15 Apr 2004, 4:15pm - 5:30pm

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Proceedings: Fifth International Conference on Case Histories in Geotechnical Engineering
New York, NY, April 13-17, 2004

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ABSTRACT

The AASHTO seasonal and temperature adjustment models do not take into consideration state specific conditions. New Jersey Department of Transportation initiated a study with an objective to calibrate the AASHTO models, or to develop new ones that will take into consideration New Jersey specific conditions. To achieve the objective, twenty-four pavement sections were instrumented and nondestructive testing (NDT) program is being conducted for a period of two years. The main task of the instrumentation is to monitor environmental parameters: air and pavement temperature, moisture, frost/thaw depth and rainfall. Seismic Pavement Analyzer (SPA) and Falling Weight Deflectometer (FWD) are used to evaluate the pavement structural response and its properties on a monthly basis, except during the spring thaw period when it is on a bi-monthly basis. The models will be developed through a two-stage process by performing statistical analyses, such as analysis of variance (ANOVA) and regression analysis. This paper concentrates on pavement evaluation and model development based on SPA results using different seismic tests, including Ultrasonic Surface Wave (USW), Impulse Response (IR), and Spectral Analysis of Surface Waves (SASW). Correlation of environmental variables and pavement properties is also presented.

INTRODUCTION

Pavement long term and short term response is significantly affected by seasonal climate variations and temperature changes and should be considered in design and rehabilitation of pavements. AASHTO design guide recognizes this need and proposes seasonal adjustment models for considering effects of climatic conditions on pavements. However, these models were developed using Illinois data and do not necessarily reflect the specific climatic conditions of other. 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).

Temperature and climatic changes also affect the FWD measurements, an important tool in monitoring of pavement response. The deflection basin measured by the FWD at different temperatures and climatic conditions vary and should be corrected using temperature correction models to a standard condition to reflect changes in the pavement response on a consistent basis. Similar to the seasonal adjustment models, these models should reflect the state specific conditions.

To take into consideration the state specific conditions in design and FWD evaluation of pavements, New Jersey Department of Transportation (NJDOT) initiated a study with the objective of calibrating the AASHTO temperature and seasonal adjustment models or developing 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

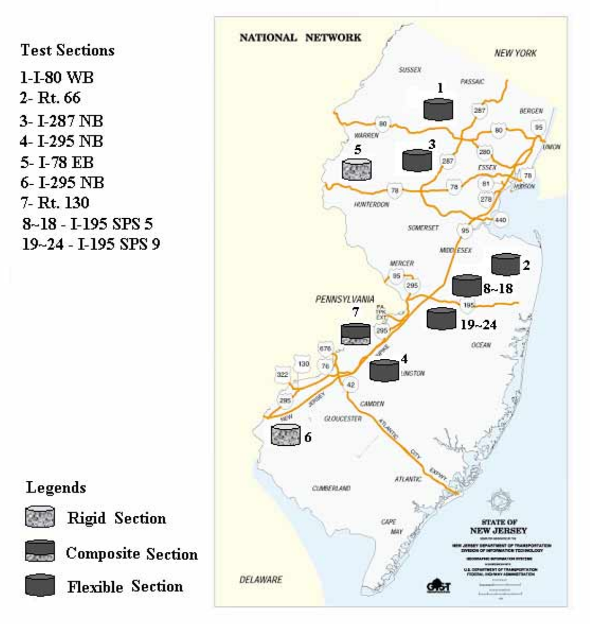

Fig. 1. Location of test sections.

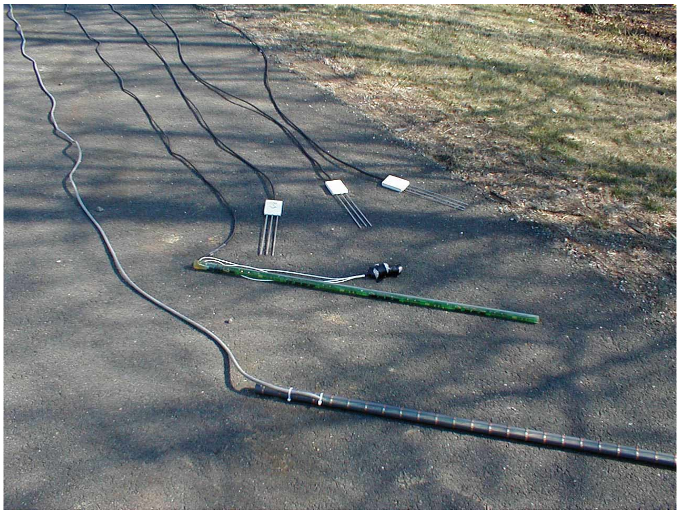

Fig. 2. TDR (top), temperature (middle), and resistivity (bottom) probes to be installed in test section 3.

