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Measuring moisture susceptibility of Cold Mix Asphalt with a modified boiling test based on digital imaging

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HIGHLIGHTS

- A quick and simple modified boiling test utilizing digital imaging is introduced.
- Results from the modified boiling test correlates well with BBS and TSR tests.
- Use of modified emulsion can improve the moisture resistance of CMA significantly.

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ABSTRACT

Cold Mix Asphalt (CMA) is a promising alternative material for a wide range of paving applications from preventive maintenance and repair, to new pavement construction. However, the reported higher moisture susceptibility of CMA relative to traditional Hot Mix Asphalt (HMA) presents a challenge that limits the more widespread usage of CMA in the field up to date. To identify the potential of moisture susceptibility for CMA, a simple and effective test procedure based on modifications to the Boiling Test specified in ASTM D3625 is proposed in this paper. The modified boiling test can provide a quick measurement of moisture susceptibility for CMA in the material selection stage of the mix design. Digital imaging is used to quantify the coating of CMA mixture samples before and after the boiling test instead of subjective visual assessment. The "Coating Ratio" parameter is proposed as an index to evaluate the coating quality of CMA, and as a means to ensure adequate bonding between asphalt and aggregate. The results from the modified boiling test were verified by AASHTO TP-91 Binder Bond Strength (BBS) test and the AASHTO T-283 Tensile Strength Ratio (TSR) test of the compacted mixture. It is found that the results from modified boiling test correlated very well with those from BBS test and TSR test, indicating that the modified boiling test can be used as an effective tool to evaluate the moisture damage potential of CMA.

1. Introduction

Hot Mix Asphalt (HMA) is the most widely used construction material for pavements in the United States as it provides good quality and smooth ride. In recent years an emphasis on sustainability has resulted in implementation of warm mix asphalt which is similar to conventional HMA, but produced at lower temperatures as a means to reduce energy consumption and emissions. In another effort to reduce energy consumption of the production phase of asphalt-based highway materials, research on improved asphalt emulsion characterization and expanding possible emulsified asphalt applications is being conducted. One of these applications is Cold Mix Asphalt (CMA) for use as a pavement layer. CMA in this paper refers to the mixtures produced with virgin aggregate (without RAP materials) mixed with emulsified asphalt instead of hot asphalt binder, with possible environmental benefits including reduced energy consumption and emissions due to storing the emulsified asphalt at ambient temperature and the ability to use aggregates from the stock pile without drying [1]. Also, CMA can be stockpiled and has a longer working life, meaning it can be transported longer distances and placed in locations generally inaccessible or impractical for more traditional methods.

Despite the potential environmental benefits of CMA, a number of performance-related concerns need to be addressed before CMA can be systematically applied in the field, one of which is the moisture damage in the form of stripping due to the reduced bonding between binder residue and aggregate caused by the low temperature application of the asphalt emulsion in production,

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which represents one of the "weak aspects" of CMA with respect to the traditional HMA. A primary challenge associated with measuring the moisture susceptibility of CMA is the presence of water in the mixture within the wet aggregate and in the asphalt emulsion. In both cases, the water slowly evaporates over time as the mixture cures, which in turn affects the bulk mixture physical property and mechanical response. As a direct result of prolonged exposure to moisture, the CMA has higher potential in exhibiting early-life distress relative to HMA.

In order to address the moisture susceptibility of the CMA materials, a simple and effective evaluation method is needed to support the selection of quality materials. A number of methods have been successfully used to evaluate the moisture susceptibility of asphalt mixtures [2–5] either on loose mixture or compacted mixture for HMA. The boiling test specified in ASTM D3625 is a well-established test on loose mixture to evaluate coating effectiveness by visually assessing the percentage of coated area remaining after boiling. To promote the application of boiling test, however, a quantitative analysis is needed to better characterize the effect of moisture on the coating to remove the subjectivity of visual observation from the test method. In addition, no extensive application of boiling test to CMA has been conducted due to the lack of a specific and uniform sample preparation procedure.

Other than boiling test, the Binder Bonder Strength (BBS) test developed by previous researchers [6–9] and currently specified in AASHTO TP-91 provides a means to directly measure the ability of asphalt binder to maintain its bond on an aggregate surface under specific moisture conditioning. The BBS test has been successfully applied in the prediction of the moisture susceptibility of HMA and chip seal samples [10,11], indicating the bond strength as a good indicator of moisture susceptibility of the asphalt materials.

For compacted mixtures, the Tensile Strength Ratio (TSR) test specified in AASHTO T283 is the most commonly used procedure to evaluate the moisture resistance of HMA. The procedure involves testing of the indirect tensile strength on dry and moisture conditioned samples to assess the moisture resistance of the mixture. Based on the empirical correlations to observations in the field as well as the need to include moisture damage resistance in mix design, the TSR was included in the SuperPave mix design as a pass/fail criterion [12].

