TECHSUMMARY April 2019

SIO DOTLT 1000009 / LTRC Project No. 14-2P

A Mechanistic Approach to Utilize Traffic Speed Deflectometer (TSD) Measurements into Backcalculation Analysis

INTRODUCTION

Backcalculation analysis of pavement layer moduli is typically conducted based on falling weight deflectometer (FWD) measurements; however, the stationary nature of FWD requires lane closure and traffic control. To overcome these limitations, a number of continuous deflection devices were introduced in recent years including the traffic speed deflectometer (TSD). Recent studies conducted in Louisiana and elsewhere suggest that the TSD is a promising device for pavement evaluation at the network level because it can measure deflection at traffic speeds, which enable large spatial coverage and can provide continuous deflection profile rather than measuring pavement deflection at discrete points, which is the case with FWD. In spite of the encouraging advantages of TSD, currently available tools to backcalculate layer moduli use FWD deflection measurements as the main input and cannot be directly used with TSD deflection measurements.

Figure 1
Traffic speed deflectometer testing in Louisiana

OBJECTIVE

The research objective of this study was to develop and to validate a mechanistic-based methodology using 3D-Move in order to utilize TSD deflection measurements in backcalculation analysis.

SCOPE

3D-Move software was used to model TSD and FWD loading configurations and to calculate pavement deflections from these two devices. Surface deflections calculated from 3D-Move were validated with field measurements. The 3D-Move models were then used in a parametric study simulating pavement sections with varying structures and material properties and their corresponding FWD and TSD surface deflections were calculated. The results obtained from the parametric study were utilized to develop a Windows-based application, which uses artificial neural network as the regression algorithm to convert TSD deflections to the corresponding FWD deflections. The converted deflections may then be used in regular backcalculation analysis software to backcalculate the pavement layer moduli.

METHODOLOGY

TSD loading and viscoelastic material properties were simulated in 3D-Move to predict pavement surface deflections. Pavement response was also simulated under a static load to simulate FWD using 3D-Move. For FWD simulation in 3D-Move, the elastic material properties of the AC layer

LTRC Report 612

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was incorporated in the analysis. The 3D-Move models simulating TSD and FWD were validated by comparing pavement responses (surface deflections) from 3D-Move to field measurements. Validation of these 3D-Move models was followed by a parametric study, which consisted of using 3D-Move models to simulate a wide range of pavement designs. In this parametric study, 162 pavement designs were simulated with varying layer thicknesses and moduli. These cases were run by 3D-Move to calculate pavement surface deflections for TSD and FWD. The theoretical surface deflections obtained from both TSD and FWD were then used to develop an ANN model. The ANN model correlated the theoretical TSD deflections to the theoretical FWD deflections. The ANN model can be used to estimate the corresponding FWD deflections if the TSD deflections are known. Therefore, the ANN model would facilitate the backcalculation of layer moduli from TSD measurements.

Results

3D-Move models simulating the TSD were developed for the test sections. Each input was fed into 3D-Move to calculate the corresponding pavement responses. The GPS coordinates of the extracted core locations were used as a reference to compare the 3D-Move outputs to the field measured deflection bowls. 3D-Move produced reasonable results for TSD as compared to the field measurements. In addition, the comparison between FWD-measured deflections and 3D-Move calculated deflections was acceptable in terms of a Root Mean Square Error (RMSE) less than 5%.

An application to convert TSD deflections into FWD deflections was created as a Windows Form application using Visual Basic. The application uses an artificial neural network as the regression algorithm to convert TSD deflections to the corresponding FWD deflections. This conversion would allow backcalculation of layer moduli using TSD measured deflections, as equivalent FWD deflections can be easily used with readily available tools to backcalculate layer moduli.

CONCLUSIONS

This study presented the development of a comprehensive mechanistic methodology that can incorporate TSD measured deflections into backcalculation analysis of layer moduli. The analysis was based on the use of 3D-Move into estimating the pavement response under traffic loading, which was supported by field testing program of FWD and TSD as well as the laboratory testing of in-situ material properties. The developed methodology is mechanistic-based as it considers the realistic representation of moving load and material characteristics in 3D-Move. A Windows-based software application was developed using ANN as the regression algorithm to convert TSD deflection to the corresponding FWD deflections. This tool will greatly reduce the computational effort to backcalculate layer moduli from TSD measurements.

Based on the findings and the results of this project, the developed Windows-based software application is implementation-ready. It can be easily used to convert TSD deflection to the corresponding FWD deflections. The converted deflections can then be used with regular backcalculation tools such as ELMOD to backcalculate the layer moduli from TSD measurements.