Experimental Study on Splitting Strength of AC-25 Emulsified Asphalt Cold Recycled Mixture

Zhaohui Sun¹, Zhiqi Song¹, Hanyag Cheng¹ and Weidong Sun²

¹The Transportation Engineering School of Shenyang Jianzhu University, Shenyang, China
²Liaoning Provincial Communications College Quality Supervision Guidance Evaluation Center, Shenyang, China
Happhforevernicety@126.com

Abstract. In the asphalt pavement design, determining reasonable structural parameters plays an important role in reducing early damage to the pavement and increasing use time of the pavement. Based on the optimized design, the dry-wet splitting strength and freeze-thaw splitting strength of AC-25 cold recycled emulsified asphalt mixture were studied. The results indicate that the dry-wet splitting strength of AC-25 cold recycled emulsified asphalt mixture is much higher than the technical requirements of the specification. The ratio of dry-wet splitting strength and the ratio of freezing-thawing cycle strength meet the indicators of the specification. Engineering application can refer to grading results of design.

1. Introduction

Generally speaking, the cold recycled asphalt mixture of emulsified asphalt has low tensile strength, and the asphalt pavement of the structure layer of cold recycled asphalt mixture is more likely to cause crack deformation and damage. Based on the preliminary work, this paper further develops the splitting strength test of AC-25 emulsified asphalt cold recycled mixture, which lays a foundation for the application of AC-25 emulsified asphalt cold recycled mixture in pavement.

2. Raw Material Testing

The asphalt mixture base of this testing road that is cold mixing and cold paving emulsified employs small crushed stone and stone chips in the stone pit with Fuxin clay. Xinmin Highway Asphalt Mixing Station manufactures the emulsified asphalt. Normal Portland cement is produced by Shenyang Hongxiang Cement Co., Ltd. Grade 32.5. The results of raw-material testing are shown in the Table 1 to Table 5. The properties of the raw materials tested accords with the requirements of specifications.

| Table 1. Results of mineral screening tests |
|--------------------------------------------|
| Mineral specifications name | Percentage of passing the following grid (mm) (%) |
| Milling planer material | 26.5 | 19 | 16 | 13.2 | 9.5 | 4.75 | 2.36 | 1.18 | 0.6 | 0.3 | 0.15 | 0.075 |
| gravel | 100 | 97.3 | 94.9 | 89.4 | 74.7 | 39.9 | 24.3 | 13.2 | 8.1 | 3.4 | 0.5 | 0.1 |
| Splinter | 100 | 72.8 | 39.2 | 12.6 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cement | 100 | 100 | 100 | 100 | 98.2 | 57.5 | 35 | 24.2 | 16.6 | 13.4 | 6.5 | 99.8 |
Table 2. Test results of recovery asphalt pavement materials (RAP)

| Material specifications name | Water content (%) | Asphalt content (%) | Sand equivalent (%) |
|-----------------------------|------------------|---------------------|---------------------|
| RAP                         | 0.55             | 4.3                 | 75.6                |

Table 3. Various indexes of emulsified asphalt

| Test projects                | Unit     | Quality indicators | Test results |
|------------------------------|----------|--------------------|--------------|
| Demulsification speed        |          | Slow split         | Slow split   |
| Residue on screen (1.18mm screen) | %       | 0.1                | 0.1          |
| Viscosity                    |          |                    |              |
| Engla viscosity E25          |          |                    |              |
| 25°C Saybolt viscosity Va    |          |                    |              |
| Penetration (25°C)           |          | 0.1 mm             | 50–300       |
| Solubility                   |          | 97.5               | 98           |
| Adhesion with coarse aggregate, wrapping area | No less than | 2/3               | >2/3         |
| Mixing test with coarse and fine aggregate | Uniform |                   | Uniform      |
| Ordinary temperature storage stability | 1d       | No higher than     | 1            |
|                               | 5d       | No higher than     | 5            |

Table 4. The technical index of coarse aggregate

| Test projects                        | Technical indicators | Test results |
|--------------------------------------|----------------------|--------------|
| The crushing value of the stone (%)  | ≤30                  | 19.5         |
| Los Angeles wear value               | ≤35                  | 17.0         |
| Apparent relative density            | ≥2.45                | 2.743        |
| Hydroscopicity (%)                   | ≤3.0                 | 0.69         |
| Needle flake particle content (%)    | ≤20                  | 6.2          |
| Water washing method <0.075mm particle content (%) | ≤1       | 0.1          |
| Content of soft rock (%)             | ≤5                   | 2.6          |

