Feasibility Study of Cement Modified Mastic Emulsified Asphalt Concrete

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Abstract. Cement Asphalt Concrete (CAC) is a newly developed cold-mixed pavement material at room temperature. In this paper, a kind of cement fast-cracked emulsified asphalt mastic and a gradation of stone mastic asphalt was used to obtain a high-performance pavement material. This material improves the gradation by calculating volume parameters and observing the state of the concrete, and then we determine the optimal cement asphalt mastic content through specific gravity, Marshall stability value and aggregate wrapping state. Finally, the Marshall stability value, flow value, indirect tensile strength and Cantabro loss were used to evaluate the performance of Stone Mastic Cement Asphalt (SMCA), Continuous-graded Cement Asphalt (CCA) and SMA. This paper shows that SMCA's technical performance is relatively similar to CCA, and the Cantabro loss is much lower than CCA. In comparison with SMA, except for flow value, other performances are higher than SMA.

Keywords: Fast Cracking Cationic Emulsified Asphalt, Pavement Engineering, Cement Asphalt Concrete, Stone Mastic Cement Asphalt

1. Introduction
At present, the most widely used pavement is still hot-mixed asphalt pavement. If the hot-mixed asphalt can be replaced by cold-mixed asphalt, lots of asphalt smoke, energy consumption and environmental pollution can be reduced [1-4]. In past studies, scholars have noted the great potential of CAC. CAC uses Cement Asphalt Mastic (CAM) as the binder, and CAM is an organic-inorganic composite cementitious material composed of cement, emulsified asphalt and various additives [5-9].

However, the emulsified asphalt most used in previous studies is slow cracking type, while the study of fast cracking type is lacking. Cheng-Tsung Lu [10] firstly tried to pre-treat fast-crack emulsified asphalt (PC-1) with F-type superplasticizer. Due to the isolation of superplasticizer, the emulsified asphalt can be directly mixed with cement particles to form a homogeneous viscous material. It is used as a binder to make asphalt concrete. He [11] obtained NSP-I CAM (C/A=1, SNF/A= 2.7%), The A in front is the cationic emulsified asphalt. The SNF in front is 30% solution of
Sulphonated Naphthalene Formaldehyde condensates). This paper attempts to use the NSP-I CAM studied by He as a binder for SMA pavement.

At present, the degree of influence of the actual gradation of cement added to CAC is inconclusive. Since the cement used in this paper is Portland Cement Type II (P·II), which contains about 5% limestone powder. These ingredients will affect the gradation, so it is necessary to consider the influence of cement on gradation.

The properties of CAM exactly meet the requirements of SMA for binder so this paper attempts to use CAM as a binder for SMA. That is SMCA. Since SMCA is still a type of SMA, for convenience, SMA in the following is for SMA with hot-mix asphalt.

2. Experimental Materials
The emulsified asphalt used in this study is cationic fast cracking type (PC-1). The asphalt used by SMA is No. 70 asphalt. In this paper, P·II Portland cement was used in this study, and the strength grade is 42.5.

3. Preliminary Experiments
The preliminary experiment is mainly divided into two steps, the determination of the gradation and the optimal cement asphalt mastic content. In this study, all test blocks used is standard Marshall Blocks, with continuous compaction for 75 times on both sides.

The structure of SMA is characterized by interlocking of coarse aggregates. Because the structure is not conducive to subject to the loading of Marshall test, volume parameters are more important for SMA [12]. In this study, the passing rate of 4.25 mm sieve is 26%, referring to the gradation A (listed in table 1) used by Shen [13]. On the basis of the passing rate of the 4.75mm sieve, the filler that can pass the 0.075mm sieve shall be removed, and the passing rate of the other sieves shall be adjusted, so as to obtain a better gradation for SMCA-20.

| Screen size/mm | 25 | 19 | 12.5 | 10 | 4.75 | 2.36 | 0.3 | 0.075 |
|---------------|----|----|------|----|------|------|-----|-------|
| Pass rate (mass ratio)% | 100 | 95 | 58 | 33 | 26 | 20 | 15 | 10 |

After the volume parameter measurement, SMCA with 18% 4.75mm sieves pass rate (VCADRC = 0.465, VCAmix = 0.309) has a lot of voids, and its appearance are extremely bad. Compared with 18%, the concrete with 22% (VCADRC=0.465, VCAmix=0.342) and 26% (VCADRC=0.465, VCAmix=0.376) passing rate of 4.75mm sieve has a good appearance.

