, 2016, 121:18-24.