COMPARISON OF THE FALLING WEIGHT DEFLECTOMETER AND THE DYNAFLECT FOR PAVEMENT EVALUATION

Bary Eagleson, Scott Heisey, W. Ronald Hudson,
Alvin H. Meyer, and Kenneth H. Stokoe

SUMMARY REPORT 256-1(S)

SUMMARY OF

RESEARCH REPORT 256-1

PROJECT 3-8-80-256

CENTER FOR TRANSPORTATION RESEARCH

BUREAU OF ENGINEERING RESEARCH

THE UNIVERSITY OF TEXAS AT AUSTIN

NOVEMBER 1982

SUMMARY REPORT 256-1(S)

Foreword

Research Report 256-1 is the first report describing the work done on project 3-8-80-256, "The Study of New Technologies for Pavement Evaluation." It presents the results of an analytical study undertaken to determine the best model for pavement evaluation using the criteria of cost, operational characteristics, and suitability.

Introduction

The Texas State Department of Highways and Public Transportation currently uses a Dynaflect to perform nondestructive testing of pavement sections. Recently, critics have argued that the load applied by the Dynaflect is inadequate for providing accurate information for the structural evaluation of thick rigid pavements. Because of this and since several other nondestructive testing devices currently available deliver heavier loads, it has become necessary to evaluate these to determine if they are more suitable for pavement evaluation than the Dynaflect.

A literature search was made to compare five deflection measuring devices which are currently available: the Dynaflect, the Road Rater Model 2000, the WES 16-kip Vibrator, the Falling Weight Deflectometer (FWD), and the FHWA Thumper. Basically, all except the falling weight device impose a sinusoidal vibratory loading on a static preload. The falling weight device uses a weight dropped from a predetermined height to apply a load impulse to the pavement.

The Dynaflect, Road Rater, and FWD ranked highest when compared using the criteria of cost, operational characteristics, and suitability. The Road Rater was not tested since it is similar to the Dynaflect and Texas already has several Dynaflects in use. There has been much information gathered on and thought given to adaption of the falling weight device in the United States in the past three years and, since the falling weight device delivers relatively heavy loads, it was decided to compare those two devices.

Approach

A comparison between the Dynaflect and the Falling Weight Deflectometer was made on pavements of continuously reinforced concrete, jointed reinforced concrete, asphalt cement concrete, and continuously reinforced concrete with an asphalt cement concrete overlay. The testing was performed to determine the suitability of the Falling Weight Deflectometer for Texas conditions and to determine if the higher dynamic load it provides could yield information not available from Dynaflect measurements.

A study of wave propagation techniques was also made. These techniques are based on determining the velocities of Rayleigh waves propagating through the pavement structure at different frequencies. The modulus of elasticity is related to the wave velocity. After the velocity versus depth relationship is established, a modulus versus depth relationship is defined. Thus, layer thickness can be determined by examination of the modulus profile. The prospect of using the Falling Weight Deflectometer to generate the Rayleigh waves is examined in the report, as is the use of a smaller drop hammer, for comparative purposes.

Results

Field testing proved the Dynaflect and FWD were nearly equal except in operational speed. Here the Dynaflect rated superior, primarily due to its having an automatic sensor placement.

The correlation coefficient obtained showed good agreement between the deflections measured by the two devices on all pavements except overlaid CRCP. Additional analysis of the FWD deflection versus load data showed there was insignificant stress sensitivity in the pavements tested, under loads varying from 6,000 to 11,000 pounds. A study of the FWD impulse load using a digital signal analyzer showed major frequencies generated by the FWD load were less than 250 Hz, thus making it impractical to use the FWD and signal analysis to determine layer moduli of in-situ pavements.

Static Analysis of Dynaflect and FWD Results

One shortcoming of both the Dynaflect and Falling Weight Deflectometer methods is the assumption of static loading which is made in the elastic layered analysis of the measured deflections. In fact, both tests involve dynamic loading and wave propagation and, hence, should be analyzed accordingly.

