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Dynamic soil models for backcalculation of material properties from falling weight deflectometer deflection data

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Abstract

Falling Weight Deflectometer (FWD) test is one of the most widely used methods for in-situ nondestructive evaluation of pavement/soil properties and examination of the structural condition of in-service pavements. A dynamic half-space model is employed in the present work for backcalculation of engineering soil properties from the FWD data. The advantages, limitations and the reliability of the backcalculation elastic moduli evaluated from dynamic soil model are discussed in this paper. Selected numerical results are presented to portray the influence of governing parameters, for example, the presence of shallow stiff layer and the mass density of soil material on dynamic backcalculation of the soil elastic modulus. The investigation presented in this study provides a better understanding of dynamic backcalculation processes which is essential for the development of dynamic backcalculation program and its applications.

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Keywords: Dynamic backcalculation; nondestructive test; material properties; falling weight deflectometer; dynamic soil models

1. Introduction

Backcalculation is an inverse problem with the objective of predicting the modulus of pavement or soil layers. Backcalculation is usually carried out using a computer program. Several static and dynamic backcalculation programs have been developed for evaluating in-situ elastic moduli from Falling Weight Deflectometer (FWD) test deflection

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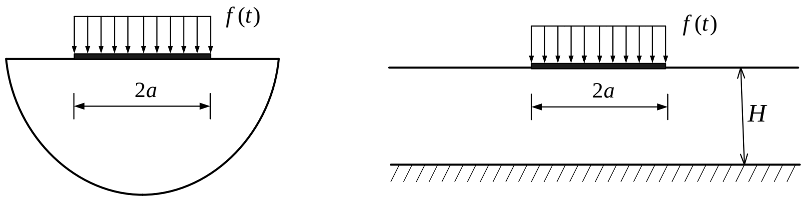
data through inverse analysis [1, 2]. Most of the commercial backcalculation programs are based on static backcalculation. Due to the dynamic nature of the FWD test, static backcalculation is known to be capable of producing erroneous estimation of the moduli associated with the neglect of dynamic effects. Despite the advantages in accounting for the time-dependent load and responses, the accuracy of evaluating elastic moduli based on dynamic backcalculation analyses is, however, significantly depended on the dynamic soil models employed in the backcalculation process [3].

The analysis of interaction of a plate on a poroelastic half-space can be found in the literature (see, for example, Philippacopoulos [4], Zeng and Rajapakse [5] and Senjuntichai and Sapsathiarn [6, 7]). Field tests of experimental sites have been conducted by Asli *et al.* [8] using the portable deflectometer device. The effect of a rigid or stiff layer was investigated by Roesset *et al.* [9] by employing the static backcalculation of layer moduli. The estimated backcalculation moduli can be different as a result of the assumptions, iteration technique, back-calculation, or forward calculation schemes used within the backcalculation programs [10–12]. The primary objective of this study is to investigate the influence of forward soil models for backcalculation of soil properties. Selected numerical results are presented to portray the influence of governing parameters on dynamic backcalculation of the soil elastic modulus.



(a) (b)

Fig. 1. Schematic illustration of (a) dynamic half-space model; (b) dynamic model with the presence of shallow stiff layer considered in the present study.

2. Dynamic soil models

The schematic representation for the dynamic soil models considered in the present paper is presented in Fig. 1. The plate is subjected to axisymmetric time dependent loading and its response is governed by the classical plate theory. The soil domain is represented by a poroelastic medium. Dynamic behavior of the poroelastic medium is governed by Biot 's poroelastodynamic theory [13, 14]. Two types of dynamic soil models are considered in the present study, namely, dynamic half-space model and dynamic model with the presence of shallow stiff layer as shown in Figs. 1(a) and 1(b) respectively. The equations of motion for a poroelastic medium undergoing axisymmetric deformations, in the absence of body forces (solid and fluid) and a fluid source, can be expressed according to Biot [13, 14] as

$$\mu\nabla^2 u_r + \left(\lambda + \alpha^2 M + \mu\right)\frac{\partial e}{\partial r} - \mu\frac{u_r}{r^2} - \alpha M\frac{\partial \zeta}{\partial r} = \rho\,\ddot{u}_r + \rho_f\ddot{w}_r \tag{1a}$$

$$\mu\nabla^2 u_z + \left(\lambda + \alpha^2 M + \mu\right)\frac{\partial e}{\partial z} - \alpha M\frac{\partial \zeta}{\partial z} = \rho\,\ddot{u}_z + \rho_f\ddot{w}_z \tag{1b}$$

$$\alpha M\frac{\partial e}{\partial r} - M\frac{\partial \zeta}{\partial r} = \rho_f\ddot{u}_r + m\ddot{w}_r + b\dot{w}_r \tag{1c}$$

$$\alpha M\frac{\partial e}{\partial z} - M\frac{\partial \zeta}{\partial z} = \rho_f\ddot{u}_z + m\ddot{w}_z + b\dot{w}_z \tag{1d}$$

where u_i and w_i are the average displacement of the solid matrix and the fluid displacement relative to the displacement of the solid matrix, in the $i-$direction ($i = r, z$), respectively; p is the excess pore fluid pressure