PAVEMENT EVALUATION AND DEVELOPMENT OF SEASONAL AND TEMPERATURE ADJUSTMENT MODELS USING SEISMIC PAVEMENT ANALYZER (SPA)

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Abstract

Changes in material properties of pavement layers with temperature and seasonal climate variations significantly affect the pavement response. The AASHTO design guide requires that seasonal and temperature corrections be taken into consideration. Since the AASHTO adjustment models were developed based on data collected in Illinois, most of the states initiated studies that would take in consideration state specific conditions.

New Jersey Department of Transportation (NJDOT) initiated a study with the same objective. Twenty-four flexible, rigid and composite pavement sections, throughout New Jersey, have been instrumented. The sites have been instrumented for the purpose of continuous monitoring of temperature, frost-thaw, moisture, ground water table and environmental changes (air temperature and rainfall). Simultaneously, a two-year field evaluation using Falling weight Deflectometer (FWD) and Seismic Pavement Analyzer (SPA) is in progress. FWD and SPA testing is being conducted on a monthly basis, except during the spring-thaw period that is on a bi-monthly basis. So far 16 testing cycles have been completed. In addition, samples recovered in the field were taken for a detailed laboratory evaluation.

This paper presents an overview of the study with an emphasis on the use of applied geophysical methods, in this case seismic techniques, in the development of the seasonal and temperature adjustment models. Typical pavement instrumentation, collected data, and their preliminary correlations with SPA data are presented.

Introduction

Seasonal climate variations and temperature changes affect the response of pavements and should be taken into consideration. Similarly, a deflection basin measured by the FWD at different temperatures and climatic conditions should be corrected to a standard condition to reflect changes in the pavement response on a consistent basis. The AASHTO design guide proposes adjustment models for considering effects of climatic conditions and temperature on pavements. Since these models are developed based on data collected in Illinois, they do not reflect the specific conditions of each state. The inaccuracy of the AAHTO procedure has been also reported by different highway agencies (Kim et al. 1994, Johnson and Ronald 1992, and Baltzer and Jansen 1994). As a result, most of the states initiated studies that take into consideration state specific conditions.

New Jersey Department of Transportation (NJDOT) initiated a study with an objective to calibrate the AASHTO temperature and seasonal adjustment models or to develop new models. Twenty-four flexible, rigid, and composite pavement sections throughout the state of New Jersey have been instrumented to monitor climatic parameters. A two-year NDT field evaluation using FWD and SPA (Nazarian et al. 1993) is in progress on a monthly basis (except during the spring-thaw period that is on a bi-monthly basis).

The paper presents an overview of the study with an emphasis on the use of applied geophysical methods, in this case seismic techniques, in the development of the seasonal and temperature adjustment models. Details of instrumentation of a typical test section, collected instrumentation and SPA test data for a period of one year, as well as result of a preliminary analysis are presented.

Test Section Instrumentation and NDT Monitoring Plan

The study has two main components, the seasonal adjustment study and the temperature correction study. Since influence of seasonal variation is more important for flexible pavements, in the seasonal adjustment study, the focus of study is on flexible pavements. However, two rigid and a composite pavement are also included in the test sections to study seasonal effects on rigid and composite pavements. In the selection of the test sections, the total pavement thickness (>24" or <24"), freezing index represented by geographical location (northern vs. southern zone), and subgrade types were the controlling factors. For the temperature correction study, only flexible and composite sections are selected because the temperature mainly affects the stiffness of asphalt layers. Based on the mentioned components, 24 test sections were selected throughout the state of New Jersey, of which 17 sections are LTPP SPS 5 and 9 sections on Interstate I-195. Locations of the test sections are shown in Figure 1.