The FWD generates compression, shear, and Rayleigh waves in the pavement structure during each test. These waves propagate at different velocities away from the loaded area, and the amount of material sampled during the test depends on the wave velocity and load duration.

The Dynaflect generates all wave types, as the FWD does. The Dynaflect, however, generates mostly Rayleigh waves at a frequency of 8 Hz. For this type of test, the effective sampling depth is on the order of one-third of the wavelength.

In both test methods, the results are complicated by reflections and refractions in the pavement system, which, of course, are not considered in any static analysis.

Dynamic analyses of these test methods should be developed. They can be used to show where the static solutions are correct and where they are inappropriate.

Surface Wave Propagation Method

One of the main results of this study is the indication that modern wave propagation techniques using surface waves may be more useful in evaluating pavements than either the Falling Weight Deflectometer or the Dynaflect. The method shown to have much promise in this work involves a small hammer, used to apply transient impulses at the surface, and vertical receivers, placed on the surface and used to monitor the passage of Rayleigh waves. The Rayleigh waves are analyzed in the frequency domain to determine the velocity-wavelength relationship. From this relationship and wave propagation theory, the depths of the layers and the moduli of each layer can be determined for a complete pavement system.

A special study of the FWD impulse load using a digital signal analyzer showed the major frequencies generated by the FWD load were less than 250 Hz. This makes it impractical to use the FWD as the source in the Rayleigh wave analysis in the frequency domain to determine layer moduli of in-situ pavements. A smaller hammer, which generates higher frequencies, is better for characterizing the surface layers.

It is also interesting to note that, for the testing performed in this study, the FWD and the impulse from a 10-lb hammer gave the same moduli for different layers below the pavement. This test shows that for this system the FWD did not load the pavement system in the nonlinear range.

Closing Discussion

This study has confirmed both the experience of engineers and the information of other studies that in most pavements the Dynaflect provides deflection data that is comparable to other, heavier and more expensive devices. It has also shown that there are some pavements and conditions where comparable data were not obtained. Additional studies under controlled conditions are needed to determine the limits of where useful data from the Dynaflect can and cannot be obtained. The possibility exists that, in some cases, heavier deflection devices may provide more reliable information.

Other methods of interpreting the data should be explored and further studies in the use of the surface wave propagation method should be made.

Conclusions and Recommendations

An examination of the literature and the field study data leads to the following conclusions.

(1) The Dynaflect and FWD are nearly equal when evaluated on the basis of operational characteristics and cost.
(2) The Dynaflect's major advantage is the large existing empirical data base relating Dynaflect measurements to performance.
(3) The major advantages of the FWD lie in its load magnitude and its variable load force.
(4) The variable load enables the detection of stress sensitivity of the pavement structure as it exists in the field.
(5) The Dynaflect and FWD data were highly correlated, indicating the two devices would yield similar design sections.
(6) Digital signal analyzers can yield information for wave propagation analysis.

Based on the above conclusions the following recommendations for further study are offered.

(1) Choose a section of roadway for overlay design and perform an overlay analysis with an FWD capable of delivering 18 kips and compare it with a design based on the Dynaflect and current SDHPT methodology.

(2) Investigate more thoroughly the capabilities of Digital Signal Analyzers to perform wave propagation tests.

The first study, involving an actual overlay design, would show whether the load magnitude of the FWD and its variability translate into significantly different overlay designs. This would clearly demonstrate whether the Dynaflect with its 1000-lbf peak-to-peak loading is sufficient to characterize pavements for overlay design.

KEY WORDS: Pavements, deflections, Dynaflect, Falling Weight Deflectometer, Rayleigh waves, Digital Signal Analyzer.

The research reported here was conducted for the Texas State Department of Highways and Public Transportation in cooperation with the U.S. Department of Transportation Federal Highway Administration.

The full text of Research Report No. 256-1 can be obtained from Mr. Phillip L. Wilson, State Planning Engineer, Transportation; Transportation Planning Division, File D-10R; State Department of Highways and Public Transportation; P. O. Box 5051; Austin, Texas 78763.