Application of RAP Variability Control in Plant-Mixed Hot Regeneration of Asphalt Pavement

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Abstract. Plant-Mixed hot regeneration technology is widely used because it can solve all the diseases of used asphalt pavement, however, in the current stage of reuse, there is a phenomenon that the indices of recycled asphalt mixtures(RAP) are discrete and difficult to control, the reason for the analysis is due to the large variability of the used asphalt mixture. In this paper, the traditional RAP design method is improved by the classification of the used materials, extraction-microporous membrane vacuum decompression filtration-distillation combined separation device, reduce the coefficient of variation of asphalt and aggregate in used asphalt mixture, effectively control the variability of the used asphalt mixture, so that the each index of the Plant-Mixed hot regeneration can achieve precise control of various indicators in the mix design stage.

1. introduction

Plant-Mixed hot regeneration technology can solve all the problems of the used road surface, but in the application process of the Plant-Mixed hot regeneration, the asphalt mixture itself and the indicators have the problems of large variability and difficult quality control[1]. The reason for the analysis is that due to the large gradation discreteness and the inaccurate determination of the asphalt content, how to improve the grading condition in the used materials and improve the participation of the used asphalt in the used materials is the key to solving the problem[2-3]. When milling the asphalt pavement, the used asphalt mixture in a certain depth will be centralized stored after milling and crushing or separately stored after simple screening, the pavement structure layer is usually not a single structure layer, the milling material usually contains materials of upper, middle and lower layers, or materials of certain two layers, and its variability is obvious, and the used asphalt mixture also has a large segregation during transportation and storage, and it is difficult to ensure the stability and continuity of the used asphalt mixture. This paper based on the first-class highway engineering project of Nierji-Tengke section of 111 national highway in Hulunbuir City, through the observation of recycled waste materials, it can be found that the segregation of waste materials is serious and mixed with water-stabilized base materials. In RAP mix design, the traditional method directly uses the extraction centrifugation distillation combined test method to separate the used asphalt mixture into asphalt, aggregate and mineral powder, and in the grading design, the extracted used aggregate is usually graded as a first-class aggregate[4-5]. In the design, according to the results of the variation analysis, three kinds of aggregates partitioning methods are used to control the variability of the
gradation, at the same time, in order to more thoroughly separate the ore and asphalt in the extract, a
device of microporous membrane vacuum decompression filtration is used to accurately obtain asphalt
content in used asphalt mixture. The experimental analysis shows that the aggregate grading method
and the microporous membrane vacuum decompression filtration method used in this paper can
effectively control the variability of aggregate and asphalt content in the used material, achieve
accurate control of gradation and asphalt content, and provide a basis for the design of RAP and the
controllability of RAP performance.

2. Variability Analysis of Used Asphalt Mixture

The variability of used asphalt mixture mainly includes three aspects: performance variability of used
asphalt, content variability of used asphalt mixture and gradation variability of used asphalt
mixture[6].

According to the experimental conditions, three groups of recycled used materials were randomly
and uniformly selected, and the recovered used materials were extracted to analyze the asphalt content,
performance and aggregate grading. See Table 1~2.

| Group number | Asphalt content(%) | Penetration (25℃)/0.1mm | Softening point (℃) | Ductility (15℃,5cm/min) |
|--------------|-------------------|-------------------------|---------------------|------------------------|
| 1            | 4.8               | 50.1                    | 57.0                | 13                     |
| 2            | 5.1               | 47.9                    | 60.3                | 15                     |
| 3            | 5.7               | 46.0                    | 63.0                | 11                     |
| Average      | 5.2               | 51.33                   | 60.1                | 13                     |

| Group number | Percentage of mass through different Sieve pore(mm)(%) |
|--------------|--------------------------------------------------------|
| 0.075        | 0.15 0.3 0.6 1.18 2.36 4.75 9.5 13.2 16 19 26.5 |
| 1            | 7.0 8.8 10.2 15.0 16.0 33.0 47.0 68.0 84.9 97.3 100.0 - |
| 2            | 6.5 9.0 10.8 16.0 18.0 43.0 52.0 71.0 83.0 97.2 100.0 - |
| 3            | 6.9 9.3 11.5 15.2 22.0 36.0 53.0 74.6 87.7 96.8 100.0 - |
| Average      | 6.8 9.0 10.8 15.4 18.7 37.3 50.7 71.2 85.2 97.1 100.0 - |
| Origin       | 6.5 8.5 10.6 14.3 18.8 27.5 40.9 60.0 73.4 83.7 94.8 100   |

