

Low and Intermediate Temperature Evaluation of Asphalt Binders through Dynamic Shear Rheometer

Introduction

The grading system for asphalt binders improved from penetration into a more detailed version of viscosity through the early 1960s. After roughly 30 years, the Performance Grading (PG) system was developed to address the rising need for the improved characterization of asphalt binders. It has been more than 25 years since the AASHTO M 320 and AASHTO T 313 standards were implemented. While additional test methods have been implemented for high-temperature characterization, low-temperature characterization has been conducted with the Bending Beam Rheometer (BBR), with no change during this time. The lack of novel testing methods has caused significant issues for the low-temperature properties. Environmental and traffic-induced stresses, along with the application of recycled materials (e.g., RAP and RAS), are degrading the low-temperature behavior of asphalt binders.

Agencies are motivated toward innovative asphalt binder characterization methods due to increasing modification of the asphalt binder. Asphalt binder is subjected to many additive modifications for the purposes of performance enhancements or cost improvement. BBR testing requires considerable time for preparation and cannot be performed in the limited plant production timeline; therefore, alternative methods may be adopted to meet production timelines.

Conventionally, the DSR is used to characterize asphalt binders at high and intermediate temperatures. Based on the viscosity of the asphalt binder in these environments, the geometry of the DSR has been determined to address the torsion limits of the device. By lowering the temperature of the asphalt binder, the viscosity increases and the sample size is decreased to be tested within the DSR device limits. Figure 1 presents different spindle sizes that represent the common asphalt binder sample sizes.



Figure 1. 4mm, 8mm, and 25mm DSR spindles

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Research has been performed on the capability of the 4mm and 8mm DSR samples in predicting the low-temperature behavior of asphalt binders. Western Research Institute (WRI) has pioneered a method to determine the stiffness of asphalt binders at low temperatures based on the parameters derived from a master-curve of asphalt binders at low to intermediate temperatures.

Pavement Systems LLC has developed an 8mm method called Incremental Creep at Low-Temperature (iCCL) to address the difficulties of sample preparation and timeliness of BBR testing. iCCL determines the low-temperature characteristics of the asphalt binder through a constant shear (creep) load in increments at low temperatures. Pavement Systems LLC has further expanded their method and developed another test method. The Ultra-Thin Film Oven (UTFO) test has the same mechanism and preparation as iCCL; however, in this method, asphalt binders can be tested in their original state without any RTFO and PAV aging.

Objective

The primary objective of this research was to evaluate the effectiveness of newly proposed methods (iCCL, UTFO, and WRI) for the low-temperature performance grading of asphalt binders by comparing them against the conventional Bending Beam Rheometer (BBR) test. Ultimately, this study aimed to determine whether these alternative methods can provide reliable, efficient, and practical options for binder characterization that could potentially enhance or replace traditional BBR testing.

Scope

To achieve this objective, the research focused on comparing key performance indicators between the testing methods, specifically stiffness and thermal cracking resistance. The study's material scope included a diverse, representative sample of both modified and unmodified asphalt binders and additives. These materials were sourced directly from producers throughout Louisiana to ensure the findings are highly applicable to the state's current infrastructure and paving practices.

Methodology

Twenty asphalt binders from various suppliers throughout Louisiana were collected and evaluated. Samples went through the 4mm DSR with the WRI method. In this method, isotherms are generated by testing samples in a range of 0.1 to 100 Hz frequency at -24°C, -12°C, 0°C, 12°C, and 24°C.

Similar sample preparation processes are used for the iCCL and UTFO methods. An asphalt binder was prepared with a weight of 0.031-0.038 grams. The sample is sandwiched between an 8mm plate and spindle with no trimming and a 0.5mm gap.

Finally, BBR testing was performed in accordance with AASHTO T 313 at two different temperatures, one above and one below the known performance grade.

Conclusions

- Statistical analysis through ANOVA shows that the majority of samples have significant continuous grading differences when DSR methods are compared to BBR results. The WRI and iCCL methods showed the least instance of differences, followed by the UTFO method.
- While statistical differences in continuous grades were significant in many of the samples, the proposed methods were able to practically determine the low-temperature grade of the asphalt binder accurately, as compared to the BBR-determined grade.
- The BBR resulted in a warmer continuous grade in the majority of the samples evaluated. Therefore, the BBR result is more conservative than DSR methods.

Recommendations

Based on the results of this study, DSR methods aim to predict the BBR results based on correlations through different methods. While the results show acceptable and practical correlation, statistical analyses differ. Further, if these methods are applied for low-temperature performance grade, they need to be thoroughly investigated when unconventional asphalt binder samples with high modifications are used. Based on the results of this study, it is recommended that practitioners can use these alternative testing methods for low-temperature verifications of low-temperature performance grade.