Mixing temperature design and properties evaluation for SMA-13 mixture

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Abstract. The mixing temperature of hot asphalt mixture could be reduced by adding WMA additive Sasobit, as well as reducing smoke emissions and energy construction during the mixing construction and paving. The reasonable mixing temperature were investigated in this paper. In addition, high temperature stability, water stability and low-temperature performance of warm asphalt mixture were evaluated. The test results indicate that the mixing temperature of SMA-13 with WMA additive Sasobit may reduce 15-20°C at the same energy (compaction times). the dynamic stability were improved after adding WMA additive Sasobit, and the Water stability and low-temperature performance of mixture decreased, while all kinds of asphalt mixture properties can meet the requirements.

1. Introduction

Asphalt concrete construction are characterized by the work environment to the high temperature, smoke more, poor visibility and air circulation characteristics such as slow, common risk factors, harm has three aspects: one is toxic or harmful gases [1]. This is because the channel tunnel space narrow, poor ventilation, plus the asphalt send out of high temperature homework gasses and smoke, and car, paver, roller and other kinds of machinery equipment exhaust gas not easy to send out, gathered in the narrow space in the homework, construction workers once the body absorbs excess, will cause poisoning accident; second is high temperature. The asphalt concrete paving as high as 110 °C temperature above, plus poor ventilation and cooling effect is poor, and workplace temperature is higher, easy to cause the homework personnel heatstroke, affect human health and safety [2-3]; Three is fire. There are mainly the high temperature of asphalt surface and wash the shovel scraper with diesel, and vehicle machine operation and the temporary fire hazard of electricity [4-5]. In order to guarantee the channel tunnel in the process of paving asphalt concrete construction safety, in addition to strictly control the construction technology measures, but also by reducing asphalt mixing in order to reduce the viscosity of the compaction temperature, construction environment improvement avoid a lot of asphalt smoke production, improve the working environment, to ensure the construction quality [6].

For those purposes, the paper carry warm mix asphalt mixing and temperature control study on road performance, the findings for warm mix asphalt SMA-13 design has a guiding value.
2. Materials
The addition of Sasobit is 0.3% of the dosage of HMA, the temperatures of stone and mixing are reduced by 15~30 °C on the basis of HMA whose temperatures are 185 °C and 190 °C respectively. Test graduation of SMA-13 can be seen in Table 1. The binder content was 5.9% by weight of mix. Lignin fibre was added at the rate of 12% by the mass of mixture.

Table 1. Gradation of SMA-13 for testing.

| Mixtures | Passing (by Mass) under different sieve size (mm), % | Binder content, % |
|----------|---------------------------------------------------|------------------|
| PAC-13   | 100 90.5 61.4 26.9 22.9 17.9 15.2 12.6 11.1 8.5 5.9 |                  |

3. WMA's mixing temperature
In order to determine the mixing temperature, following molding temperature molding specimens and test mix parameters were tested.

1) stone’s temperature is 170 °C, the mixing temperature is 175 °C; 2) stone’s temperature is 170 °C, the mixing temperature is 170 °C; 3) stone’s temperature is 165 °C, the mixing temperature is 175 °C; 4) stone’s temperature is 155 °C, the mixing temperature is 165 °C; 5) stone’s temperature is 150 °C, the mixing temperature is 160 °C; The volume indexes of WMA at different temperatures are shown in Table 2.

Table 2. The volume indexes at different temperatures

| temperatures (°C) | 185+190 (HMA) | 170 | 175 | 170 | 175 | 165 | 165 | 155 | 160 |
|-------------------|---------------|-----|-----|-----|-----|-----|-----|-----|-----|
| asphalt-aggregate ratio (%) | 5.9           | 5.9 | 5.9 | 5.9 | 5.9 | 5.9 | 5.9 | 5.9 | 5.9 |
| fiber content (%) | 0.3           | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Sasobit content (%) | 0.3           | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| volume of air voids VV(%) | 4.1           | 3.7 | 4.1 | 4.2 | 5.2 | 5.5 |      |      |      |
| voids in mineral aggregate VMA(%) | 16.5          | 16.2 | 16.5 | 16.6 | 17.4 | 17.7 |      |      |      |
| Voids filled with asphalt VFA(%) | 75.2          | 76.6 | 75.2 | 74.5 | 70.4 | 69 |      |      |      |
| Bulk specific gravity(%) | 2.465 | 2.477 | 2.467 | 2.463 | 2.439 | 2.431 |      |      |      |
| VCAmix | 38.4 | 38.1 | 38.3 | 38.5 | 39 | 39.2 |      |      |      |