Fig. 3. SPA testing on test section 4. Instrumentation cabinet and climate measurement pole are visible at the right part of the picture.

spring-thaw period that is on a bi-monthly basis). Locations of these test sections are shown in Fig. 1.

This paper concentrates on the pavement evaluation and model development based on the SPA results. Different seismic tests including Ultrasonic Surface Wave (USW), Impulse Response (IR), and Spectral Analysis of Surface Waves (SASW), were deployed for this purpose. Correlation of environmental variables and pavement properties is also presented.

TEST SECTION SELECTION AND INSTRUMENTATION

Twenty-four test sections were selected and instrumented throughout the state of New Jersey for the purpose of this study, of which 17 sections are LTPP SPS 5 and 9 sections on Interstate I-195. The location of test sections was selected so that they cover different ranges of controlling factors in the pavement response. Since the influence of seasonal variation is more significant for flexible pavements, the development of seasonal adjustment models is focused on flexible pavements. However, two rigid and a composite pavement are also included in the test sections to study the seasonal effects. On the other hand, for the development of temperature correction models, only flexible and composite sections are selected because the temperature mainly affects the stiffness of asphalt layers. In the selection of the test sections, the total pavement thickness (>60 cm (24”) or <60 cm (24”)), freezing index represented by geographical location (northern vs. southern zone), and subgrade types were the controlling factors.

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) are monitored at test section. In class B instrumentation, only subsurface temperature is measured and in class C, air and pavement temperature, and rainfall are monitored. TDR, temperature, and resistivity probes to be installed in test section 3 are shown in Fig. 2. Sensors for monitoring air temperature and rainfall were mounted on a pole, as shown in Fig. 3, where as other probes are placed in an augured hole at different elevations. The data is collected continuously using data loggers.

NDT MONITORING

To monitor the pavement response, FWD and SPA pavement evaluation (Fig. 3) is being conducted on a monthly basis for two years. So far more than one year of evaluation is completed. Several seismic testing techniques are being used to evaluate the pavement response using the SPA. In particular, Ultrasonic Surface Wave (USW), 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.

FWD and SPA a pavement evaluation is being done at same set of test points marked at each test section. The layout of the test points for test section 3 is shown in Fig. 4.

ANALYSIS AND RESULTS

Results of data collection and monitoring of test sections 3 and 4 are presented to illustrate the monitoring plan and typical results obtained in northern and southern part of New Jersey.

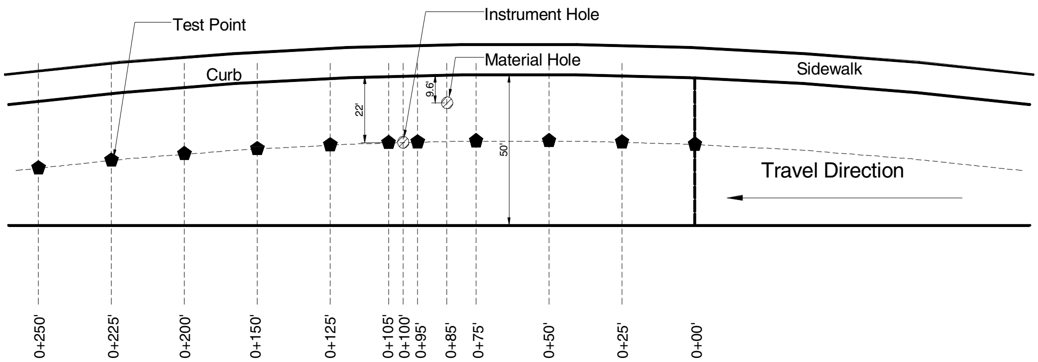

Fig. 4. Layout of the test poinst, instrumentation and material holes for test section 3

respectively. The NDT monitoring of test sections started in January of 2002 and is planned to continue for two years. Therefore, the results presented herein correspond to the first year ones only.