Table 5. The technical index of fine aggregate

| Test projects                        | Technical indicators | Test results |
|--------------------------------------|----------------------|--------------|
| Apparent relative density            | ≥2.45                | 2.743        |
| Mud content (content less than 0.075mm) (%) | ≤5        | 13.9         |
| Sand equivalent (%)                  | ≥50                  | 75.6         |

3. AC-25 Emulsified Asphalt Cold Recycled Mixture Design Scheme
As AC-25 emulsified asphalt cold recycled mixture is used for pavement base, according to the aggregate gradation design scope stipulated in the current “Highway asphalt pavement recovery technical code”[2], combined with the screening results of cold recycled material, The synthesis
classification is shown in Table 6, and the mineral materials composition is shown in Table 7. The optimal moisture content is 5.836%, the best ratio of emulsified asphalt to stone content is 3.8%.

| Mesh size (mm) | 37.5 | 26.5 | 19 | 16 | 13.2 | 9.5 | 4.75 | 2.36 | 1.18 | 0.6 | 0.3 | 0.15 | 0.075 |
|----------------|------|------|----|----|------|-----|------|------|------|-----|-----|------|-------|
| Level limit    | 100  | 100  | -  | -  | 80   | -   | 60   | -    | 45   | -   | -   | 20   | 7     |
| Level lower limit | 100  | 80   | -  | -  | 60   | -   | 25   | 15   | -    | 3   | -   | 1    |       |
| Synthetic grading | 100  | 100  | 91.4 | 81.5 | 71.3 | 59.1 | 35.8 | 21.5 | 12.1 | 7.7 | 3.9 | 1.7 | 0.7   |
| Target mix ratio | 100  | 99.6 | 90.8 | 81.6 | 72.5 | 55.1 | 32.9 | 21.6 | 14.1 | 8.9 | 5.6 | 4.2 | 2.1   |

Table 6. Target mix ratio design

| Material type (mm) | Milling planer material | 10–25 mm Crushed stone | Spltier | Mineral powder | Cement |
|--------------------|-------------------------|------------------------|---------|----------------|--------|
| Composition ratio (%) | 65                      | 25                     | 10      | /              | 1.5    |

Table 7. Mineral Composition (Mass fraction)

4. Dry-Wet Splitting Strength Test of AC-25 Emulsified Asphalt Cold Recycled Mixture

The recommended AC-25 cold recycled emulsified asphalt mixture was tested in accordance with the modified Marshall test method. Cylindrical specimens of diameter × height = 101.6mm × 63.5mm were prepared by secondary compaction method, and the two sides were compacted 50 times, placed in a 60 °C ventilated oven for 40 hours, and the two sides were compacted. 25 times after being cured, demoulding after it was at indoor temperature for 12 hours, according to the “Standard Test Methods of Bitumen and Bituminous Mixtures for Highway Engineering” (JTG E20-2011) T0716, the experiment temperature is 15 °C ± 0.5 °C, and the loading rate is 50 mm/min. When the diameter of the test piece is 100 mm ± 2.0 mm and the width of the bead is 12.7 mm, calculating the tensile strength of the split as shown in Equation (1).

\[ R_t = 0.006287 \frac{P_T}{h} \]  

(1)

Where: \( R_t \) - splitting tensile strength, MPa;  
\( P_T \) - the maximum value of the test load, N;  
\( h \) - test piece height, mm.

Put the tested piece into the water of 15 ± 0.5 °C for 24 hours to carry out a wet splitting strength test. The test results of dry-wet splitting strength are shown in Table 8 and Table 9. When the difference between a certain set of measured values and the average value is greater than \( k \) times the standard deviation, the measured value shall be discarded, and the average of the remaining measured values shall be used as the test result. When the number of tests is 4, the \( k \) value is 1.46, and the tested data are valid. The effective test value of the measured splitting strength is directly taken as the splitting strength value for pavement design.
Table 8. Test results of dry splitting strength (15 °C) of AC-25 emulsified asphalt cold recycled mixture

