Research on Gradation Design of Recycled Cement Stabilized Macadam Material

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Abstract. According to the characteristics of the recycled materials of the old pavement, the blending ratio of different recycled materials is selected, and the grading design is adopted by using the splitting mode. After comprehensive comparison, the CB-3 grade is selected as the target grade, P·O42.5 cement is the binder, and the RA (old cement concrete pavement material) type and RA+ with 30% and 50% recycled materials are disposed. RAP type (combined from old cement concrete pavement and asphalt concrete pavement) cement stabilized gravel material. The results show that the maximum dry density of the material is reduced after adding RA and RAP to the cement stabilized macadam material. After adding RA, the optimum water content of the material is obviously increased, and the optimum water content can be slightly reduced after mixing with some RAP.

1. Introduction
With the acceleration of the construction of national grassroots facilities, the development and utilization of building materials has accelerated the consumption of resources and the destruction of the environment. According to statistics, at the end of 2016, the total length of national highways reached 4,696,300 km [1], and the proportion of large and medium-sized roads in China's national trunk highways accounted for about 13% of the total mileage per year [2]. A large number of roads will be generated in the reconstruction and expansion project. How to dispose of the waste generated by the renovation of old roads effectively has become a problem that must be faced and solved.

Zhang Ximian [3] and other researches on the application technology of cold regenerated base layer in situ. The results of laboratory tests show that the main factor affecting the strength of the cold recycled mixture is cement content and grading and the recommended cement content is about 5.0%. Wang Zhen [4] et al. showed that the low content of asphalt or cement would significantly affect the fatigue performance of cold recycled mixture. Xiao Jianzhuang [5] and Xiong Zijun [6] proposed the process of crushing and screening of waste concrete blocks. The recycled aggregate production process can basically meet the requirements of crushing and grading of waste concrete. Taha Ramzi [7] explored the feasibility of stable and cold regeneration of cement kiln dust as a base material through indoor mixing ratio tests.

This paper mainly focuses on the characteristics of old pavement reclaimed materials. By selecting different blending ratios of recycled materials, the grading design is carried out by means of binning. The changes of the maximum dry density and the optimum water content of cement stabilized macadam under different molding methods and different blending ratios were studied.
2. Mix ratio design

2.1 Aggregate screening
The gravel and stone chips used in this paper are 1# material (26.5~31.5mm), 2# material (13.2~26.5mm), 3# material (4.75~13.2mm), and 4# material (0~4.75mm). The particle size of each recycled aggregate is approximately 1# material (15~30mm), 2# material (5~15mm), and 3# material (0~5mm). In order to distinguish from natural aggregates, the three types of recycled coarse aggregates are referred to as recycled 1# materials to recycled 3# materials.

2.2 Aggregate grading
For the grading range of cement stabilized macadam or cement stabilized gravel, the new specification has made special provisions. Through comprehensive comparison, this paper selects the C-B-3 grading range and 4.5% Cement dosage for grading design.

In this paper, the replacement ratio of the two recycled materials was chosen to be 50%. The amount of recycled material was 30% and 0% for comparison test. There are five groups of experimental design grades. The content of natural materials, RA and RAP in each group are: 100:0:0, 70:30:0, 70:22:8, 50:50:0, 50:36:14, the group number and aggregate blending ratio are shown in Table 1.

| Numbering     | Aggregate ratio (%) |
|---------------|---------------------|
|               | Natural material   | RA | RAP |
| NA            | 100                 | 0  | 0   |
| RA1           | 70                  | 30 | 0   |
| RA-RAP1       | 70                  | 22 | 8   |
| RA2           | 50                  | 50 | 0   |
| RA-RAP2       | 50                  | 36 | 14  |

3. Effect of different compaction methods on maximum dry density and optimum water consumption

3.1 Compaction test method
(1) Heavy-duty compaction method
Experimenters use the balance to measure 5 to 6 parts of the air-dried sample. The density of the raw materials is different according to the material. The quality of each sample is between 5.4 and 5.8 kg. The samples were infiltrated by 5 to 6 different water contents, with a difference of 0.5%. The cement was added to the sample after 4 h of infiltration and mixed uniformly, and the test tube was placed in three times, and each layer was hammered 98 times. After three times of compaction, the sample was pushed out with a stripper, the test piece was broken, and a representative sample of 2 kg was taken from the inside of the sample to measure the water content.

Wet density calculation:
\[ \rho_w = \frac{m_1 - m_2}{V} \]  \hspace{1cm} (1)

Dry density calculation:
\[ \rho_d = \frac{\rho_w}{1+0.01\omega} \]  \hspace{1cm} (2)
(2) Vibration compaction method

Use the balance to measure 5 to 6 parts of the air-dried sample. The density of the raw materials is different according to the material. The quality of each sample is between 5.5 and 6.5 kg. Five to six different water contents are scheduled for the comparison of the three test water content-dry density curves. The test uses the same water content difference as the heavy-duty compaction test to infiltrate the sample. The cement was added to the sample after 4 h of infiltration and mixed uniformly, and the diagonal mixture was sequentially loaded into the test mold by a quarter method. The mold mixture was pushed out with a stripper, the mixture was broken with a hammer, 2500 g of the mixture was taken from the middle, and dried in an oven to measure the water content.

