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Assessing Pavement Layer Condition Using Deflection Data

An NCHRP digest of the findings from the final report on NCHRP Project 10-48, "Assessing Pavement Layer Condition Using Deflection Data," conducted by North Carolina State University. Dr. Y. R. Kim served as Principal Investigator.

INTRODUCTION

This digest describes the features of a method for assessing pavement layer condition, developed under NCHRP Project 10-48, on the basis of surface deflection data obtained from Falling Weight Deflectometer (FWD) measurements.

The use of nondestructive testing has become an integral part of the structural evaluation and rehabilitation process of pavements in recent years. Various types of equipment are used by state highway agencies to apply patterns of loading and record deflection along the pavement. When pavements experience some form of distress such as rutting or cracking, variations in pavement deflections and shape of deflection basin along a project will occur because of differences in the condition of pavement layers. Currently available procedures for the analysis of deflection data do not identify the presence, location, and extent of distress within the pavement structure. Therefore, there is a need to develop a means for assessing pavement layer condition based on surface deflection data and thus reduce the need for destructive testing. NCHRP Project 10-48 was conducted to address this need.

The research was conducted under NCHRP Project 10-48, "Assessing Pavement Layer Condition Using Deflection Data," by North Carolina State University. The research, completed in late 2000, presented a method for assessing pavement layer condition on the basis of layer condition indicators estimated from FWD deflection data. This digest provides a summary of the work performed in this research. The materials in this digest are extracted from the project's final report.

FINDINGS

In this project, a method for assessing the condition of pavement layers based on FWD deflection measurements was developed. The method applies to all layers of rigid and flexible pavements that include an asphalt concrete surface layer [i.e., asphalt concrete (AC) pavements with granular-untreated, asphalt-treated, and cement-treated bases and portland cement concrete (PCC) pavements with AC overlays]. The process of developing this method involved the following four steps:

1. Developing a database of pavement deflections, strains, and stresses for a 9,000-lb FWD load-time history;
2. Identifying "damage indicators" that relate to pavement layer condition or distress;
3. Identifying or developing models that relate "damage indicators" to pavement response and materials properties that contribute to pavement layer distress (e.g., cracking, stripping, and debonding); and
4. Evaluating the models' applicability using field data and developing refined models for incorporation into a computer program.

Database Development

Two types of data were used in this research: data from field measurements and synthetic data. The field measurement data included data collected as part of the Long Term Pavement Performance (LTPP) studies (available in the LTPP Information Management System and on the DataPave 2.0 CD-ROM) and data obtained from state departments of transportation. The synthetic data were generated using ABAQUS finite element software package for a range of pavement layer thicknesses and material properties.

Damage Indicators

Potential damage indicators, including different forms of deflection basin parameters (DBP), effective modulus, and stress-strain parameters were investigated. The relationships among these indicators, known distress manifestations, and structural characteristics were examined using regression analysis and artificial neural networks. This examination involved a parametric sensitivity study to investigate the ability of the potential damage indicators to adequately describe the condition of pavement layers. Based on this study, the DBPs best suited to describe the condition of the different layers of flexible pavements with different base types and of rigid pavements with AC overlays were identified. The DBPs that are sensitive to changes in a specific pavement characteristic, as determined by the root mean square error, were considered appropriate indicators of this characteristic.

Condition Assessment Models

Regression and artificial neural network models were developed to relate pavement surface deflections to those condition indicators relevant to each pavement layer. For example, subgrade rutting potential of aggregate base pavements is related to four indicators that can be estimated from surface deflections and related material properties. These indicators are (1) subgrade effective modulus; (2) base curvature index (BCI), defined by the difference in deflections at 24 and 36 in. from the center of the load; (3) compressive strain on top of the subgrade; and (4) subgrade stress ratio (SSR), defined by the ratio of the compressive stress on the top of the subgrade to the subgrade confined strength. This approach does not use backcalculation or forward modeling to estimate the strains and stresses in the pavement structure. A regression model was developed to estimate the compressive strain on the top of the subgrade on the basis of the BCI and the base damage index (BDI), defined by the difference in deflections at 12 and 24 in. from the center of the load. Also, an artificial neural network model was developed to relate SSR to the surface deflections at seven locations and the thicknesses of the different pavement layers. Subgrade condition can be determined by examining these condition indicators.

Model Application and Refinement

The methodology adopted in this project for assessing layer condition relies on a comparison of the estimated pavement material properties to those expected for pavements in good conditions. The layer condition will then be categorized based on the relationship of the estimated value to that for a material in a good condition. For example, modulus values for AC layers, Eac, are compared and the AC layer is considered distressed if the estimated Eac value is less than 70 percent that expected for a layer in a good condition. Similarly, subgrade condition in aggregate base pavements will be judged based on the magnitudes of compressive strain, BCI, and SSR. Although data from pavements with known layer conditions are used as a reference and a means for estimating the layer condition, no attempts were made to relate the difference to specific distress types or causes. Also, data from pavements with known layer conditions were used to evaluate and refine the models for incorporation in a software program.

LAYER CONDITION ASSESSMENT SOFTWARE

The method for assessing pavement layer condition, developed in this research, was incorporated into software designated APLCAP (Asphalt Pavement Layer Condition Analysis Program) to facilitate implementation. The software includes the methods for evaluating full-depth AC pavements and AC pavements with granular bases; AC pavements with cement-treated bases and PCC pavements with AC overlays are not included. Recognizing the effects of temperature on FWD measurements, the developed models incorporate temperature-adjustment factors.

CONCLUSIONS

The need to develop cost-effective means for assessing pavement layer condition based on surface deflection data and thus reducing the need for destructive testing has been recognized by state highway agencies and other organizations. This research presented a methodology for conducting such an assessment. The method incorporates artificial neural network models and regression equations for estimating layer condition indicators from surface deflection data. The methodology also incorporates criteria, for assessing layer condition, that were developed on the basis of limited field data. The method assesses layer condition by comparing the estimated values of specific condition indicators to those for layers in good conditions; it does not relate the difference to specific types of distress or other reasons. Because this research involved a limited evaluation of the method's applicability, further calibration and collection of specific data may be required to enhance interpretation of the method's outputs and ensure their validity.

FINAL REPORT

The agency's final report titled "Assessing Pavement Layer Condition Using Deflection Data" gives a detailed account of the project, findings, and conclusions, including software for the analysis of the condition of layers of full-depth AC pavements and AC pavements with untreated granular bases. The report, which was distributed to NCHRP sponsors (i.e., the state departments of transportation), is available for loan on request to the National Cooperative Highway Research Program, Transportation Research Board, 2101 Constitution Avenue, N.W., Washington, DC 20418.

ACKNOWLEDGMENTS

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These **Digests** are issued in order to increase awareness of research results emanating from projects in the CRP. Persons wanting to pursue the project subject matter in greater depth should contact the Cooperative Research Programs Staff, Transportation Research Board, 2101 Constitution Ave., NW, Washington, DC 20418.

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