CENTER FOR TRANSPORTATION INFRASTRUCTURE SYSTEMS
THE UNIVERSITY OF TEXAS AT EL PASO

Project Summary Report 0-1780-S
Project 0-1780: Design Moduli from Seismic Data
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PROJECT SUMMARY REPORT

A New Algorithm for Determining Design Moduli from Seismic Data

In many current procedures for structural design of pavements, an accurate determination of layer moduli is required. With the onset of the movement toward the Mechanistic Pavement Design based on NCHRP Project 1-37A, investigating the feasibility of supplanting the existing methods with more mechanistic approaches would be desirable. Nondestructive testing techniques are widely used to determine moduli of pavement materials, to determine the critical strains and, thus, to estimate the remaining lives of pavement systems.

The Falling Weight Deflectometer (FWD) is one of the most popular nondestructive testing devices. Since the load applied by the FWD to the pavement is similar to that exerted by traffic, the FWD moduli are often used in pavement design and analysis without considering the nonlinear behavior of materials. For some pavement structures, the determination of reliable moduli with the FWD may be difficult. Another nondestructive testing device is the Seismic Pavement Analyzer (SPA) whose operating principle is based on generating and detecting seismic waves in a layered medium. Seismic methods provide fundamentally-correct linear-elastic moduli of different layers. However, seismic moduli are low-strain moduli and cannot be directly used in pavement analysis and design. The traffic load applied to the pavement is

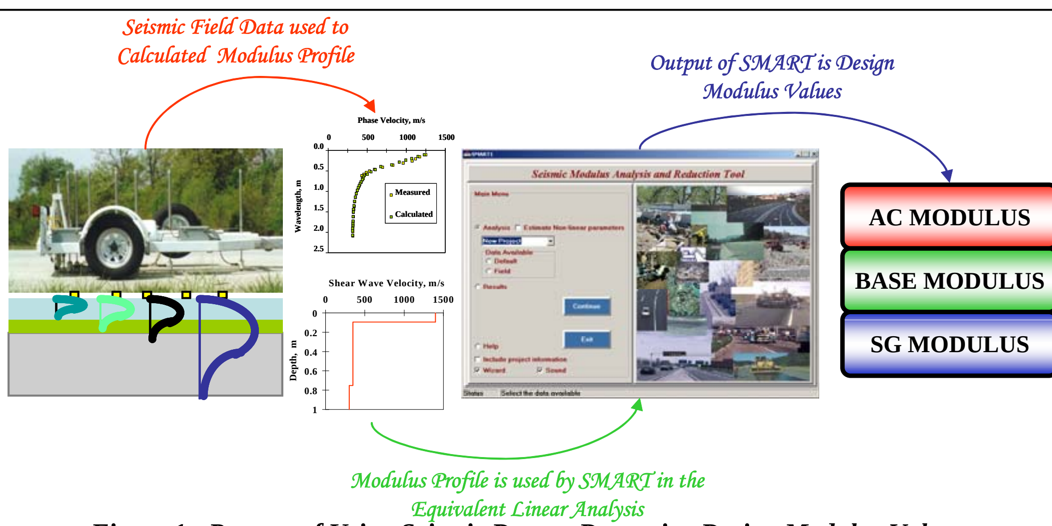

Figure 1 - Process of Using Seismic Data to Determine Design Modulus Values

larger than that applied by the seismic source. To use seismic moduli, load-induced nonlinear and time-dependent behaviors of pavement materials have to be taken into consideration.

What We Did …

The major objective of this study was to develop a theoretically-sound algorithm that uses seismic moduli and well-substantiated nonlinear relationships and time-dependent models to provide moduli that can be used in for pavement design and analysis. Based on information in diverse areas such as nondestructive testing, pavement design, pavement material testing, geotechnical engineering, seismology and earthquake engineering, a comprehensive conceptual design methodology has been implemented in a computer program called Seismic Modulus Analysis and Reduction Tool (SMART).

For the asphalt layer, the inputs to the system are the seismic modulus and parameters for time-dependent models such as those advocated by NCHRP Project 1-37A based on complex modulus. For the base and subgrade layers, the seismic moduli and the nonlinear parameters of each layer are input.