Considering the unknown content of limestone powder and fine cement hydrate in cement, in order to have greater operability in subsequent experiments, SMCA with 22% passing rate of 4.75mm sieve is selected. After proper adjustment, the experiment gradation of SMCA-20 used in this study was obtained (listed in Table 2), and its volume parameter was measured (specific gravity=2.08, VV=0.034, V=0.287, VFA=0.893).

| Screen size/mm | 19 | 12.5 | 10 | 4.75 | 2.36 | 0.3 |
|---------------|----|------|----|------|------|-----|
| Passing rate/% | 95 | 70 | 40 | 22 | 4 | 0 |

In SMCA’s experiments, CAM was used instead of asphalt as the binder. The situation was more complicated because the binder contained cement. On the basis that the aggregate is just wrapped, adjust the CAM content amount of 20g each time. The optimal CAM content is determined with reference to the Marshall stability in 7 days and specific gravity.

According to the experimental results (listed in Table 3), the Marshall stability of group C is too low. When the CAM content in group A is 260g, although the Marshall stability is similar to that in
group B, the effective utilization rate of CAM is too low. Therefore, 240g is selected as the optimal CAM content.

| Group | CAM content/g | Actual CAM content/g | Specific gravity | Marshall stability (kN) |
|-------|---------------|-----------------------|-----------------|------------------------|
| A     | 260           | 214.2                 | 2.198           | 60.12                  |
| B     | 240           | 211.8                 | 2.208           | 64.12                  |
| C     | 220           | 203.4                 | 2.213           | 42.31                  |

4. Experimental Plan
After determining the gradation and CAM content of SMCA-20, we refer to Shen's paper to make SMA-20 and He's experimental results on CCA-20 [11] (CCA is the application of NSP-1 CAM to continuously graded asphalt concrete) as a control. The performance of the asphalt mixture was evaluated by Marshall stability value, flow value, indirect tensile strength and Cantabro loss.

5. Experimental Data Analysis
It can be seen from Figure. 1. The Marshall stability of SMCA-20 at each age is from 30kN to 75kN, while the Marshall stability of SMA-20 is only 12.84kN, and the Marshall stability of SMCA-20 in each period can be 2.45, 4.89, 5.18 and 5.86 times that of SMA-20. In addition, Marshall stability of SMCA-20 developed most rapidly in the first 7 days, reaching more than 80% of the 28-day Marshall stability. From Figure. 2, the flow value of SMCA-20 is about 50% ~ 60% of that of SMA-20, between 2.2mm ~ 2.7mm. And the flow value is 51.1%, 54.4%, 57.3%, 59.8% of SMA-20 in 1 day, 7 days, 14 days, and 28 days respectively. With reference to the American SMA design specification, 2~4mm is appropriate. Compared with CCA-20, SMCA-20 does not show great differences in the fields of flow value and Marshall stability.

**Figure.1.** Comparison of Marshall stability.  
**Figure.2.** Comparison of flow value.

As shown in Figure. 3 the indirect tensile strength of SMCA-20 at each period ranges from about 600kPa to 1700kPa, which is slightly higher than that of CCA-20. The indirect tensile strength of SMCA-20 reached 2.70, 4.74, 5.83, and 7.13 times of SMA-20 in 1 day, 7 days, 14 days, and 28 days respectively. The indirect tensile strength of SMCA-20 developed most rapidly in the first 7 days, reaching more than 65% of the 28-day indirect tensile strength.
Figure 3. Comparison of tensile strength

Comparing with SMA-20, SMCA-20 is a material with stronger brittleness and worse toughness, as shown in Figure. 4. Therefore, SMCA's resistance to dynamic impact decrease with the increase of mechanical strength. The resistance to dynamic impact is worse than SMA-20, but close to SMA-20. Compared with CCA-20, SMCA-20 fully demonstrates stone mastic asphalt's ability of resistance to abrasion.

