Joint Transportation Research Program

Principal Investigators: Antonio Bobet, Purdue University, bobet@purdue.edu, 765.494.5033
Tommy Nantung, Indiana Department of Transportation, tnantung@indot.in.gov, 765.463.1521

Program Office: jtrp@purdue.edu, 765.494.6508, www.purdue.edu/jtrp
Sponsor: Indiana Department of Transportation, 765.463.1521

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Improved Reliability of FWD Tests Results and Correlations with Resilient Modulus

Introduction

The resilient modulus (M_R) is an important parameter to assess the performance of subgrade soils subjected to traffic loading. It is widely used for the analysis and design of pavements and is also a key factor in the *Mechanistic-Empirical Pavement Design Guide* (MEPDG), which was adopted by INDOT in January 2009. Accurate determination of the resilient modulus is important for the pavement design of new road projects, for pavement rehabilitation, and for making predictions on the lifespan of existing pavements. The available literature is rich with attempts at estimating the M_R of the subgrade obtained in the laboratory using estimates from FWD tests in the field. However, the review conducted on the work finished thus far shows very contradictory and inconsistent findings and clearly indicates that the issue is far from being resolved. Thus, there is need and opportunity to improve the interpretation of the FWD data and enhance the reliability of the FWD results by decreasing the sources of uncertainty, including the performance of the field tests and the quality and interpretation of the data. This project addresses these issues and aims at improving the reliability and the interpretation of FWD tests by (1) performing a comprehensive literature review of available FWD protocols and back calculation tools; (2) evaluating non-destructive testing methods for pavement thickness determination; and (3) expanding the existing database of high-quality data pairs of FWD and M_R. A total of six sites (I-865, SR-46, US-31, S-BRITE, SR-37, and I-65) across Indiana were selected for this project to perform field tests (FWD and GPR) and to collect subgrade soil samples for laboratory testing.

Findings

Six sites were selected to collect subgrade soil samples: (1) I-865 (PCCP over a cement stabilized subgrade layer), (2) SR-46 (asphalt pavement over an untreated subgrade), (3) US-31 (PCCP pavement over a cement treated subgrade), (4) S-BRITE (compacted base over a cement treated subgrade layer), (5) SR-37 (PCCP over a cement treated subgrade), and (6) I-65 (PCCP over a cement treated subgrade). FWD and GPR tests were performed on four sites—I-865, SR-46, US-31, and SR-37. FWD data was analyzed using MODTAG and ELMOD. To establish correlations between the two tests, the backcalculated moduli for the subgrade layer was then compared with the laboratory resilient modulus results for both treated and untreated soil specimens. The following key conclusions were derived from the work.

- GPR is a useful tool to determine the thickness of pavement layers and to identify discrepancies between as-built and design pavement thickness. For flexible pavements, GPR is able to distinguish between the HMA and base course layer. For rigid pavements, GPR was able to identify the top two layers of the pavement—PCCP and the base/subbase layer.
- For rigid pavements, results of FWD backcalculation analysis using both ELMOD and MODTAG greatly overestimate the resilient modulus of the soil. The backcalculated results for the subgrade are 1.3 to 6 times higher than the laboratory results.
- For flexible pavements, results of the FWD backcalculation analysis suggests that a one-to-one

correlation exist between FWD modulus and laboratory resilient modulus values for untreated subgrade soils. That is, $E_{FWD} \sim M_{R,UNTREATED}$.

- The code ELMOD is recommended for routine calculations because it is easy to use and provides accurate results for the resilient modulus. MODTAG can be used for research or to provide an in-depth analysis of the results at any given location.

Implementation

1. When good quality FWD data are available, the resilient modulus of untreated subgrade soils under flexible pavements can be estimated from FWD tests using ELMOD or MODTAG. The recommended relation is that resilient modulus backcalculated from FWD is equal to the resilient modulus obtained in the laboratory.
2. The resilient modulus obtained from FWD data performed on rigid (PCCP) pavements overestimates the resilient modulus obtained in the laboratory. The backcalculated modulus for the subgrade is 1.3 to 6 times higher than the laboratory results. An initial estimate of the resilient modulus of the subgrade on rigid pavements could be obtained by dividing the backcalculated moduli from the FWD by a factor of three. However, this estimate should not be used for design but only as a reference.
3. It is hypothesized that the errors in the resilient modulus on PCCP pavements are due to a number of factors—magnitude of the load and/or small deflections obtained, position of the sensors relative to pavement joints, and rigid movements of the pavement slabs that mask the “basin” deflection expected for the calculations. Further research is recommended to bring the level of interpretation of FWD test results to that of flexible pavements.
4. It is recommended to run, concurrently with FWD tests, GPR tests to determine the actual thickness of the pavement layers, and more specifically of the asphalt and concrete layers (layers with high stiffness). The study conducted suggests that errors on pavement layer thickness of ±1″ result in approximately a 45% difference in the moduli of the subbase and subgrade layers.
5. Most of the DOTs surveyed perform FWD tests using a drop sequence comprised of a seating load and repetitive drops for the same load. Repetitive loading seems to improve the accuracy of the results and allows for better interpretation of FWD data. It would be interesting to set up a testprogram that compares the results of FWD tests conducted at the same location following current INDOT protocol with the ‘‘drop sequence’’ used by other DOTs to see if there is a performance improvement. This may be particularly interesting in PCCP pavements, where the results are not satisfactory. The current protocol that INDOT uses provides satisfactory results on asphalt pavements.
6. Based on the analysis performed for both flexible and rigid pavements, the software ELMOD is preferred for routine calculations based on its simplicity and accuracy. MODTAG could be used for research or for detailed analysis of results, as it offers tools to analyze the quality of data and include a larger number of pavement layers.

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