As can be seen from the Table 2, when the compaction works (compaction times) of WMA and HMA are consistent, if the degree of compaction of WMA is supposed to be same to HMA’s, the temperatures could be reduced by 15 °C ~20 °C. Finally, stone’s temperature is determined to 170 °C, the mixing temperature is 170 °C.

4. Performance of WMA

4.1. High temperature stability
The specific test is rutting test in which the index is dynamic stability at 60 °C, under the wheel pressure of 0.7 MPa, the test results are shown in Table 3.
Table 3. Results of rutting test

| Asphalt-aggregate ratio (%) | Dynamic stability (times/mm) | WMA average value | Criteria |
|-----------------------------|-----------------------------|-------------------|----------|
| 5.9                         | 15750                       | 13695.65          | 14653.74 | 14699.79 | ≥3000 |

It is observed that the addition of Sasobit has an important influence on WMA’s dynamic stability (14699.79 times/mm) and it is much larger than HMA’s (10962.265 times/mm). Because at the normal temperature of road surface, Sasobit forms the lattice structure in the binder, which improves the high temperature stability of road and enhances the resistance to rutting, WMA’s dynamic stability has improved significantly compared to HMA, and doesn’t cause rutting damage due to inadequate compaction by lower temperatures in the process of the mixing and compaction or the ease of asphalt’s aging.

4.2. Water stability

4.2.1. Test of soaking Marshall Stability. WMA’s soaking Marshall stability is shown in table 4.

Table 4. WMA- soaking Marshall stability

| Groups | Theoretical maximum specific gravity /\( r_t \) | measured bulk specific gravity /\( r_b \) | VV (%) | VMA (%) | VCA (%) | VFA (%) | WMA Marshall stability (KN) | WMA soaking Marshall stability of residues (%) | Criteria |
|--------|-----------------------------------------------|------------------------------------------|--------|---------|---------|---------|-----------------------------|-----------------------------------------------|----------|
| MS     | 2.572                                        | 2.469                                    | 4.0    | 16.4    | 38.3    | 75.6    | 11.98                       | 100.503                                       | ≥80      |

The comparative results of soaking Marshall stability of HMA and WMA are displayed in Table 5.

Table 5. The comparative of soaking Marshall stability of HMA and WMA

| Groups | Theoretical maximum specific gravity /\( r_t \) | HMA Marshall stability (KN) | HMA soaking Marshall stability (%) | WMA Marshall stability (KN) | WMA soaking Marshall stability of residues (%) | Criteria |
|--------|-----------------------------------------------|-----------------------------|----------------------------------|-----------------------------|-----------------------------------------------|----------|
| MS     | 2.572                                        | 12.70                       | 98.83                            | 11.98                       | 100.50                                       | ≥80      |

Compared to the HMA’s, the values of WMA’s soaking Marshall stability- MS are reduced a little, the difference of soaking residual stability MS0 of them looks small relatively. This result shows that the addition of Sasobit has a little negative effect on the short-term stability of asphalt mixture, but the effect on the long-term stability is little. Obviously the values of the MS0 of WMA with Sasobit aren’t less than 80%, meeting the requirement of code (JTGF40-2004) in wet zone where annual rainfall is greater than 1000 mm.