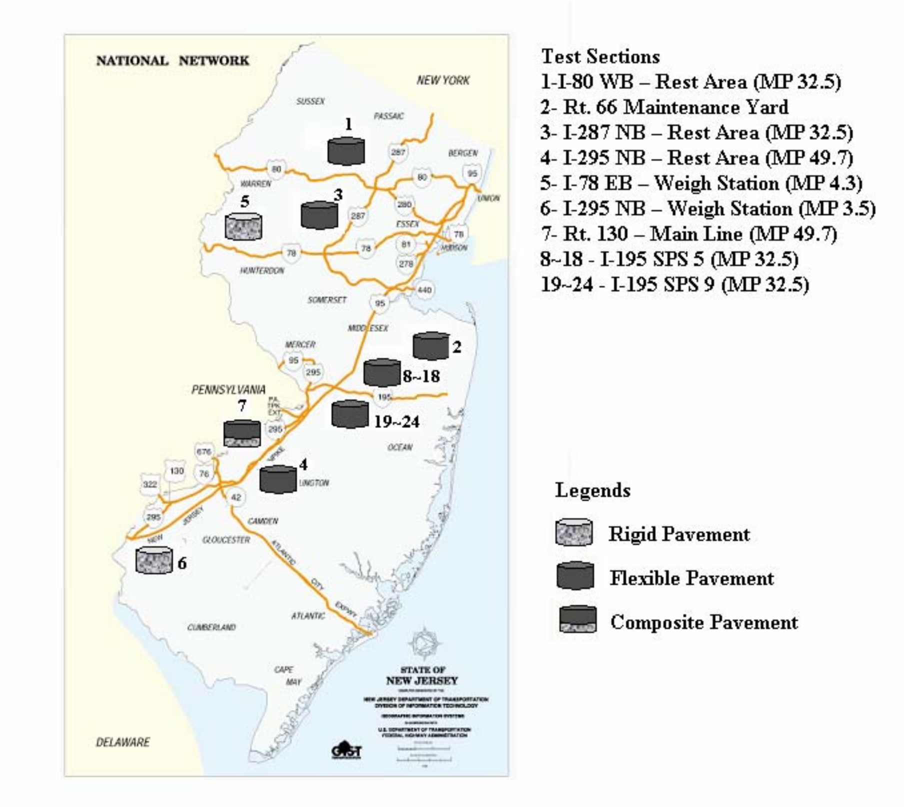

Figure 1- Location of test sections.

To monitor environmental variables, each section was instrumented according to the objective of the study for that particular section. Three classes of instrumentation were chosen and the sections instrumented accordingly. In class A, air temperature, rainfall, ground water table, moisture content (using Time Domain Reflectometry (TDR) probes), subsurface temperature at different levels, and frost-thaw depth (using resistivity sensors) were monitored at test section. For class B instrumentation, only subsurface temperature was measured and for class C, air and pavement temperature, and rainfall were monitored. The data is being continuously collected and saved for future analysis.

To monitor the pavement response, FWD and SPA pavement evaluation (Figure 2) is being conducted on a monthly basis. The monitoring will last for two years. Several seismic testing techniques are being used to evaluate the pavement response using the SPA. In particular, Ultrasonic Surface Wave (USW), Impact Echo (IE), Impulse Response (IR) and Spectral Analysis of Surface Waves (SASW) are conducted to obtain information about variations in the elastic modulus profile of the test section with time. The FWD testing is utilized for similar purpose. In addition, material characterization of samples recovered from each of the test sections was conducted in the geotechnical and asphalt laboratories of Rutgers University.

Figure 2- SPA testing on a rigid test section.

Results and Analysis

To illustrate the monitoring plan and typical results obtained from test sections, the instrumentation and monitoring of test section 3 is presented. Test section 3 for monitoring seasonal variation of pavement properties is at the northbound rest area of Interstate I-287, close to milepost 32.5. This section is located in the northern climatic zone of New Jersey, for the purpose of this study. The section is a flexible section consisting of a 10 in asphalt concrete layer on a 4 in crushed stone base, followed by a 13 in of sandy gravel with pebbles sub base layer. This is considered to be a thick pavement (total depth > 24 in) in this study.

