Structural Evaluation of a Highly Polymer-Modified Asphalt Pavement

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

RESEARCH SYNOPSIS

Problem Statement

Polymer-modified asphalt (PMA) is a well-established product that has typically been used in upper pavement lifts to enhance pavement performance. In particular, styrene-butadiene-styrene (SBS) polymers are often used to improve permanent deformation resistance and durability in surface courses. The use of PMA in intermediate and bases courses has been limited partly because base courses are perceived to be less susceptible to fatigue cracking resulting from extreme temperature and traffic conditions.

However, ever-increasing traffic volumes and pavement loading coupled with depleted funds among state highway agencies have created demand for high-performing pavement structures with reduced life-cycle costs. This provides motivation for using PMA in the lower lifts of a flexible pavement; however, the effect of PMA on the structural characteristics of the pavement when used in base courses is uncertain.

Objective

The objective of this research was to evaluate the in-place structural characteristics of a highly polymer-modified (HPM) asphalt pavement relative to a control section under the same traffic and environmental conditions on the 2009 NCAT Pavement Test Track.

Description of Study

While laboratory testing of an HPM formulation was promising, showing resistance of the HPM to permanent deformation and fatigue cracking, field trials were necessary to fully understand its in-situ characteristics. From a structural design and analysis perspective, this was needed to assess whether HPM asphalt performs like a conventional material so that it can be modeled with conventional approaches (e.g., layered elasticity) within mechanics-based design. From a performance perspective, the field trials were necessary to evaluate whether a 40 percent reduction in thickness as a result of the HPM formulation is viable.

To address this need, Kraton Polymers, LLC, sponsored an experimental HPM test section on the 2009 NCAT Pavement Test Track. This section was designed to be thinner than a control section to investigate the performance of using HPM materials. Test track sections S9 (control) and N7 (HPM) were used for this study, and each section was constructed with an array of strain gauges, pressure plates and temperature probes. This study focused on the asphalt strain, vertical pressure in the aggregate base and mid-depth temperature data. The strain gauges were installed to allow both longitudinal (in the direction of traffic) and transverse (perpendicular to traffic) strains to be measured, though only the longitudinal strain data pertain to this research. Vertical pressures measured at the asphalt/aggregate base are also presented as indicators of how well each cross-section distributes stresses and as an indicator for rutting performance.

Weekly dynamic strain and pressure measurements made between August 2009 and September 2011 formed the basis of this analysis. On each collection date, three passes of each truck traveling about 45 mph on both sections were recorded. The measured mid-depth pavement temperature was used to correlate strain and pressure to temperature. The "best hit" longitudinal strain and vertical pressures under single axles versus mid-depth pavement temperature for each section were recorded over the testing period. These data showed the dependence of strain and pressure on temperature and can be characterized by regression equations, which were previously used with test track strain and pressure data. To further investigate statistically significant differences between the two sections, temperature-corrections were then performed at three reference temperatures (50, 80, and 110˚F) representing the range of measured temperatures. Figure 1 summarizes this data for both sections.

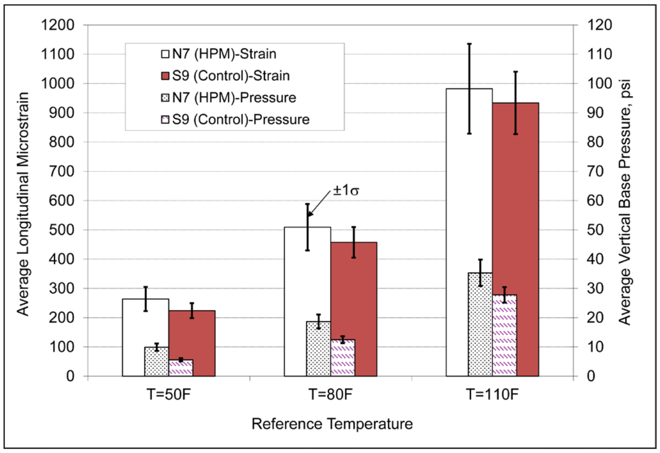

Figure 1 Temperature-corrected strain and pressure.

