National Center for Asphalt Technology NCAT at AUBURN UNIVERSITY

Mixing and Compaction Temperatures of Asphalt Binders in Hot Mix Asphalt

RESEARCH SYNOPSIS–NCHRP REPORT 648

Problem Statement

The use of modified asphalt binders in hot mix asphalt (HMA) is increasing, as is the need for a better way to select appropriate temperatures for handling these binders. The traditional method for determining laboratory mixing and compaction temperatures for HMA has been based on asphalt viscosity measurements. However, for modified binders, this method has been found to result in excessively high temperatures, which can possibly lead to emissions problems and degradation of the binder's properties.

Objective

The objective of this study was to identify or develop a simple, reliable, and effective laboratory procedure to determine appropriate mixing and compaction temperatures for both modified and unmodified binders.

Description of Study

Conducted by researchers at the National Center for Asphalt Technology (NCAT) and John Casola of Malvern Instruments, the study included a literature review of several alternatives for determining mixing and compaction temperatures. Three methods were selected to undergo a detailed laboratory evaluation:

- High Shear Rate Viscosity: This method, developed by Yetkin Yildirim et al., relies on evidence that most modified binders exhibit shear thinning behavior and uses rotational viscometer measurements at two temperatures over a range of shear rates. Using the Cross-Williams model, the data is then extrapolated to a higher shear rate of 500 1/s and plotted on a conventional log viscosity versus log temperature chart to obtain temperatures that correspond to the traditional viscosity criteria of 0.17±0.02 Pa•s for mixing and 0.28±0.03 Pa•s for compaction.
- Steady Shear Flow: Developed by Gerry Reinke, this method uses the dynamic shear rheometer (DSR) to measure a binder's viscosity over a range of shear stresses at temperatures from 76 to 94˚C. The viscosity of most modified binders approaches a steady state at higher shear stresses of approximately 500 Pa. These viscosity results are then extrapolated to 180˚C, using a log viscosity vs. log temperature chart. The appropriate mixing temperature is then selected at the traditional viscosity criteria (0.17±0.02 Pa•s), while compaction temperature is selected at the viscosity recommended by Reinke: 0.35±0.03 Pa•s.
- Phase Angle: The third method, developed by Casola, is based on the observation that the phase angle is a binder-consistency property that takes into account the viscoelastic nature of asphalt binders. This method uses a DSR with 25-mm parallel plate geometries and a 1-mm gap set up in oscillatory shear mode over a range of angular frequencies. The frequency sweep data is used to construct a phase angle versus frequency master curve at a reference temperature of 80˚C. The frequency that corresponds to the transition from viscous to viscoelastic behavior (represented by a phase angle of 86˚C) is then correlated to the temperatures at which binders coat the aggregate well during mixing and lubricate effectively during compaction.

Figure 1 The Steady Shear Flow and Phase Angle methods use a standard dynamic shear rheometer (DSR).

The three candidate methods were compared using modified and unmodified binders from different U.S. binder suppliers to include a range of crude sources, refining processes, and modification systems.

Two series of experiments were conducted, the first involving tests of candidate methods as well as other tests to assess emissions potential and binder degradation due to high-temperature exposure.The second set of experiments involved laboratory mixture tests to determine how temperatures affect aggregate coating during mixing, compactability, and workability, as well as low-temperature properties of asphalt mixtures with different binders.

Key Findings

Both the Steady Shear Flow and Phase Angle methods provided lower mixing and compaction temperatures for modified binders than those derived from the traditional equiviscous methods. For unmodified binders, the Steady Shear Flow method also yielded lower mixing and compaction temperatures, though the temperature difference between the two methods was not as great as for modified binders. While the Phase Angle method also yielded more reasonable (lower) temperatures for modified binders than those provided by the traditional method, there was not a consistent trend between results for the set of unmodified binders.

The High Shear Rate Viscosity method yielded high mixing temperatures similar to those obtained using the current traditional method, offering no improvement.

Results from both the Steady Shear Flow and Phase Angle methods correlated well with the compactability test results. Correlations of the mixing temperatures from the Steady Shear Flow and Phase Angle methods with coating test results were weak due to inconsistencies with the subjective nature of the coating test. Poor repeatability was also a problem with the mixture workability test results.

Both of these methods can be carried out using standard DSR equipment, recognizing that standard DSR testing has practical limitations, including the test temperatures at which binder properties are measured and the interference of particulate matter, such as ground rubber particles, with the rheological response in the 1 mm gap of the instrument.

Recommendations for Implementation

The Steady Shear Flow and Phase Angle methods are recommended for further evaluation in determining mixing and compaction temperatures for asphalt binders. However, the temperatures determined by these methods should only be applied in a laboratory setting for mix design work, quality assurance testing of HMA and fabricating HMA samples for laboratory performance tests. These temperatures should not be used to control plant production or pavement construction temperatures.

Further Research and Development

These alternative methods for determining mixing and compaction temperatures should be validated using a broader range of binders. The test procedures should also be refined (to include experiments with alternate instrument geometries to avoid issues with temperatures and some filled binders). In addition, precision statements need to be established and asphalt binder technicians should be trained on these methods as part of an implementation plan.

Acknowledgements and Disclaimer

This research was performed under NCHRP Project 9-39 by the National Center for Asphalt Technology, Auburn University. This Research Synopsis provides a brief summary of the study's final publication. This document is for general guidance and reference purposes only. NCAT, Auburn University, and the listed sponsoring agencies assume no liability for the contents or their use.