From Tables 1~2 it can be found that the data of the three samplings is highly discrete. In order to
analyze the influence of discreteness on RAP design, the coefficient of variation is introduced[7]. The
formula for calculating the coefficient of variation of asphalt and aggregate gradation is shown in
Equations 1~2 respectively. The calculation results are shown in Tables 3~4, and the coefficient of
variation of aggregates at different sieve openings and the comparison curve between the recovered
used materials and the original gradation are plotted. See Figures 1~2.

\[
\delta = \frac{\sigma}{\mu} \times 100\% \quad (1)
\]

\[
\delta_i = \frac{\sigma_i}{\bar{p}_{i+1} - \bar{p}_i} \times 100\% \quad (2)
\]

\(\delta\) — coefficient of variation, \(\sigma\) — standard deviation, \(\mu\) — average

\(\delta_i\) — Percentage Coefficient of Variation for Grade i Pass,

\(\sigma_i\) — Standard deviation of pass percentages for level i,

\(\bar{p}_{i+1}\) — Mean Percentage of Pass at Level i+1, \(\bar{p}_i\) — Mean Percentage of Pass at Level i.
### Table 3 Asphalt Variability Coefficient of Used Asphalt Mixture

| Testing item | Asphalt content (%<br>Coeficient | Penetration (25℃)/0.1mm | Softening point (℃) | Ductility (15℃,5cm/min) |
|--------------|----------------------------------|------------------------|----------------------|-------------------------|
| 𝜎            | 0.37                             | 1.25                   | 0.24                 | 1.63                    |
| 𝛃            | 7.20                             | 6.66                   | 4.08                 | 12.56                   |

### Table 4 Aggregate Variability Coefficient of Used Asphalt Mixture

| Sieve pore (mm) | Percentage of mass through different sieve pore (%)<br>Coeficient | 𝜎₀ | 𝜒₀ |
|-----------------|---------------------------------------------------------------|----|----|
| 0.075           | 0.22                                                          | 0.20 | 0.53 | 0.43 | 2.49 | 4.19 | 2.62 | 2.70 | 1.93 | 0.22 | 0.00 |    |
| 0.15            | 9.70                                                          | 10.90| 11.63| 13.23| 13.36| 31.42| 12.78| 19.27| 16.22| 7.45 | 0.00 |    |

3. Control and Analysis of Variability of Used Asphalt Mixture

3.1 Variability control measures

From Table 3, it can be found that the variation coefficients of asphalt content and three major indicators of asphalt are larger. The reason is that the sampling is not uniform and may be mixed with cement stabilized base material. In the process of centrifugal separation of asphalt and mineral powder, it is found that there are phenomena of extraction liquid dispersion or centrifugal tube eccentricity. This makes the separation of asphalt and mineral powder incomplete, affecting the accuracy of asphalt content and indicators.

From figure 1, it can be found that the coefficient of variation of used material gradation is very large, up to 31.42%, and peaks appear at 2.36 mm and 9.5 mm sieve holes. From figure 2, it can be seen that the gradation of used material is obviously smaller than the original gradation. The reason may be due to the uneven sampling and the possible inclusion of cement stabilized base material, which makes the gradation variability very large. In addition, during the long-term use of pavement, vehicle load directly acts on the surface of asphalt pavement. This makes the compressive and shear strength between aggregates gradually higher than the ultimate strength of aggregates, and large particle size gradually broken into small and medium particles, which makes the used asphalt mixture coarse aggregate less and fine aggregate content more. Meanwhile, in the separation process, the bond separation of fine and medium particles will not be complete, making the coefficient of variation at 2.36 mm and 9.5 mm peak.

3. Control and Analysis of Variability of Used Asphalt Mixture
sieve holes should be considered as key sizes in RAP mix design. In view of the above reasons, the separation method of asphalt and aggregate should be improved to completely separate asphalt and mineral powder, and the key sieve holes should be strictly controlled. To this end, the following measures are taken:

Aiming at the phenomenon of mixed cement stabilized base material and aggregate caking, this paper preheated the recycled material in 100℃ oven for 30 minutes, then kneaded and rubbed it as much as possible, picked out the cement stabilized material and dispersed the aggregate as possible.