The A class instrument installation at this section was done between December 19 and 21 of 2001. The equipment installed includes the air, pavement and subsurface temperature probes, TDR probes for subsurface moisture content measurements, resistivity probes for monitoring of the frost depth, precipitation gauge, and ground water table level monitoring vibrating wire piezometer. An equipment cabinet, to hold data logger, battery pack, and all electrical connections from instruments, was installed. TDR, temperature and resistivity probes to be installed in the test section are shown in Figure 3. The instrumentation hole for was augered 22 ft from the right curb at station 0+100.

FWD and SPA test section starts at station 0+00 and continues up to station 0+250 with a testing station at every 25 ft. Two test stations were also selected at both sides of the instrumentation hole (0+95 and 0+105). The test stations are selected at 22 ft from the curb on the right wheel path. A material sampling hole was augered at station 0+90, 9.5 ft from the right curb. Locations of the test points, material and instrumentation holes are shown in Figure 4. The instrumentation cabinet was installed at station 0+100, 16.5 ft to the right of the curb in the grass area and the weather pole placed next to the cabinet. The piezometer/benchmark was installed about 10 ft away from the equipment cabinet in the grass area.

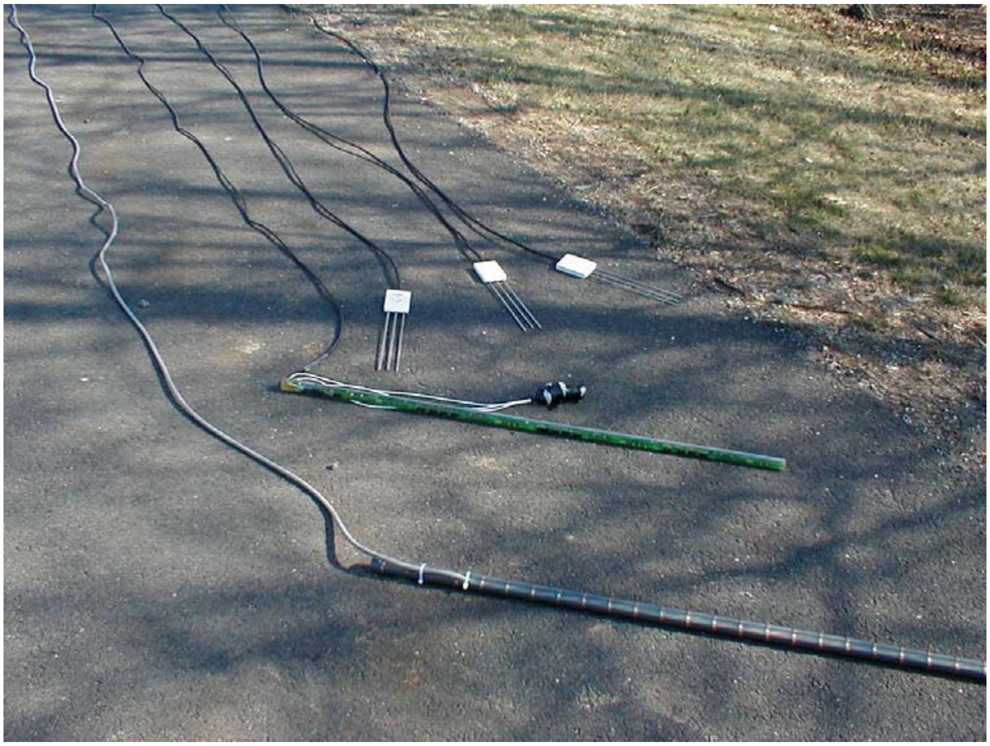

Figure 3- TDR (top), temperature (middle), and resistivity (bottom) probes to be installed in test section 3.

