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Tech Brief

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Material Characterization and Seasonal Variation in Material Properties

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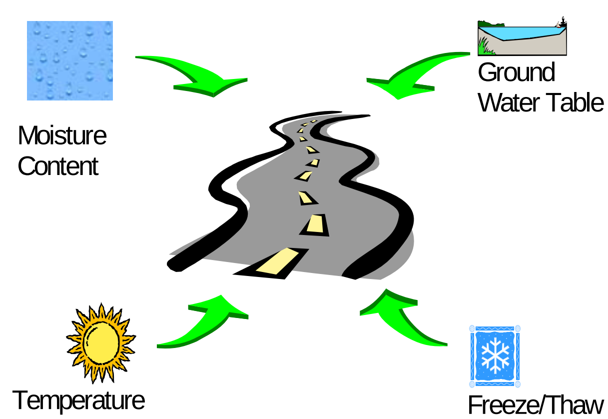
THIS IS THE PROBLEM…

Pavement design and performance are highly influenced by environmental factors, such as temperature and moisture. Since temperature and moisture conditions vary with time (daily, seasonal, and longer cycles), adjustment models are required to account for these variations and to bring pavement response parameters measured at different periods to the same standard conditions. The climatic changes from region to region, coupled with the variation of site specific conditions across North America, make it difficult to develop standard models for all regions.

AND, HERE IS THE SOLUTION…

The ability to predict regional environmental effects, and to incorporate seasonal variability of pavement material into current design pavement procedures will greatly enhance pavement performance and reduce maintenance expenditures. Therefore, the development of regional models is an essential requirement in the design procedure for most transportation departments.



Environmental Factors Affecting Pavement

IMPLEMENTATION; HERE WE COME…

In early 2001, the New Jersey Department of Transportation (NJDOT) in association with the Federal Highway Administration (FHWA) initiated a study to evaluate and calibrate some of the available seasonal and temperature adjustment models, or to develop new models, to suit New Jersey conditions. These models will be used to account for the impact of the temperature and seasonal variations on pavement response and results of nondestructive pavement evaluations using Falling Weight Deflectometer (FWD) and/or Seismic Pavement Analyzer (SPA). These models will be ultimately incorporated into NJDOT's pavement design procedures.

OBJECTIVES OF THE STUDY…

The main objective of this study was to provide the NJDOT with seasonal and temperature adjustment models, based on New Jersey conditions, that can be used to consider the daily and seasonal variations in the stiffness of pavement materials. More specifically, the objective included:

- Developing an understanding of the seasonal and climatic changes, such as temperature, moisture, rainfall, on material properties and their influence on pavement performance.
- Monitoring the freeze, thaw cycle and estimating the frost depth.
- Developing suitable adjustment models for pavement material properties of flexible and rigid pavements, such as asphalt concrete and concrete modulus, flexural strength of subgrade and subbase layers.

To achieve this objective, some of the available models, which are incorporated in the new Mechanistic-Empirical Pavement Design Guide were evaluated. If they were found to be suitable, these models would be calibrated and validated with field-measured data. If the models were not found to be suitable, new models would be developed. In addition, to the main objective, other objective included:

- Evaluating the performance of Non-Stabilized Open Graded (NSOG) base layers for rigid pavements under different moisture and temperature conditions.
- Comparing the results of the FWD and the SPA analyses and performing a correlation analysis between them.
- Investigating the impact of the pavement structure; thin vs. thick, and environmental parameters, e.g., temperature, and moisture, on measured deflections with FWD or evaluation results from SPA.
- Studying the response of pavement structures with different thickness and material properties under different environmental conditions.

THIS IS WHAT WE DID…

To achieve the objectives of the study, twenty-four test sections (21 hot-mix asphalt, 1 composite and 2 Portland Cement Concrete) were instrumented to continuously measure environmental and climatic parameters. The following were the main components of the pavement instrumentation program.

- Moisture content measurement using Time Domain Refectometery (TDR)
- Pavement temperature measurement using temperature probes at different depths

- Frost/Thaw depth measurement using resistivety measurements at different depths
- Ground water depth measurement
- Climatic measurements (air and rainfall)

Pavement deflection and seismic testing with FWD and SPA were performed on a monthly basis (and bi-monthly during the recovery periods) for two years. In addition, two 24-hour testing cycles, in which tests were repeated every 2 hours for a 24-hour period, were performed on selected sections.


