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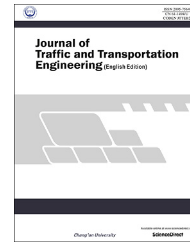

Original Research Paper

Dynamic analysis of falling weight deflectometer

Q5 Ainalem Nega [a,*], Hamid Nikraz [a], Imad L. Al-Qadi [b]

[a] Department of Civil Engineering, Curtin University, Perth, WA 6845, Australia
[b] Illinois Center for Transportation, University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA

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ABSTRACT

Falling weight deflectometer (FWD) testing has been used to evaluate structural condition of pavements to predict the layer moduli using backcalculation process. However, the predicted pavement layer moduli sometimes may not be accurate even if computed and measured deflection basin has fulfilled the standard and is in concurrence with certain tolerable limits. The characteristics of pavement structure, including pavement layer thickness condition and temperature variation, affect the predicted pavement structural capacity and back calculated layer modulus. The main objective of this study is to analyze the FWD test results of flexible pavement in Western Australia to predict the pavement structural capacity. Collected data includes, in addition to FWD measurements, core data and pavement distress surveys. Results showed that the dynamic analysis of falling weight deflectometer test and prediction for the strength of character of flexible pavement layer moduli have been achieved, and algorithms for interpretation of the deflection basin have been improved. The variations of moduli of all layers along the length of sections for majority of the projects are accurate and consistent with measured and computed prediction. However, some of the projects had some inconsistent with modulus values along the length of the sections. Results are reasonable but consideration should be taken to fix varied pavement layers moduli sections.

1. Introduction

FWD testing has been an integral part of flexible pavement's condition assessment for a decade. Various approaches and procedures for FWD deflection analysis have been developed in several studies (Xu et al., 2002a, b). Most of these procedures and guidances for FWD deflection do not take account either the dynamic loading effect or nonlinear material behavior. Although few procedures do take account for these effects, their implementations are very challenging because of their complexity and the large number of variable (Xu et al., 2002a, b).

Sebaaly et al. (1986) evaluated the dynamic analyses data from falling weight deflectometer by using a multi-degree of freedom elastodynamic analysis, which was based on a Fourier solution synthesis for periodic loading elastic or viscoelastic moduli layered strata. The results indicated that inertial effects were important in the pavement response

* *Corresponding author*. Tel.: +61 431548494; fax: +61 8 9266 2681.
E-mail address: ainalem.nega@curtin.edu.au (A. Nega).

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prediction. Xu et al. (2002a, b) developed a mechanistic relationship between FWD deflection and asphalt pavement layers condition. From the results, deflection basin parameters (DBPs), effective layer moduli, and stresses and strain were identified as pavement layers condition indicators. Xu et al. (2002a, b) also presented a new condition assessment criterion for flexible pavement layers using FWD from field data. Nondestructive condition assessment criteria were developed for application in conjunction with the condition evaluation indicators that were estimated using on falling weigh deflectometer deflection.

Kim and Park (2002) developed a mechanistic empirical method for assessing pavement layer condition as well as estimated the remaining life of flexible pavement using multi-load level FWD deflection. Synthetic deflection database was generated using FWD and a stress-dependent soil model. Results showed that the base and subgrade pavement layer moduli condition can be estimated using multi-load level FWD deflection. AC layer moduli were found to be better indicators than deflection basin parameters. Appea and Al-Qadi (2000) also have assessed FWD data for stabilized flexible pavements. The performance and structural condition of nine flexible pavement test sections that were built in Bedford and Virginia, have been monitored for 5 years using FWD. The flexible pavements had three groups with aggregate base layer moduli thickness of 100, 150, and 200 mm. The deflection basins obtained from the flexible pavement testing were analyzed using the ELMOD back calculated program in order to find the pavement structural capacity and to defect changes in the aggregates resilient modulus. The analysis showed a 33% reduction in the back calculated resilient modulus for the 100 mm thick base layer over 5 years for non-stabilized as compared to the geosynthetically stabilized section.