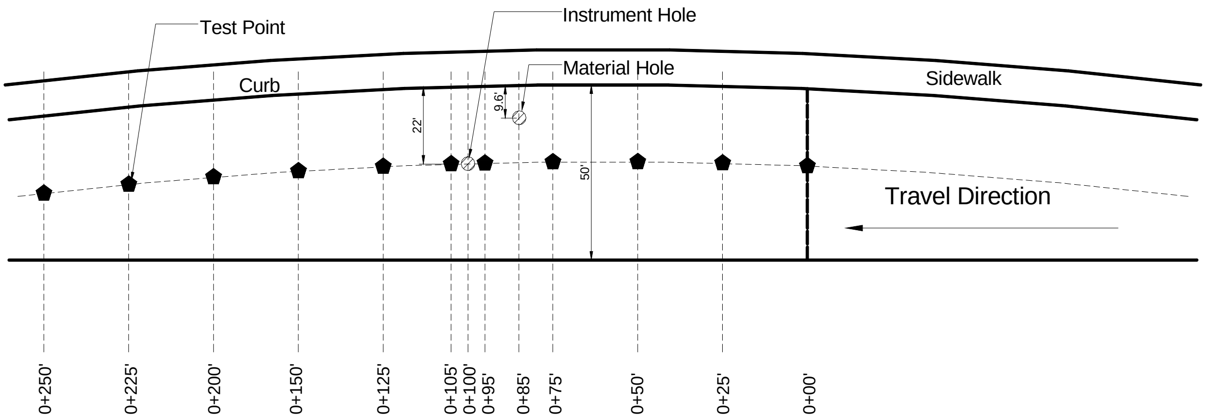

Figure 4- Layout of test point, instrumentation and material holes for test section 3.

The NDT pavement monitoring started in January of 2002 and is planned to continue till December of 2003. Since the monitoring is not complete yet, the results presented herein correspond to the first year ones only.

The pavement shear wave velocity profiles obtained from the SASW test for test section 3 are shown in Figure 5. As expected, during a warm period between June and August low asphalt concrete (AC) velocities were measured due to a decrease in AC modulus. The pavement and subsurface temperatures during the SASW testing and the subgrade moisture content are shown in Figures 6 and 7, respectively.

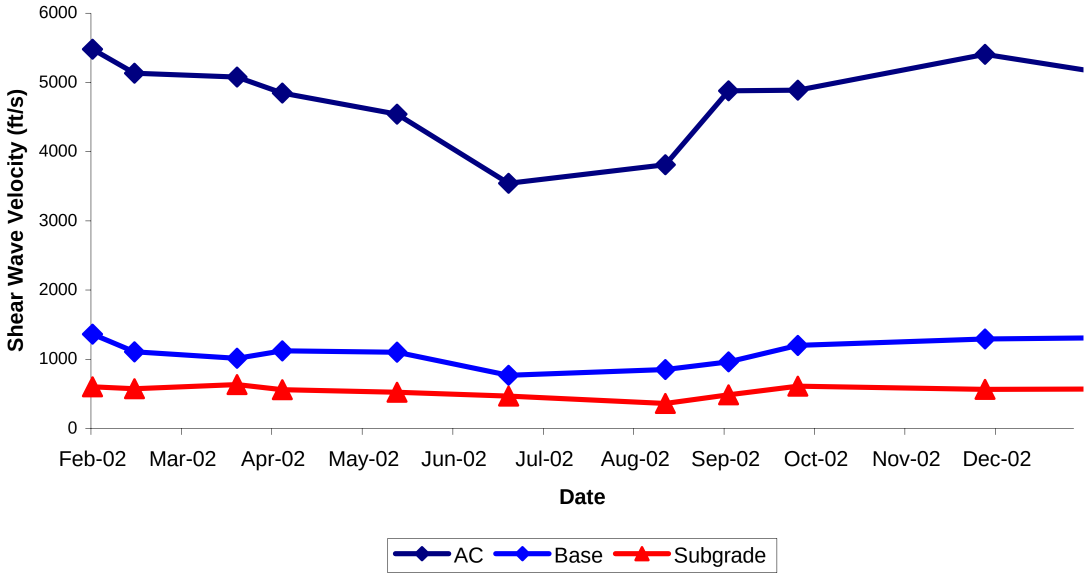

Figure 5- Variation of shear wave velocity of AC, base, and subgrade obtained from SASW tests.