The input parameters are used with a structural model to determine the design moduli for each layer of pavement.

We also validated the software by conducting rigorous field and lab tests at about a dozen sites with significantly different pavement structures. In most cases, the results from the algorithm demonstrated that the program provides reasonable results.

One of the unique features of the program is its flexibility to incorporate data at several levels. For instance the default options in SMART allow users to analyze pavement sections without the need for complete field data. Partial seismic data (e.g. modulus of AC from PSPA) can be substituted in for the default values. In such cases where laboratory seismic values are available, users are able to substitute those values as well. Another feature of the program is the types of material models available for each layer. SMART features both linear-elastic and three viscoelastic models for the AC layer. As for

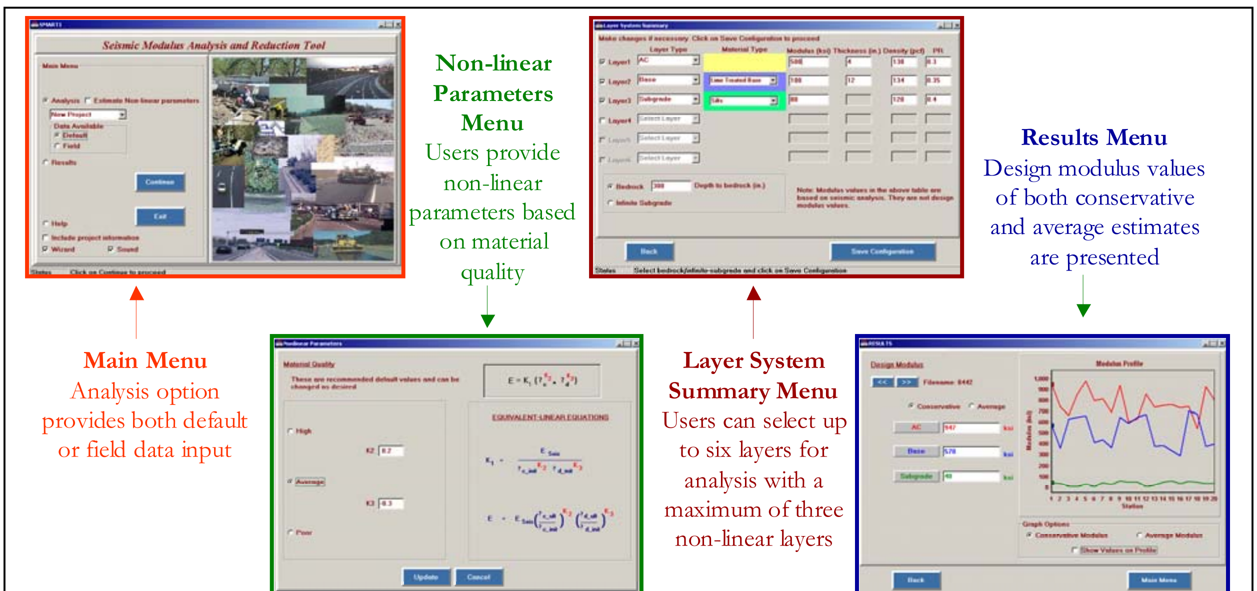

Figure 2 - Snapshots of Menus and Features in SMART

the base, subbase and subgrade layers, one of the following three models can be used: a) linear elastic, b) nonlinear based on lab resilient modulus testing and c) nonlinear based on a model that requires plasticity index.

What We Found …

The results from this project will not only assist TxDOT to better understand the concept of design with seismic moduli, it will also assist in implementing design procedures based on FWD results. FWD tests are considered to provide a design simulation, whereas SPA tests conduct material characterization. In material characterization, one attempts, in a way that is the most theoretically correct, to determine the engineering properties of a material (such as modulus). The material properties measured in this way are fundamental material properties that are not related to a specific modeling scenario. To use these material properties in a certain design methodology, they should be combined with an appropriate analytical or numerical model to obtain the design output. In the design simulation, one tries to her/his best ability to experimentally simulate the design condition and then back-figure some material parameter that is relevant only to that condition. Methods based on material characterization are more desirable. These methods have a distinct advantage because they can be combined with compatible laboratory tests to ensure that the properties specified during design are obtained during construction.