(3) Static pressure method

The test procedure for determining the optimum water content and the maximum dry density by the static pressure method is referred to the compaction test method and the test piece forming method. The main principle of the method is to pressurize to 450KN at a speed of 1mm/min, measure the height of the test piece to calculate the volume of the test piece, calculate the dry density by the sum of the aggregate and the cement quality in the filler, and add the water before the compaction. The water content is calculated by losing water after compaction.

Use the balance to weigh 5~6 parts of the air-dried sample. The weight of each sample is about 6000kg~6500kg. Five to six different water contents are scheduled, with a difference of 0.5%. The infiltration is carried out at a water content which is 1% lower than the predetermined water content, a predetermined amount of cement is added and the mixture is uniformly mixed, and the reserved water is added during the mixing. The mixture is loaded into the test mold 3 times, and after each loading, the transplanting is carried out, and uniform filling should be ensured during the filling process. The filled test piece was placed on a press, pressurized to 450 KN at a loading rate of 1 mm/min, and unloaded after being stabilized for 2 minutes.

Water content calculation:

$$\omega = \frac{m_w - (m_1 - m_2)}{m_2} \quad (3)$$

Dry density calculation:

$$\rho = \frac{m_2}{V(1+\omega)} \quad (4)$$

3.2 Test results and analysis

The test results of the three compaction tests are plotted as a graph, with the water content as the abscissa and the dry density as the ordinate, and the water content-dry density curve is plotted. Each point of the experiment is fitted by a quadratic curve. The value of the apex pair of the curve is the optimum water content and the maximum dry density. The water content-dry density curves of the three tests are shown in Figures 4~5, respectively.
It can be seen from Figures 4~5 that the dry density and water content curves of the five proportioning materials obtained by heavy-duty compaction method, vibratory compaction method and static pressure method can be connected into a complete convex curve, indicating three kinds. The method can obtain the optimum water content and the maximum dry density of the cement stabilized macadam material. The curve was fitted by the quadratic curve method, and the optimum moisture content and maximum dry density of the five grades were obtained in Table 2. The optimum water content and maximum dry density distribution of the three test methods are shown in Figure 6.

Table 2. Optimal moisture content and maximum dry density for five grades

| Experiment method | Heavy-duty compaction | Vibration compaction | Static pressure | Average value |
|-------------------|-----------------------|---------------------|-----------------|---------------|
| NA                | Optimum water content (%): 5.82 | 5.18 | 5.89 | 5.63 |
|                   | Maximum dry density (g/cm³): 2.418 | 2.448 | 2.402 | 2.423 |
| RA1               | Optimum water content (%): 6.08 | 5.61 | 6.19 | 5.96 |
|                   | Maximum dry density (g/cm³): 2.365 | 2.392 | 2.359 | 2.372 |
| RA-RAP1           | Optimum water content (%): 6.20 | 5.70 | 6.05 | 5.98 |
|                   | Maximum dry density (g/cm³): 2.353 | 2.390 | 2.355 | 2.366 |
| RA2               | Optimum water content (%): 6.27 | 5.81 | 6.34 | 6.14 |
|                   | Maximum dry density (g/cm³): 2.294 | 2.334 | 2.294 | 2.307 |
| RA-RAP2           | Optimum water content (%): 6.32 | 5.73 | 6.18 | 6.08 |
|                   | Maximum dry density (g/cm³): 2.285 | 2.342 | 2.290 | 2.306 |
Figure 6 Optimal moisture content and maximum dry density scatter plot for five grades

The moisture in the cement stabilized macadam material includes: water absorbed by the coarse aggregate, water absorbed by the fine aggregate, preliminary hydration reaction of the cement, and water required to lubricate the cement mortar. The water absorbed by the coarse and fine aggregates under the same grade with different cement dosages is almost unchanged. The initial hydration reaction of the cement and the water required to lubricate the cement mortar are only related to the cement dosage. In the case of constant compaction work, in the compaction results at different cement dosages, the increased dry weight is only the weight of the increased hydration product, and the increased volume is only the increased cement volume.

It is indicated that replacing some natural materials with RA will increase the optimum water content of cement stabilized macadam material. After adding PAP, the optimum water content can be reduced to some extent, but the reduction is not large. The maximum dry density is ranked from large to small: NA>RA1≈RA-RAP1>RA2≈RA-RAP2, indicating that the maximum dry density of the material will decrease and decrease after adding RA and RAP to the cement stabilized macadam material. The amount is related to the total amount of RA and RAP added.

4.Conclusion

(1) After comprehensive analysis, the C-B-3 grade, cement dosage 4.5%, recycled material blending ratio 30%, 50% were selected for the mix design.

(2) After adding RA and RAP to the cement stabilized macadam material, the maximum dry density of the material will decrease, and the amount of reduction is related to the total addition amount of RA and RAP.

(3) The optimum moisture content and maximum dry density of cement stabilized macadam materials can be obtained by compaction test method, vibration test method and static pressure method, but the maximum dry density ratio obtained by vibration method is compaction method and static pressure method. The yield is large, and the water content is smaller than that obtained by the compaction method and the static pressure method. The results of heavy-duty compaction tests are more suitable for laboratory tests.

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