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Modeling deflection basin using artificial neural networks with cross-validation technique in backcalculating flexible pavement layer moduli

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Abstract

Through the new technological developments, for highway maintenance engineering the structural capacity of pavement is to be determined using non-destructive techniques. Up to now various methodologies have been applied based on the surface deflection bowl obtained under either a known moving wheel load or devices such as falling weight deflectometer. Backcalculating pavement layer moduli are well-accepted procedures in the evaluation of the structural capacity of pavements. The ultimate aim of the backcalculation process from non-destructive testing (NDT) results is to estimate the pavement material properties. Using backcalculation analysis, *in situ* material properties can be backcalculated by the measured field data for appropriate analysis techniques. To backcalculate reliable moduli, the deflection basin must be modeled more realistically.

Here, in this study, the deflection basins measured on the surface of the flexible pavements are modeled using artificial neural networks (ANN) with cross-validation technique. Distances between transducers can be varied with different producer companies. The distances between transducer are used for the form deflection basin. Layer thickness and distance to loading center are used as input in the present study. Limited experimental deflection data groups from NDT are used to show the capability of the neural network technique in modeling the deflection bowl. Since enough data are not available to construct a reliable neural network, a methodology based on the cross-validation technique can be used. The results show that the proposed methodology give the deflection bowl satisfied accuracy.

Keywords: Backcalculation; Flexible pavements; Deflection; Non-destructive testing; Artificial neural networks; Cross validation

1. Introduction

An assessment of structural condition might be necessary during the pavement life for monitoring its rate of deterioration, calculating its residual life and planning future maintenance requirements.

The pavement is commonly modeled as a multilayered elastic system (where each layer is described by its elastic modulus and Poisson's ratio) or using a finite element method, in order to predict its response in terms of stresses strains and deflections to surface loading.

In order to design pavement structure, the future traffic loading and the pavement material properties (moduli), which include the subgrade are to be known. Pavement layer thicknesses are specified; the stresses and strains at critical locations are calculated under a standard axle load employing a structural analysis model. These stresses and strains are compared with allowable values and adjustments according to geometry and materials until satisfactory design is achieved.

On the other hand, the assessment of an existing pavement for prediction, its condition and residual life involves

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measuring the pavement response in terms of deflections under surface loading (such as the falling weight deflectometer, FWD) and calculate the best set of layer moduli using a procedure known as backcalculation.

Non-destructive testing (NDT) and backcalculating pavement layer moduli are well-accepted procedures for the evaluation of the structural capacity of pavements [1]. NDT enables the use of a mechanistic approach for pavement design and rehabilitation since *in situ* material properties can be backcalculated from the measured field data through appropriate analysis techniques [2]. In order to backcalculate representative moduli, it is essential to accomplish several deflection tests at different locations along the highway sections having the same layer thicknesses [1]. But it isn't sufficient to do this. In case the deflection basin is modeled more realistically, elastic pavement layer moduli obtained from backcalculation results will reflect actual behavior. Amongst deflection methods, commercially available devices are the Dynaflect, Road Rater and FWD. The most common property found by NDT is the elastic modulus of each pavement layer.

Highway and transportation agencies have an increased responsibility for maintenance, rehabilitation and management of highways, particularly with regard to asphaltic concrete pavements. Efficient and economical methods are required to determine the structural properties of existing pavements realistically from non-destructive test data and have been increasingly used in the pavement engineering community. Pavement structural properties may generally be summarized in terms of resilient modulus, which is a key element in mechanistic pavement analysis and evaluation procedures.

2. Backcalculation of pavement layer moduli

Backcalculation generally refers to an iterative procedure whereby the layer properties of the pavement model are adjusted until the computed deflections under a given load agree with the corresponding measured values. NDT is meant to produce numerous deflection bowls.

The ultimate aim of the backcalculation process from NDT results is to estimate the pavement material properties. The backcalculation procedure is to find the set of parameters corresponding to the best fit of the measured deflection bowls by the computed bowls.

FWD delivers a load to a pavement surface; then deflections are measured at the surface of the pavement. If layer elastic moduli are found so that the analytical deflections nearly coincide with measured deflections, the set of elastic moduli may be considered to represent average elastic moduli of those layers in the real pavement structure. The least squares method (LSM) has been used for comparing the computed and measured deflection basins in most backcalculation procedures. However, it can be said that LSM does not accurately model the deflection bowl. If the deflection basin is modeled as realistically as possible, then pavement layer moduli values from backcalculation results will give results that are more realistic. Hence, deflection basins were modeled here using artificial neural networks (ANN) as a more realistic approach.

Even if the deflections are measured accurately and economically, unless the backcalculation procedure is realistic, backcalculation process does not give accurate results. More precision is needed from the backcalculation procedures, and more realistic models will reduce the size of systematic errors. This will make it possible to predict the remaining life of a pavement realistically in the field immediately after it has been tested.

3. FWD testing device

The FWD is a trailer-mounted device, which applies a load to the pavement surface through a circular plate. FWD testing has been established worldwide as one of the most effective tools for measuring deflections for pavement evaluation purposes.

To simulate the truck loading on the pavement, a circular plate is dropped on the pavement from a certain height. The height is adjusted according to the desired load level. Underneath the circular plate a rubber pad is mounted to prevent shock loading. As shown in Fig. 1, geophones or sensors are generally mounted on an independent beam such as they are in truck with the pavement surface (the number of geophones or sensors can change). When the vertical load is applied on the pavement, the geophones collect the data in byte form. Using the calibration factors, the bytes can be converted to the real deflections.

Benkelman Beam and Dynaflect, which are the most widely used devices in developing countries only give deflection information concerning the loaded area, whereas the FWD gives the information about six other points which are away from the circular loading plate. Therefore,

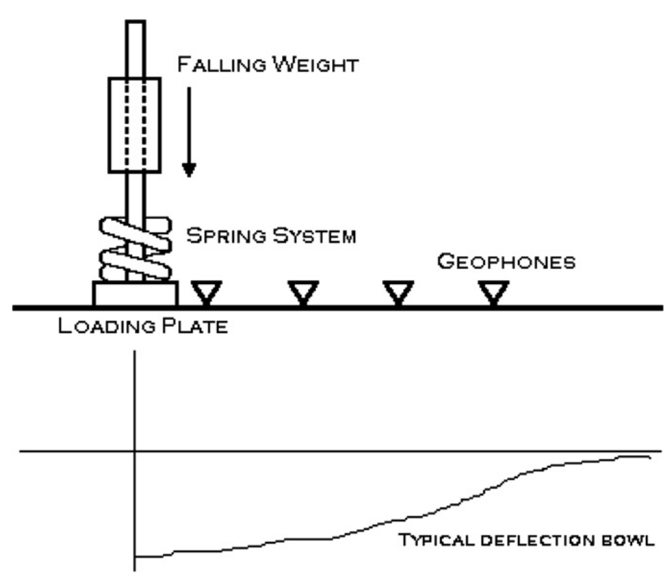

Fig. 1. Typical deflection bowl obtained from a FWD loading.