| Test piece number | Test piece height /mm | Test load maximum /N | Dry splitting strength /MPa | Average /MPa | Standard deviation | Coefficient of variation | Representative value/MPa | Splitting strength specification value (hot mix)/MPa |
|-------------------|-----------------------|----------------------|-----------------------------|--------------|-------------------|------------------------|--------------------------|----------------------------------|
| 1                 | 63.5                  | 11.92                | 1.18                        | 1.04         | 0.12              | 11.10                  | 1.04                     | 0.6~1.0                           |
| 2                 | 62.9                  | 9.03                 | 0.90                        |              |                   |                        |                          |                                   |
| 3                 | 63.4                  | 10.69                | 1.06                        |              |                   |                        |                          |                                   |
| 4                 | 62.7                  | 10.2                 | 1.02                        |              |                   |                        |                          |                                   |

Table 9. Test results of wet splitting strength (15 °C) of AC-25 emulsified asphalt cold recycled mixture

| Test piece number | Test piece height /mm | Test load maximum /N | Wet splitting strength /MPa | Average /MPa | Standard deviation | Coefficient of variation | Dry and wet splitting strength ratio/% | Dry and wet splitting strength ratio specification value |
|-------------------|-----------------------|----------------------|-----------------------------|--------------|-------------------|------------------------|--------------------------------------|-----------------------------------|
| 1                 | 63.2                  | 8.96                 | 0.89                        | 0.79         | 0.08              | 10.50                  | 75.9                                 | 75                                |
| 2                 | 63.7                  | 6.99                 | 0.69                        |              |                   |                        |                                      |                                   |
| 3                 | 63.1                  | 8.23                 | 0.82                        |              |                   |                        |                                      |                                   |
| 4                 | 63.5                  | 7.9                  | 0.78                        |              |                   |                        |                                      |                                   |

It can be seen from the test results in Table 8 and Table 9 that the dry crack strength of AC-25 cold recycled emulsified asphalt mixture is 1.04MPa, which conforms to the standard of hot mix asphalt and the dry-wet splitting strength ratio conforms to the requirements of the specification.

5. Freeze-Thaw Splitting Strength Test of AC-25 Emulsified Asphalt Cold Recycled Mixture

The freeze-thaw splitting strength test specimens were also molded into cylindrical specimens by Marshall compaction method, and the recommended AC-25 emulsified asphalt cold recycled mixture was tested according to the modified Marshall test method. The cylindrical test piece with the diameter *high=101.6mm*63.5mm was prepared by the second compaction method, and the two sides were compacted 50 times, placed in a 60 °C ventilated oven for 40 hours and the two sides were compacted 25 times after being cured, the mold was released after being placed at indoor temperature for 12 hours, and tested according to the “Standard Test Methods of Bitumen and Bituminous Mixtures for Highway Engineering” (JTG E20-2011) T0729. During the experiment, the tested pieces were divided into two groups, four test pieces in each group, one set was immersed in 25 °C water for 2 hours, and the other test process was as follows: hold under vacuum conditions of 98.3 kPa to 98.7 kPa for 15 min, then open Valve, return to normal pressure, the test piece is placed in water for 0.5h; take out the test piece into a plastic bag, add about 10ml of water, tie the bag, and put the test piece into the -18 °C refrigerator for 16 hours; then, the device was placed in a constant temperature water bath at 60 °C, the plastic bag was removed, and kept for 24 hours; then, it was immersed in water at 25 °C for 2 hours. Firstly, the pressure value at the time of fracturing is measured, and the tensile strength of freeze-thaw splitting TSR is calculated by the formula (2). The tested consequence are shown in Table 10 and Table 11.

\[
TSR = \left( \frac{R_{T2}}{R_{T1}} \right) \times 100
\]

Where: TSR - freeze-thaw splitting tensile strength ratio, %; 
\[ R_{T1} \] - splitting tensile strength of the first set of specimens without freeze-thaw cycles, MPa;
If you could take the time to split your sample of asphalt, it would be a great help to me.

R_{s2} - splitting tensile strength of the second set of specimens after freeze-thaw cycles, MPa;

h - the height of the tested piece, mm.