Test sections 3 and 4 are both flexible pavements located at rest areas on I-287 NB (MP 32.5) and I-295 NB (MP 49.5), respectively. For the purpose of this study, test section 4 is considered to be in the northern climatic zone of New Jersey, while section 3 is in the southern zone. The section profiles obtained from borings at test sections are shown in Table 1. These sites are considered to be thick pavements (total depth > 60 cm (24”)) in this study.

The average AC layer temperature along with the air temperature for these two sections are shown in Figs. 5 and 6. It in noticeable that on average, pavement temperature follows the ambient temperature closely except during the summer months, which pavement get warmer due to increased exposure to sun light.

USW (Ultrasonic Surface Waves) test results for test section 3 and 4 are presented in Fig. 7. These results represent an average shear wave velocity of the section obtained by analyzing high

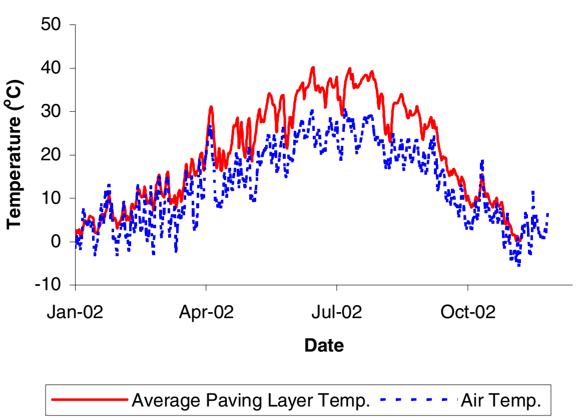

Fig. 6. Average paving layer and air temperature measurements at test section 4.

frequency part of the dispersion curve. Consequently, they represent shear wave velocity of the top portion of the paving layer.

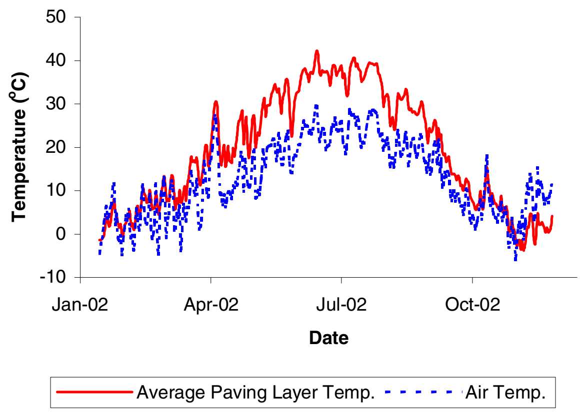

Fig. 5. Average paving layer and air temperature measurements at test section 3

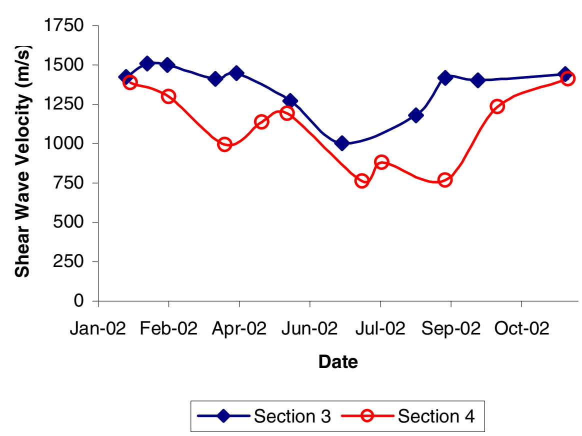

Fig. 7 USW test results for sections 3 and 4.

It is noticeable that at the beginning and end of the 2002 test period, both sections had similar shear wave velocities. However during the year, test section 4 had consistently lower shear wave velocities. To further investigate the cause of this difference, a correlation between the average pavement temperature at the time of testing and the shear wave velocity for each section is established and shown in Fig. 8. It is observed that the decrease in the shear wave velocity with temperature is higher for test section 4. This and the fact that the pavement at test section 4 had slightly higher temperature during the year explain the difference in the shear wave velocities shown in Fig. 7.

IR (impulse response) test results for the test sections 3 and 4 are presented in Fig. 9. These results are more representative of the subgrade modulus. The base/sub base moisture content is shown in Fig 10 for both sections. Based on these two graphs, there is no obvious correlation moisture content and modulus. However, for the development of a practical model, consideration of data collected from other test sections is required. As will be discussed later, search for such models is in progress using more advanced statistical tools, such as Analysis of Variance (ANOVA) and regression analysis.