Falling-weight deflectometer (FWD) testing to determine backcalculated asphalt moduli was also conducted several times a month during the testing period. Testing was scheduled to coordinate with a broad range of temperatures that corresponded to the range encountered during live traffic testing. Within both test sections, 12 locations were tested on each test date that represented four longitudinal stations and three offsets (inside, outside and between wheelpaths) per station. Mid-depth pavement temperatures were measured during testing. EVERCALC (5.0), which previously had been successfully used at the test track, was used to backcalculate the asphalt, aggregate base and subgrade soil properties in a three-layer cross-section. Temperature corrections were made to each data set that enabled statistical comparisons between the control and the HPM sections. These data are shown in Figure 2.

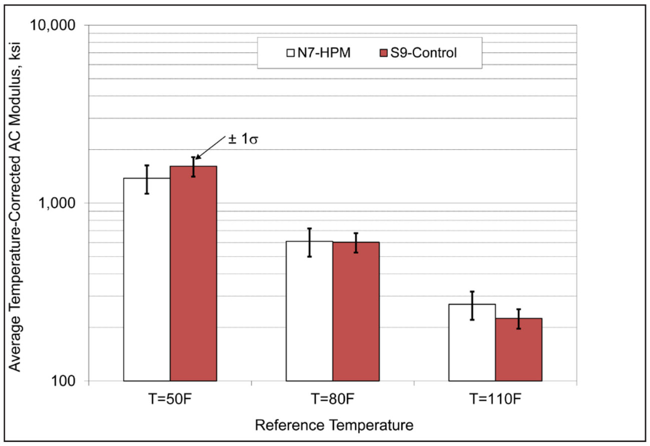

Figure 2 Temperature-corrected backcalculated moduli.

Surface performance characteristics, including rutting, cracking and ride quality, were also evaluated during this testing period. Weekly monitoring of each section was conducted on Mondays. Throughout the experiment, there was no observed cracking in either section, and they maintained similar ride quality. The Kraton HPM section had about half the total rutting of the control, though both performed extremely well. As of September 30, 2011, each section had endured about 10 million ESALs.

Conclusions and Recommendations

This study evaluated the structural characteristics of a highly polymer-modified asphalt pavement compared to the same characteristics of a control section. The following conclusions and recommendations can be made based on this research:

1) The structural behavior (i.e., strain and stress) of both sections in response to temperature could be well-characterized by exponential function. This was also true of in situ moduli, which implies that the HPM material can be successfully modeled using conventional pavement models such as layered elasticity. However, this field trial required careful study to ensure appropriate use within mechanistic-based design procedures such as the mechanistic-empirical pavement design guide (MEPDG).
2) The Kraton HPM section has performed as well as, or better than, the control section despite having a 1.2-inch thinner cross-section.
3) Backcalculated AC moduli indicated a lower modulus for the HPM section at low temperatures while it was higher than that of the control at warm temperatures.
4) Significant scatter in the measured strain data was noted in the HPM section. The reason for this is pending further investigation. Despite the scatter, statistical testing indicated no differences in measured strains at the lower two reference temperatures. At the warmest temperature (110˚F), the HPM section exhibited statistically lower strain levels (11 percent lower). This was due to increased AC modulus at the warmest temperature.
5) The HPM section is expected to exhibit better resistance to fatigue cracking upon further trafficking. Preliminary estimates, based on measured strain at 68˚F and laboratory-determined fatigue transfer functions, indicate the HPM section has nearly 64 times the fatigue life of the control section.
6) It is recommended that both the Kraton HPM and control section be left in place for the 2012 research cycle to further validate these findings.

Acknowledgements and Disclaimer

This study was sponsored by Kraton Polymers, LLC. This research synopsis provides a brief summary of the study's final report. 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.