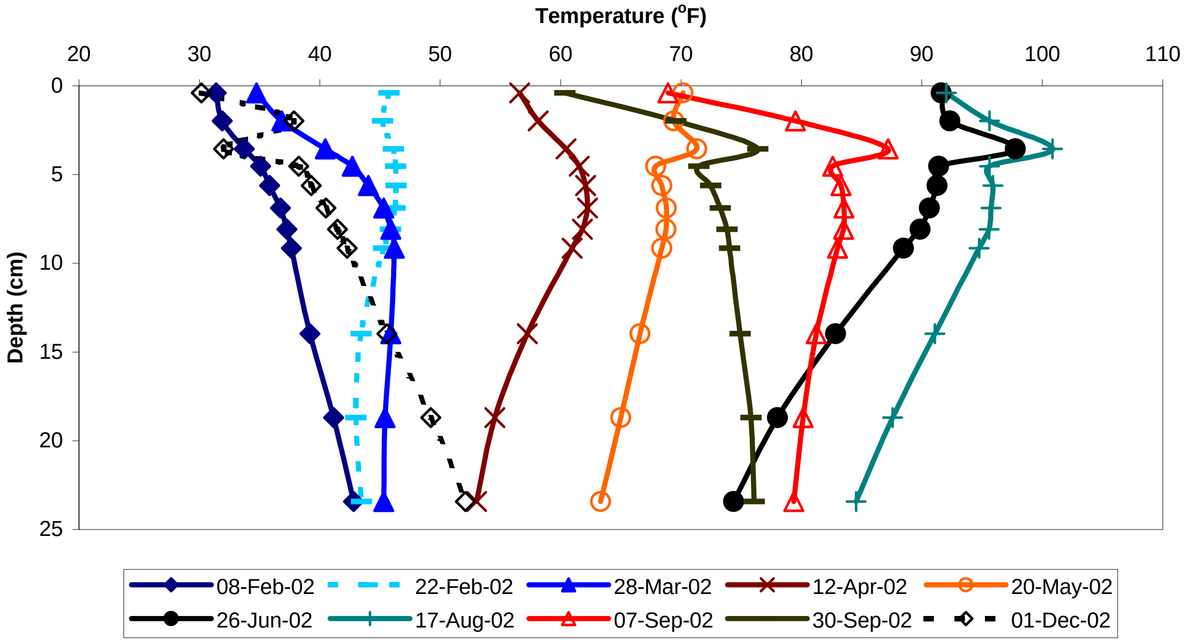

Figure 6- Variation of pavement temperature profile at the time of SPA modulus evaluation.

The temperature profiles, shown in Figure 6, point to several interesting observations about the pavement behavior. There are significant surface pavement temperature variations, with temperatures ranging from 30 to 90 degrees ^{o}F. At the same time, there is a considerable variation of the subsurface temperature, about 25 in below the surface, from about 40 to more than 80 degrees ^{o}F. It can be also observed that high temperature gradients can exist in the pavement. For example, during the September test period; there were about 20 ^{o}F temperature difference between the top and bottom of the paving layer. This temperature gradient can have significant effects on the pavement response and thus the pavement evaluation by NDT methods, such as the SASW. The gradient may explain some of the variations in the initial part (short wavelengths) of experimental dispersion curves obtained for this section, as shown in Figure 8 for station 0+75.