6. Conclusion
Marshall stability and indirect tensile strength of SMCA are similar to CCA, and they can reach more than twice as much as SMA in 1 day. However, compared with SMA, the flow value is lower and the brittleness is more obvious, but the flow value of SMCA can still reach 2mm required by the American SMA design specification.

In terms of abrasion resistance, SMCA is worse than SMA. But compared to CCA with the same binder, the Cantabro loss of SMCA is reduced by more than half.

As a type of cement modified mastic emulsified asphalt concrete, SMCA performs well on thermal stability, abrasion resistance, low temperature performance, and water exfoliation. Although the resistance to dynamic impact is slightly lower than SMA, it is within the acceptable range. According to the results of this study, cement modified mastic emulsified asphalt concrete is new potential pavement materials.

References
[1] Qian Guoping, Zhu Hai. Evaluation of Long-term Aging of Warm Mix Asphalt Mixture Containing EAF Steel Slag Coarse Aggregate [J]. China and Foreign Highway, 38 (04): 272-277.
[2] Xiao Yanwu. Road performance and energy saving and emission reduction effect of Sasobit warm-mixed asphalt mixture [J]. Highway, (10): 213-216.
[3] Cheng Yiming. Application Research of Warm Mix Asphalt Mixture and Benefit Analysis of Energy Saving and Emission Reduction [J]. China and Foreign Highway, 2014, 34 (1): 314-318.
[4] Ye Wei, Yang Bo, Wu Jin, et al. Comprehensive evaluation test of asphalt fume and dust generated by warm mixing construction technology of tunnel asphalt pavement [J]. Journal of Safety and Environment, 2018, (4): 46.
[5] TAN Y, OUYANG J, LV J, et al. Effect of emulsifier on cement hydration in cement asphalt mortar[J]. Construction and building Materials, 2013, 47: 159-164.
[6] TAN Y, OUYANG J, LI Y. Factors influencing rheological properties of fresh cement asphalt emulsion paste[J]. Construction & Building Materials, 68: 611-617.
[7] JIANG J, WEI S, WEI L, et al. Effect of Functional Chemical Admixtures on the Performance of Cement Asphalt Mortar Used in Ballastless Track[J]. Journal of Wuhan University of Technology(Materials Science Edition), 2015, 30(5): 995-1000.
[8] WANG Y, YUAN Q, DENG D, et al. Measuring the pore structure of cement asphalt mortar by nuclear magnetic resonance[J]. Construction & Building Materials, 137(Complete): 450-458.

[9] JIAN Q, JIUYE Z, YIQIU T. Modeling Mechanical Properties of Cement Asphalt Emulsion Mortar with Different Asphalt to Cement Ratios and Temperatures[J]. Journal of Materials in Civil Engineering, 2018.

[10] Cheng-Tsung Lu. Research on Asphalt Concrete Proportioning Technology and Application in Pavement Engineering [D]. National Taiwan University of Science and Technology, 2008.

[11] He Miaomiao. Feasibility Study of Surfactant Applied to Cement Asphalt Concrete [D]. Shantou University, 2019.

[12] Highway Engineering Committee of China Engineering Construction Standardization Association. Technical Guide for Highway Asphalt Mastic Pavement [M]. People's Communications Press, 2002.

[13] Shen Yunlong. Research on the mechanical behavior of SMA asphalt concrete under different intermittent loads with different modified agents [D]. National Zhongxing University, National Zhongxing University, 2003.