4.2.2. Test of freeze-thaw splitting. The results of freeze-thaw splitting test of WMA are shown in Table 6.
Table 6. The results of freeze-thaw splitting test

| groups       | theoretical maximum specific gravity /\(r_t\) | measured bulk specific gravity /\(r_t\) | VV (%) | VMA (%) | VCA\(_{\text{min}}\) (%) | VF (%) | splitting tensile strength \(R_t\)(MPa) | freeze-thaw splitting tensile strength TSR(%) | code requirement T0729 |
|--------------|---------------------------------------------|---------------------------------------|--------|---------|---------------------------|--------|--------------------------------------|---------------------------------------------|-----------------------|
| no           | 2.572                                       | 2.466                                 | 4.1    | 16.5    | 38.4                      | 75.0   | 0.917                                | 83.95                          | ≥80                   |
| freeze-thaw  | 2.572                                       | 2.467                                 | 4.1    | 16.4    | 38.35                     | 75.4   | 0.770                                | 83.95                          | ≥80                   |

The comparative results of freeze-thaw splitting test of HMA and WMA are displayed in Table 7.

Table 7. The comparisons of the results of freeze-thaw splitting test

| groups       | theoretical maximum specific gravity /\(r_t\) | HMA splitting tensile strength \(R_t\)(MPa) | HMA freeze-thaw splitting tensile strength TSR(%) | WMA splitting tensile strength \(R_t\)(MPa) | WMA freeze-thaw splitting tensile strength TSR(%) | code requirement T0729 |
|--------------|---------------------------------------------|--------------------------------------------|-----------------------------------------------|-------------------------------------------|-----------------------------------------------|-----------------------|
| no           | 2.572                                       | 1.029                                      | 85.43                                         | 0.917                                     | 83.95                                         | ≥80                   |
| freeze-thaw  | 2.572                                       | 0.879                                      | 85.43                                         | 0.770                                     | 83.95                                         | ≥80                   |

The data presented in the Table 7 suggests that TSR(83.95%) of WMA with Sasobit of 0.3% is lower than HMA’s(85.43%), however, which meets the requirement(TSR≥80%) of code(JTGF40-2004) in wet zone where annual rainfall is more than 1000 mm.

4.3. Low-temperature performance

The results of asphalt mixture WMA with Sasobit of 0.3% are presented in Table 8.

Table 8. The results of low temperature bending test of WMA

| Types        | bending-tensile strength \(R_B\)(MPa) | bending stiffness modulus \(S_B\)(MPa) | limiting bending-tensile stain \(\varepsilon_B\)(με) | code requirement \(\varepsilon_B\)(με) |
|--------------|--------------------------------------|---------------------------------------|-----------------------------------------------------|------------------------|
| HMA          | 13.22                                | 3620.54                               | 3675.85                                             | ≥3000                  |
| WMA          | 12.77                                | 3781.95                               | 3401.88                                             | ≥3000                  |

The result demonstrates that the gradation of SBS I-C modified asphalt SMA-13 meet the criterion’s requirement to limiting bending-tensile stain \(\varepsilon_B≥3000\muε\).

The comparative results of low temperature bending test of HMA and WMA are shown in Table 9.

Table 9. The comparison results of low temperature bending test

| Types        | bending-tensile strength \(R_B\)(MPa) | bending stiffness modulus \(S_B\)(MPa) | limiting bending-tensile stain \(\varepsilon_B\)(με) | code requirement \(\varepsilon_B\)(με) |
|--------------|--------------------------------------|---------------------------------------|-----------------------------------------------------|------------------------|
| HMA          | 13.22                                | 3620.54                               | 3675.85                                             | ≥3000                  |
| WMA          | 12.77                                | 3781.95                               | 3401.88                                             | ≥3000                  |

From the foregoing, we can know that the bending-tensile strength and limiting bending-tensile stain of HMA are higher than WMA’s, which suggests that Sasobit is harmful to low-temperature performance of asphalt mixture, such as the ability to resist damage and contraction deformation.

5. Conclusions

- In order to get the same compactness with the hot mix asphalt, the mixing temperature of SMA-13 with Sasobit warm agent may reduce 15-20℃ at the same energy (compaction times).
- Considering guaranteeing VMA, high temperature, low temperature and water stability and other road performance of warm mix asphalt, the temperature should be controlled appropriately at 160 ~ 175℃, and compaction temperature at 135 ~ 145℃.
• It can be found that warm agent have bad effect on asphalt mixture properties, including low temperature and water stability, while all kinds of asphalt mixture properties can meet the requirements.

References
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