A study was conducted to develop methods for using FWD measurements to determine moduli of onsite pavement material sands and compare FWD-estimated moduli with laboratory-measured values in order to achieve consistent input to thickness design procedures (Frazier, 1991). A three-layer pavement model was used to characterize flexible pavement and simple procedures were developed to account for seasonal variations and effective moduli values for granular base-subbase and subgrade soils from limited FWD measurement (Frazier, 1991). There were large differences between FWD moduli and laboratory moduli from triaxial testing (AASHTO T274). However, good agreement was demonstrated between FWD and laboratory values (AASHTO T274) moduli for subgrade soils. This was also seen when characterization of granular base-subbase was difficult.

FWD tests have been used in the evaluation of material properties of pavement system for decades. Load amplitudes and frequency content intend to provide pavement deformation levels similar to those induced by truck wheal loads in heavy urban traffic loading. Interpretation of the in situ measured data is normally based on elastic solutions and does not take into account the possible existence of localized nonlinearities. Chang et al. (1992) investigated the nonlinear effects in FWD using both a linear and nonlinear solution with the generalized cap model to reproduce the nonlinear soil behavior. The material nonlinearities were found to be important for FWD tests on flexible pavement where the subgrade is relatively soft and the pavement is thin. FWD tests are commonly considered to provide estimates of material properties for levels of loading, similar to those exerted by truck model as discussed by Uddin et al. (1985a, b).

The main objective of this study is to analyze the FWD test results for the strength of flexible pavement layer moduli character in Western Australia so that allowable loads for existing pavement structures can be determined. In addition, demonstration for a proper interpretation of FWD tests deflection data for the flexible pavement sections that have been experienced multiple milling operations and overlays. Design of typical FWD configuration, location of loading plate, geophones and measured deflection basin are shown in Fig. 1. D_j ($j = 0, 1, \ldots, 8$) is the measured deflection at pavement surface.

1.1. Analytical model and approaches

FWD testing has been extensively practiced in the past to assess structural condition and determine the model of flexible pavement layer. The set of modulus value for pavement layers obtained from the backcalculation may not be accurate even though the computed and measured deflection basin may match within tolerable limits (Mehta and Roque, 2003). Extensive data interpretation is involved in obtaining the layer moduli of these pavements. For example, guidelines and tools are provided for calculating layer moduli of flexible pavement. However, FWD interpretation has become challenging because more roads have experienced several milling operations and overlays. Flexible pavement structure characteristics (damage layers, variation in pavement thickness, and change of pavement temperature) can overwhelm the deflection data to show a more significant effect than those induced by structural layer moduli stiffness as summarized by Mehta and Roque (2003). Q2

1.2. Backcalculation of flexible pavement

Several computer programs such as ADAM, BISDEF, BOUSDEF, CHEVDEF, COMDEF, DBCONPAS, ELMOD, ELSDEF, EVERCALC,

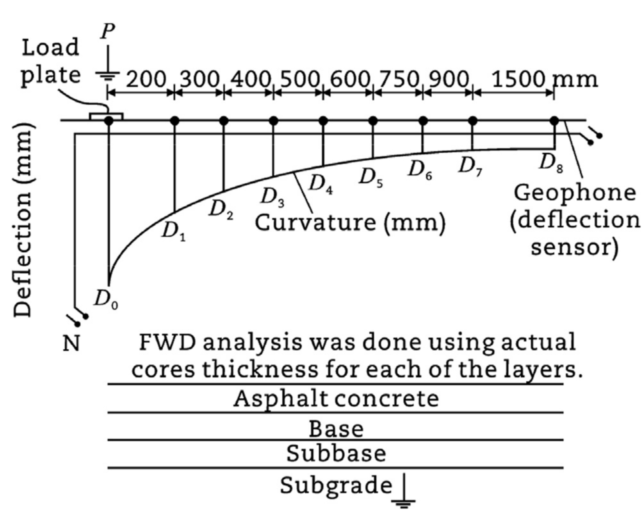

Fig. 1 – Design of typical FWD configuration, location of loading plate, geophones and measured deflection basin.