The figure below clearly demonstrates this concept. Even when a base layer is constructed uniformly, its modulus varies with the state of stress. With the seismic method, such variability is much easier to quantify. The remaining life of the layer is directly related to the modulus at the interface and not to the average modulus. The errors in critical compressive and tensile strengths shown in the figure below are, for the most part, due to such an approximation.

The Researchers Recommend …

The initial implementation of the program at several projects has shown great potential. We recommend that TxDOT implement the new software as soon as possible, especially in those areas of the states were the design based on FWD data have shown shortcomings.

Modulus Contours of Base and Subgrade Using Equivalent-Linear Algorithm

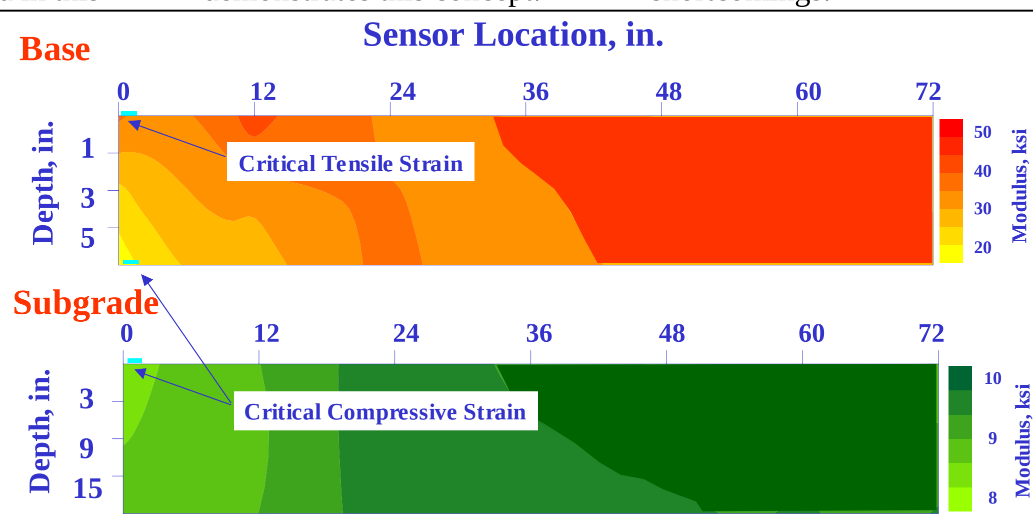

Figure 3 - Modulus Contours of Nonlinear-Pavement-Layers Based on the Equivalent Linear Algorithm Incorporated in SMART

For More Details…

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The research is documented in the following report:

0-1780-1 *Design Modulus Values Using Seismic Data Collection*
0-1780-2 A Sensitivity Study of Parameters Involved in Design with Seismic Moduli
0-1780-3 *Determination of Non-linear Parameters of Flexible Pavement Layers From Non-destructive Testing*
0-1780-4 *SMART: Software for Determining Design Modulus from Seismic Data*
0-1780-5 *Validation of Software Developed for Determining Design Modulus from Seismic Testing*

To obtain copies of a report: Center for Transportation Infrastructure Systems**,**
(915) 747-6925, email ctis@utep.edu**.**

TxDOT Implementation Status
January 2005

The algorithms to predict modulus are being implemented in new software that combines seismic and FWD data under research project 0-4393, "Integration of Nondestructive Testing and Analysis Techniques." The computer program, Seismic Modulus Analysis and Reduction Tool (SMART) is being implemented on a web site being developed by UTEP under IPR 5-1711-01. Training in the software and the ability to download the software will be available at this site.

For more information contact: Dr. German Claros, P.E., Research and Technology Implementation Office, (512) 465-7403, gclaros@dot.state.tx.us.

Your Involvement Is Welcome!

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