Tipping Bucket, Solar Panel, and Air Temperature Probe


TDR and Temperature Probes


SPA Pavement Evaluation

FWD Pavement Evaluation

A comprehensive analysis was performed on the collected FWD, SPA and environmental data from test sites to investigate the impact of the environmental parameters on pavement response. As expected, results of the Analysis Of Variance (ANOVA) performed on the pavement parameters (deflections and backcalculated moduli) and environmental parameters (base course moisture content, average Asphalt Concrete (AC), temperature, ground water table (GWT), rainfall, and air temperature) indicated that all main environmental parameters have a significant impact on the Effective Pavement Modulus (E_p) and Subgrade Modulus (M_r), with the exception of GWT and pavement temperatures, which do not have significant impact on the subgrade modulus. This finding does not agree with the common assumption made in backcalculation analysis that the GWT acts as a rigid layer.

A regression analysis was performed to develop Temperature Correction Factors (TCFs) that account for the impact of temperature changes on measured deflections and backcalculated layer moduli. Overall Correction Factors (OCFs) that account for all seasonal variations were developed. In addition, Seasonal Correction Factors (SCFs) that account for seasonal variations other than temperature, which should be applied on the temperature-corrected deflections and the resulting backcalculated moduli, were developed.

Comparative analysis was performed on the data from the two rigid pavement sections to evaluate two types of base course layers used under rigid pavements in terms of their drainage characteristics and corresponding effects on pavement response. One of the base layers was a NSOG material that promotes positive drainage. The second layer was a typical granular soil aggregate material. Assessment was carried out by monitoring rainfall and moisture contents through instrumentation and deflections. Results of the analysis indicated that for similar trends in rainfall, the site having the more permeable NSOG base material drains better in terms of reduced moisture content levels as compared to the typical soil aggregate base material. Statistical analysis was carried out to confirm the conclusion. Analysis and comparison of the Structural Adequacy Indices (SAI) indicate that the permeable base section NSOG does not significantly change the structural condition as compared to the granular soil aggregate base.

Results from testing with the SPA provided a strong correlation between the AC temperature and modulus from both spectral analysis of surface waves (SASW) and ultrasonic surface wave (USW) tests. Small differences are observed in this relationship for pavements of different thicknesses and in different geographical regions. While there was a clear general trend of decrease of the subgrade modulus with moisture content (from the impulse response (IR) test), the data dispersion was high.

Results of the FWD and SPA analyses were compared and correlated. Results provide different levels of linear correlation between pavement parameters backcalculated from the two non-destructive devices (from good correlations for AC modulus of thin pavements to poor correlations for subgrade modulus of rigid pavements). The uncorrected FWD pavement moduli showed a greater variability due to seasonal changes compared to those from the SPA.

WHAT IS THE NEXT STEP?

During the course of the research study, the following areas were identified for further research:

- Continued monitoring of the environmental parameters at the present sites with working instruments and equipment. This will help in further refining the developed temperature and seasonal adjustment models through additional data.
- A major limitation of the study was the presence of a limited number of sections for certain combinations of environmental region (north or south) and asphalt concrete thickness (thick or thin). Only one section for north-thick and one section for south-thin were present in the study for developing temperature and seasonal correction models. It is recommended that, to make the models more robust, at least 2 more sections from each of the above two combinations should be identified and instrumented in any future study.
- The 24-hour testing carried out at the two rigid pavement sections provided a deeper insight into the effects of curling and warping due to temperature variation within the pavement slab during the period. Similar investigations are recommended on additional rigid pavement sections on the NJ highways to reinforce the findings from the present study.

- A targeted pilot study is recommended for developing better testing protocols for studying the effects of slab curling.
- This study included only one composite section. Most rehabilitation activities on rigid pavements involve an asphalt concrete overlay. Future studies should include more composite sections to study the effects of climatic changes on this pavement type.

CONCLUSION…

The successful instrumentation of the test sections to monitor climatic data and the subsequent development of a database have given a better understanding of moisture retention within a pavement system and its profound effect on the cost and service life of a highway network. It has also enabled successful investigation the influence and seasonal fluctuation of environmental factors on pavement performance in New Jersey. The effect of these factors on long–term pavement performance was evaluated by studying the response of pavement structures with different thicknesses and material properties under different environmental conditions. Ultimately, new seasonal and temperature adjustment models specific to New Jersey conditions were developed.

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A final report is available online at
http://www.state.nj.us/transportation/research/research.html
If you would like a copy of the full report, please FAX the NJDOT, Division of Research and Technology, Technology Transfer Group at (609) 530-3722 or send an e-mail to Research.Bureau@dot.state.nj.us and ask for: **Material Characterization and Seasonal Variation in Material Properties**
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