**Table 10.** Test results of splitting strength (25 °C) of AC-25 emulsified asphalt cold recycled mixture

| Test piece number | Test piece height/mm | Test load maximum/N | Splitting strength/MPa | Average/MPa | Standard deviation | Coefficient of variation | Representative value/MPa | Freeze-thaw splitting strength ratio specification value/% |
|-------------------|----------------------|---------------------|------------------------|-------------|--------------------|--------------------------|--------------------------|----------------------------------|
| 1                 | 63.2                 | 6.84                | 0.68                   |             |                    |                          |                          |                                   |
| 2                 | 63.5                 | 6.36                | 0.63                   |             |                    |                          |                          |                                   |
| 3                 | 62.8                 | 6.69                | 0.67                   | 0.67        | 0.03               | 4.4                      | 0.67                     | 70                               |
| 4                 | 63.0                 | 7.01                | 0.70                   |             |                    |                          |                          |                                   |

**Table 11.** Test results of splitting strength (25 °C) after freeze-thaw

| Test piece number | Test piece height/mm | Test load maximum/N | Splitting strength/MPa | Average/MPa | Standard deviation | Coefficient of variation | Representative value/MPa | Freeze-thaw splitting strength ratio TSR/% |
|-------------------|----------------------|---------------------|------------------------|-------------|--------------------|--------------------------|--------------------------|----------------------------------|
| 1                 | 63.0                 | 5.31                | 0.53                   |             |                    |                          |                          |                                   |
| 2                 | 63.2                 | 4.83                | 0.48                   |             |                    |                          |                          |                                   |
| 3                 | 63.5                 | 5.15                | 0.51                   | 0.518       | 0.03               | 5.8                      | 0.52                     | 78                               |
| 4                 | 62.9                 | 5.5                 | 0.55                   |             |                    |                          |                          |                                   |

It can be seen from the test results in Table 10 and Table 11 that the freeze-thaw splitting strength ratio of AC-25 emulsion asphalt mixture meets the requirements of the specification.

**6. Conclusion**

Based on our country's current recycling technical rules for the road asphalt pavement, at the basis of pre-optimized design, the strength of dry-wet splitting and freeze thawing for AC-25 emulsified asphalt cold recycled mixtures were tested. The results show that the designed AC-25 emulsified asphalt cold recycled blending has a dry splitting strength of 1.04 MPa and a wet splitting strength of 0.79 MPa, which is much larger than the specification of 0.40 (base layer, subbase layer) and 0.50 (lower layer). Both the splitting strength and the freeze-thaw cycle strength meet the specification and requirement, and the designed gradation can make a reference for the engineering applications.

**7. References**

[1] Occupation Standard of the People’s Republic of China. JTG F41-2008 Technical Specification for Highway Asphalt Pavement Recycling

[2] Occupation Standard of the People’s Republic of China., JTG E20-2011 “Standard Test Methods of Bitumen and Bituminous Mixtures for Highway Engineering” [S]

[3] Highway Science Research Institute, Ministry of Communications JTG F40-2004 “Technical Specifications for Construction of Highway Asphalt Pavements" [S]

[4] Occupation Standard of the People’s Republic of China, JTG E42-2005 “Test Methods of Aggregate for Highway Engineering” [S]

[5] Zhaohui Sun*, Huazhi Wang, Hanyang Cheng and Shuai Liu Optimization Design and Performance Evaluation of Cold-mixed AC-25 Emulsified Asphalt Mixture[J] Materials Science and Engineering, 381 (1)

[6] Hong H, Yang F, Tong Y, et al. Application of Phase Change Fine Aggregate in Cold Mix Asphalt Mixture[J]. Highway, 2016.

[7] Liu X S, Zhe-Sheng G E, Xi L I. Properties of Cold Mix Asphalt Mixture with Reclaimed Granular Material after Cement Pavement Rubblization[J]. Science Technology & Engineering, 2012.
[8] Yao L J, Cai X, Ning-Li L I. Design and Application of Mixing Proportion for High Performance Cold-mix Asphalt Mixture[J]. Communications Standardization, 2006.

[9] Fan P, An F, Xu J, et al. Research on Design and Performance of Cold-Mixed Asphalt Mixture[J]. Modern Transportation Technology, 2017.

[10] Ferrotti G, Pasquini E, Canestrari F. Experimental characterization of high-performance fiber-reinforced cold mix asphalt mixtures[J]. Construction & Building Materials, 2014, 57(57):117-125.

[11] Ge Z, Li H, Han Z, et al. Properties of cold mix asphalt mixtures with reclaimed granular aggregate from crushed PCC pavement[J]. Construction & Building Materials, 2015, 77:404-408.