The shear-wave velocities for all pavement layers obtained from the SASW test are also shown in Fig. 11 and 12. As expected and confirmed with USW test results, during warm summer period low asphalt concrete (AC) velocities were measured.

Table 1. Layer thicknesses for test section 3 and 4.

Layer	Section 3	Section 4
AC	25 cm (10”)	25 cm (10”)
Base/Sub Base	43 cm (17”)	25 cm (10”)

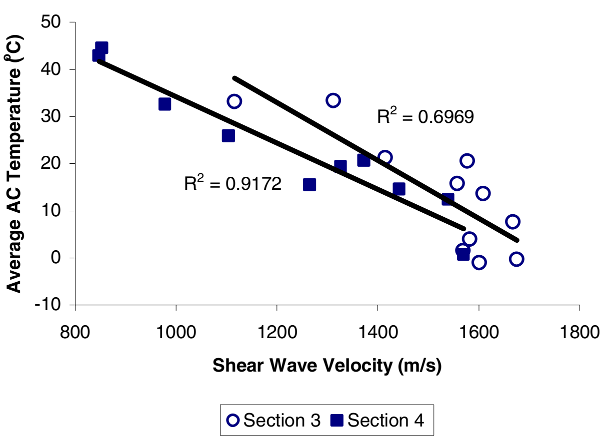

Fig. 8. Correlation between average AC temperature at the time of testing and shear wave velocity from USW tests for test section 3 and 4.

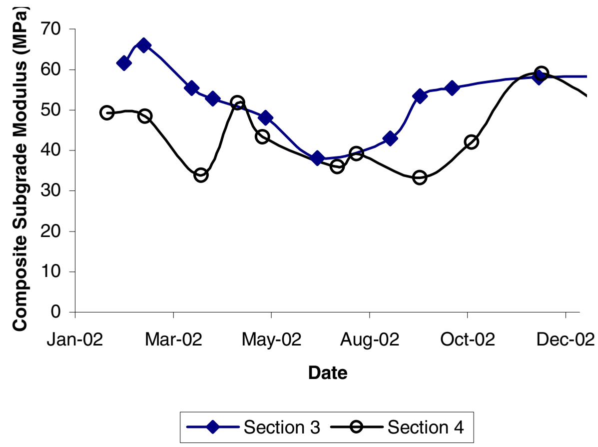

Fig 9. IR test results for test section 3 and 4.

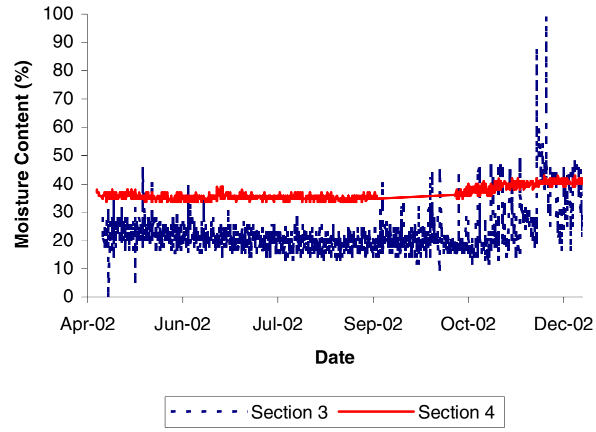

Fig. 10. Base/ sub base moisture content of test section 3and 4

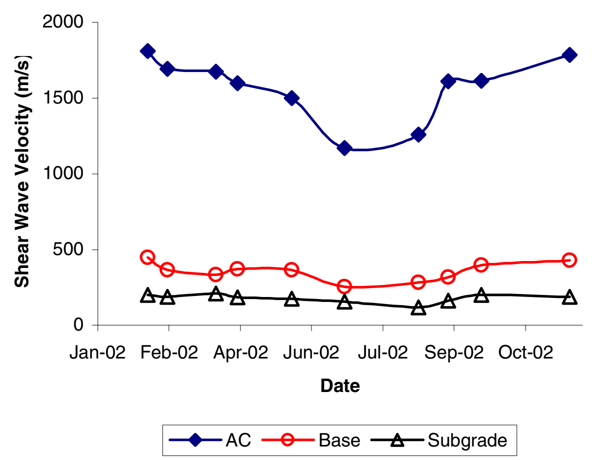

Fig. 11. SASW shear wave velocity of pavement layers for test section 3.