2.36 mm and 9.5 mm sieve holes were used as key sieve holes. The mixture dispersed from the previous step was screened into three grades: 0~2.36 mm, 2.36~9.5 mm and 9.5~16 mm.

Separation of asphalt and mineral powder was carried out separately. The asphalt content, asphalt performance and aggregate gradation of the three retaining materials are analyzed respectively. In RAP gradation design, the recycled material is used as the three retaining materials to synthesize gradation.

Improve the separation method of asphalt and mineral powder. In the separation process, the main reason is that in the centrifugal links, the extract is easy to disperse and the separation of asphalt ore powder is not complete. Therefore, the centrifugal links are mainly improved. The Buchner funnel micro-porous membrane vacuum decompression filtration device is used for the separation of mineral powder and asphalt. The filter membrane used in this device is PTFE polytetrafluoroethylene membrane, which can resist the corrosion of various organic solvents. The filter pore size is 0.45 μm. The separating device is simple in operation, and its working principle is to use the filter membrane to extract and separate the extract under vacuum or negative pressure, which has good separation effect. Other procedures remain unchanged, and the separation process is shown in Figure 3. After testing, the content of mineral powder in asphalt has been reduced to less than 0.5% by extractio-microporous membrane vacuum decompression filtration-distillation device, which has reached the degree of neglecting the influence on asphalt[8]. It proves that the device has good separation effect.

![Figure 3 Extraction-Microporous membrane vacuum decompression filtration-Distillation combined separation device schematic diagram](image)

### 3.2 Variation analysis

After the above treatment, test the properties of the recycled materials, calculate the coefficient of variation of the asphalt and aggregate, see Table 5~6, and plot the coefficient of variation of each aggregate at each sieve, see Figure 4.

| RAP specification (mm) | Asphalt content (%) | Penetration (25℃/0.1mm) | Softening point (℃) | Ductility (15℃,5cm/min) |
|------------------------|---------------------|--------------------------|---------------------|-------------------------|
| 0~2.36                 | δ₁                  | 0.79                     | 0.17                | 0.24                    | 3.88                    |
| 2.36~9.5               | δ₁                  | 1.38                     | 0.63                | 0.28                    | 3.46                    |
| 9.5~16                 | δ₁                  | 1.10                     | 0.36                | 0.69                    | 1.87                    |

| RAP specification (mm) | Percentage of mass through different Sieve pore (mm)(%) |
|------------------------|---------------------------------------------------------|
|                        | 0.075 0.15 0.3 0.6 1.18 2.36 4.75 9.5 13.2 16          |
| 0~2.36                 | δ₁                  | 2.21                     | 1.34               | 0.62                    | 0.49                    | 0.19                    | 8.84                    | 0.00                    | -                      | -                      | -                      |
From Table 5, it can be seen that the variability of asphalt has been well controlled, and from Table 6 and Figure 4, it can be seen that the variability of each block is also effectively controlled within 10%, which provides a good basis for the follow-up mix design control.

3.3 Verification of variation control
After the variation control process, the mix design is carried out to verify the role of the variation control in the mix design. Target Mix Design of AC-20 for Recycled Asphalt Mixture with Different Used Aggregate Content by Marshall Design Method, the dosage of used materials is 15%, 20%, 25% and 30% respectively, designing Aggregate Gradation based on AC-20 gradation range in Technical specifications for Construction of Highway asphalt pavements (JTG F40-2004).

The experiment found that after the variation control treatment, the recycled mixture of different used materials in the mix design, the index of the mineral material were well controlled.

4. Conclusion
After variability control, the analysis can get the following conclusions:

- In hot mix plant recycling of asphalt pavement, according to the gradation variability of used materials, the used materials should be divided into different grades to be graded.
- An improved extraction-microporous membrane vacuum decompression filtration-distillation combined separation device was used to effectively improve the separation degree of asphalt and mineral powder.
- The used material is pretreated and divided into three blocks, and the asphalt mixture separation device is improved, the variability of the used material is well controlled, and the indexes of the recycled asphalt mixture are more accurately controlled.

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