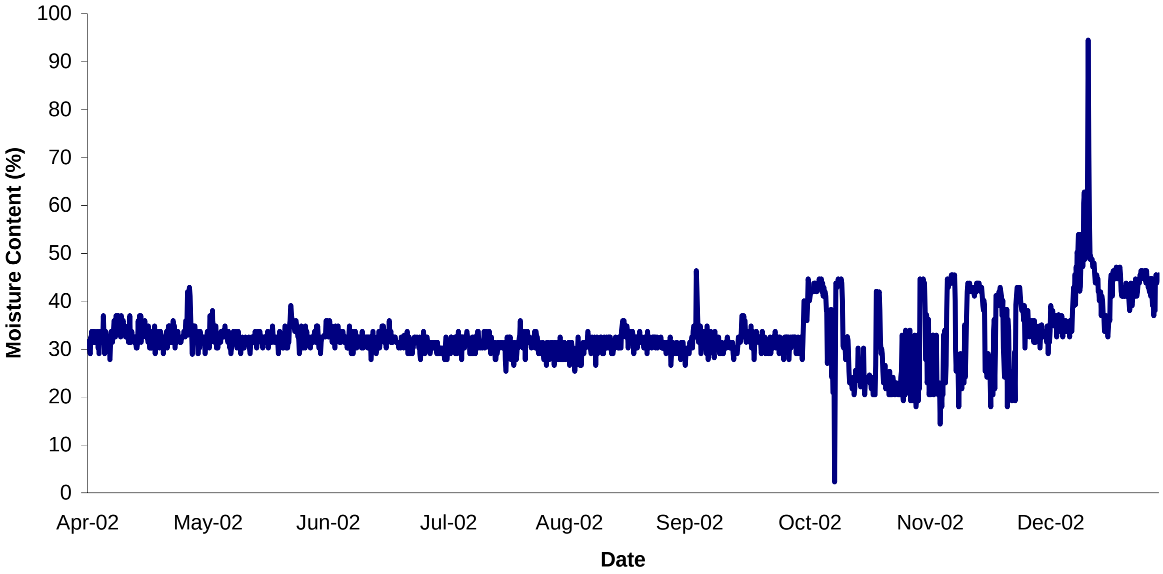

Figure 7- Variation of subgrade moisture content.

As depicted in Figure 7, the subgrade moisture content is almost constant up until October, when significant changes start occurring. However, these changes do not seem to have significant effects on the subgrade shear wave velocity, as shown in Figure 5.

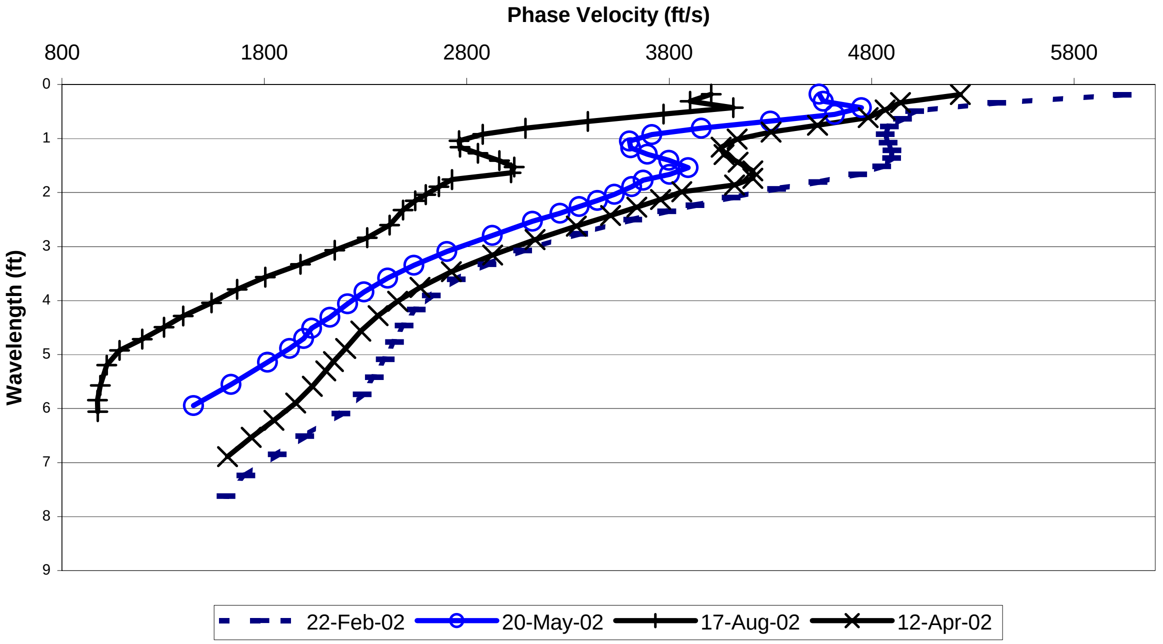

Figure 8- Field dispersion curves from the SASW test at station 0+75 for four test periods