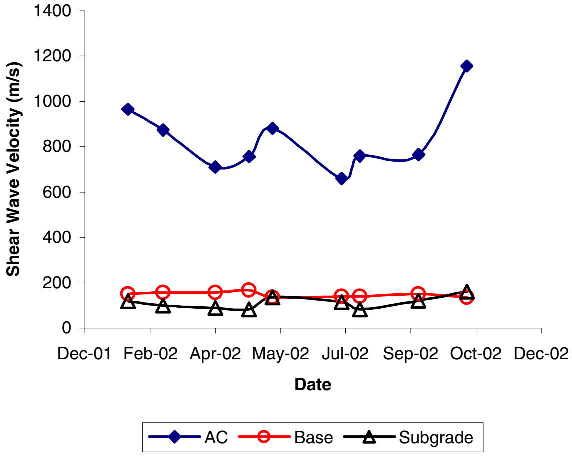

Fig. 12. SASW shear wave velocity of pavement layers for test section 4.

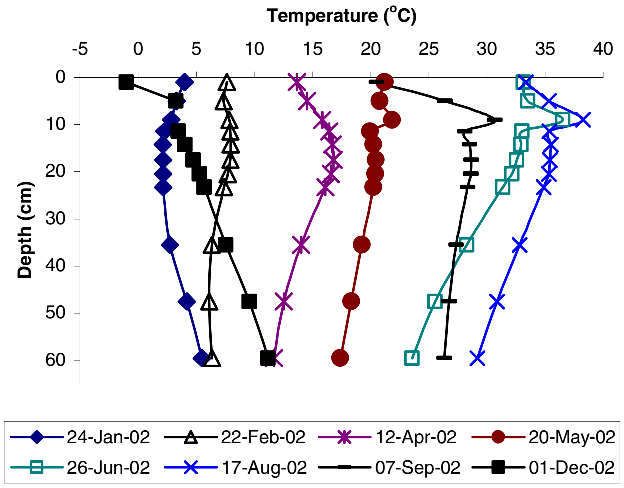

Fig. 13. Variation of pavement temperature profile at the time of SPA modulus evaluation at test section 3.

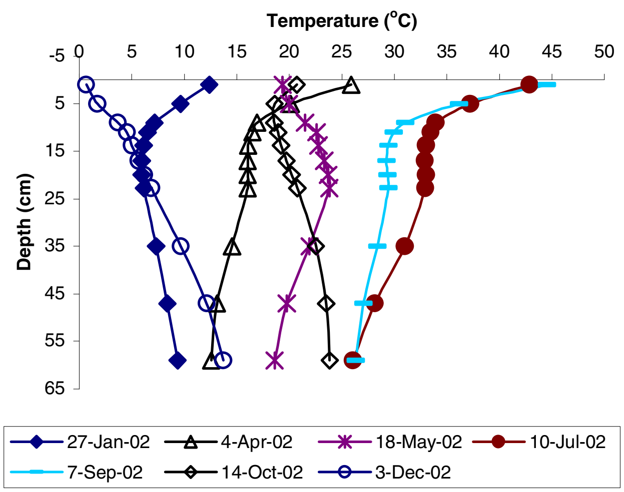

Fig. 14. Variation of pavement temperature profile at the time of SPA modulus evaluation at test section 4.

The temperature profiles at the time of SPA evaluations are shown in Fig. 13 and 14. These profiles point to several interesting observations about the pavement behavior. There are significant surface pavement temperature variations, with temperatures ranging from 0 to 45 degrees ^{o}C. At the same time, there is a considerable variation of the subsurface temperature, about 65 cm below the surface, from about 5 to more than 30 degrees ^{o}C. It can be also observed that high temperature gradients can exist in the pavement. For example, during the September test period, there was at least 10 ^{o}C 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 from the SASW test.

Results and correlations presented in this paper are very preliminary results of this study. 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 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 backcalculation.

ACKNOWLEDGMENT

This research is being supported by the New Jersey Department of Transportation through the Center for Advanced Infrastructure and Transportation (CAIT) at Rutgers University. The support is gratefully acknowledged.

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