2. Research objectives

This paper is focused on developing a modified boiling test procedure that includes use of digital imaging to evaluate the coating quality of the mixtures and identify the potential moisture susceptible materials for CMA. The specific objectives are as follows:

1. Propose a modified boiling test procedure by providing a specific material preparation guideline for CMA and using digital imaging to quantify the coating quality of the mixtures.
2. Verify that the analysis results from the modified boiling test is an effective indicator of moisture susceptibility for CMA by comparing the Ratio to results of the bond strength measurements from BBS test and the Tensile Strength Ratios from compacted mixture TSR test.

3. Materials

Both coating quantity and quality are dependent on the physical and chemical properties of the individual components of the emulsion–aggregate system [13]. In this study three different emulsion types and aggregates with different mineralogy were selected, and the experimental matrix for the modified boiling test is introduced in details below.

Two unmodified cationic emulsion CSS-1h and CSS-2 with different viscosities (CSS-2 is higher) and one latex modified cationic emulsion CSS-1hL were selected to evaluate the effect of modification of asphalt emulsion on coating quality. The residue asphalt contents for CSS-1h, CSS-2 and CSS-1hL are 57%, 62% and 61%, respectively. Both granite and limestone were included to provide both charge compatibility and charge incompatibility conditions [13,14]. The residual asphalt content of 2.0% was determined on the basis of the calculated specific surface area of the aggregates with the asphalt film thickness of 8–10 microns [13]. Only coarse aggregates with size of 3/8″ were used in this study. Aggregate with SSD condition was used to simulate the aggregate condition in the field. In this study the limestone and granite aggregates had values of absorption of 1.53% and 0.40%, respectively. All the three emulsion types and two aggregate sources used in the modified boiling test were maintained in the BBS test as well.

To prepare the compacted mixture samples for mix design and TSR test, a specific gradation is required. In this study a gradation which meets the SuperPave E-10 requirements for a nominal maximum aggregate size (NMAS) of 12.5 mm was used, the gradation curve on a 0.45 power chart is shown in Fig. 1. To maintain consistency, the same limestone and granite sources as in the modified boiling test were used and the SSD condition for aggregate before mixing was still applied. Only two emulsion types CSS-1h and CSS-1hL representing unmodified and modified asphalt emulsion respectively were included for the compacted mixture tests.

4. Test methods

4.1. Modified boiling test using digital imaging

In this study, the boiling test procedure specified in standard ASTM D3625 was followed with modifications to the CMA specific sample preparation and inclusion of digital imaging method [13] to evaluate aggregate coating before and after the boiling instead of visual assessment. The detailed procedure is described as follows.

A loose mixture sample of at least 500 g is cured at a specified condition (as discussed in the next section) after mixing. Then the sample is scanned using a standard office scanner to obtain the image of sample coating before boiling. After being scanned, the sample is placed in the 5000 ml-beaker filled with at least 3000 ml boiling water. A steel basket is used to prevent mixture directly touching the bottom of beaker which has much higher temperature than the boiling point due to the contact with the heater. The boiling test apparatus is presented in Fig. 2. Based on preliminary testing results, 10 min of boiling time (specified in ASTM D3625) is insufficient to cause significant stripping after boiling, therefore longer boiling time (20–60 min) was used to expand the range of stripping. After boiling, the stripped asphalt on the surface of water was skimmed and the basket with mixture sample was removed from the beaker. The samples were spread on silicone mats for drying at ambient temperature for at least 24 h until sufficiently dry (no water on the sample surface observed) for scanning. Then the dry samples are scanned again to obtain the coating image after boiling.

Instead of using visual observation as specified in ASTM D3625, the digital imaging method for evaluation of coating developed in previous study [13] was followed to evaluate coating extent before

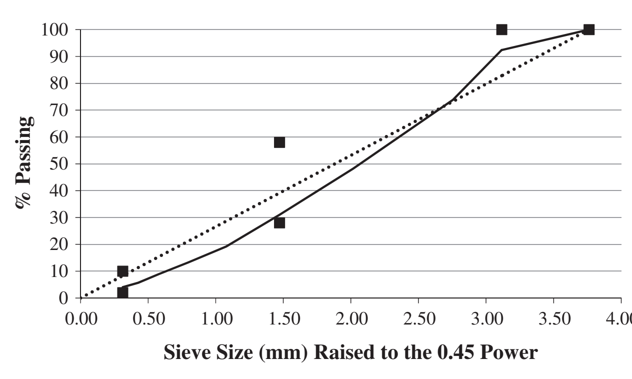

Fig. 1. Gradations used in compacted mixture TSR test.