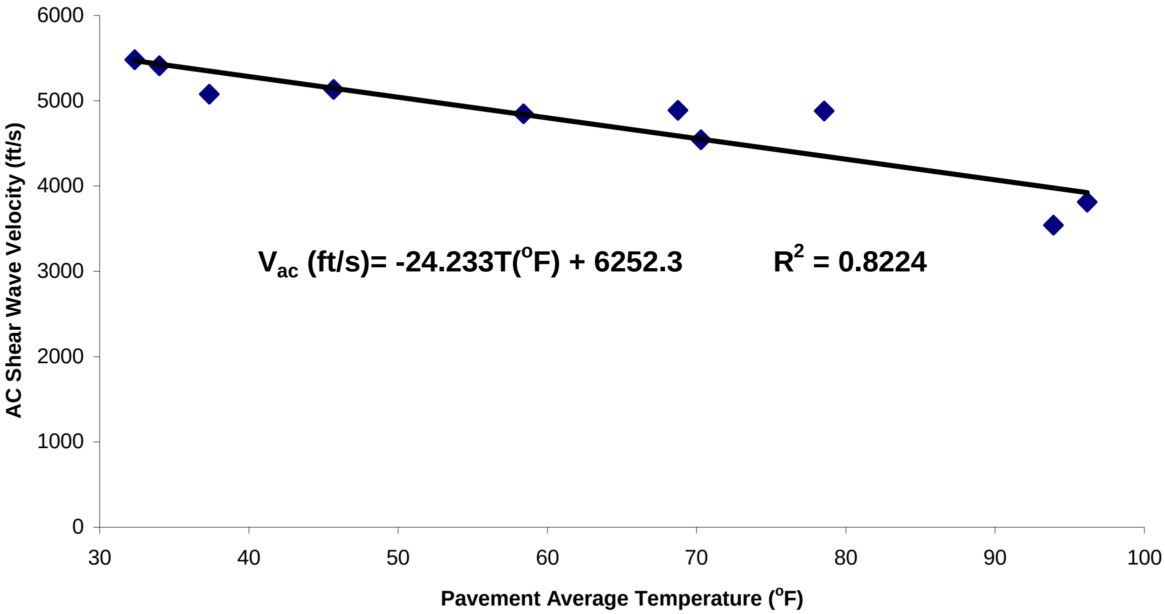

Figure 9- Correlation between pavement average temperature and AC shear modulus.

A correlation between the average pavement temperature and shear wave velocity is shown in Figure 9. As expected, there is a strong relation between pavement temperature and shear wave velocity. This is a very preliminary correlation between the collected data. Ultimately, models will be developed based on extensive statistical analysis of the data from all test sections using tools such as Analysis of Variance (ANOVA) and regression analysis. This task is still in progress and its results will be presented later. The model development and calibration will be split into two stages. In the first stage the currently available models will be tested using the collected data. Any set of the models found promising will be calibrated using the same data. Parallel to this effort, a statistical analysis will be conducted to develop a preliminary set of models. In the second stage, the calibrated and developed models will be refined and further tested for practical implementation.

Summary

New Jersey Department of Transportation (NJDOT) initiated a study with the objective to calibrate AASHTO seasonal and temperature adjustment models or to develop new models based on New Jersey conditions. Twenty-four flexible, rigid and composite pavement sections, throughout New Jersey, have been instrumented for the purpose of continuous monitoring of temperature, frost-thaw, moisture, ground water table and environmental changes (air temperature and rainfall). A two-year pavement evaluation using the Falling Weight Deflectometer (FWD) and Seismic Pavement Analyzer (SPA) is being conducted on a monthly basis. Results of the initial data examination and preliminary correlation results are promising. The result of the study will enhance the current knowledge of the pavement response and will contribute to areas such as the mechanistic pavement design in New Jersey, and FWD and SPA analysis and back calculation.

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