Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 53(3) (2021)183-186
DOI: 10.22060/ceej.2019.15510.5937

Calibration of Witczak and Modified Witczak Models for Prediction of Dynamic Modulus of In-Service Asphalt Layers

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ABSTRACT: One of the important input parameters of the Mechanistic-Empirical Pavement Design Guide (MEPDG) for asphalt pavements is the dynamic modulus ($|E^*|$) that can be defined as the viscoelastic property of asphalt materials. For the determination of dynamic modulus of in-service asphalt layers, MEPDG uses results of both Falling Weight Deflectometer (FWD) and laboratory dynamic modulus predictive models. This method in some cases lacks precision. Hence, it is needed to improve the current method and develop accurate predictive models. In this research, ten asphalt pavement sites, having various structures, ages, and conditions, were selected in Khuzestan and Kerman provinces in Iran. Field and laboratory testing were performed and the dynamic modulus of in-service asphalt layers was determined. Developed predictive models for dynamic modulus of asphalt mixes including Witczak and Modified Witczak were calibrated and new models were constructed for predicting in-situ dynamic modulus of asphalt layers. These two calibrated models entitled "In-situ Witczak Model" and "In-situ Modified Witczak Model" could be directly used for the prediction of dynamic modulus of in-service asphalt layers from volumetric properties of asphalt mixes and viscosity characteristics of extracted binders without any need for FWD testing. Performance evaluation and validation of new models showed high accuracy and low bias with a very good correlation between predicted and measured values (R^2=0.93).

Review History:

Received: Dec. 25, 2018
Revised: Jan. 24, 2019
Accepted: Feb. 13, 2019
Available Online: Feb. 20, 2019

Keywords:

Dynamic modulus of asphalt layers
FWD
Dynamic modulus predictive models
Witczak model
Modified witczak model

1. Introduction

Asphalt dynamic modulus is measured in the laboratory during expensive and time-consuming tests. Prediction models were developed to determine dynamic modulus with a few usual laboratory works based on mix volumetric properties and binder viscosity characterization. The objective of this study is to apply and evaluate two conventional dynamic modulus predictive models including Witczak and Modified Witczak in determining the dynamic modulus of in-service asphalt layers with different characteristics in Iran. In addition, new in-situ dynamic modulus predictive models with high accuracy and low bias are developed.

2. Existing Predictive Models

Two conventional dynamic modulus predictive models for asphalt mixtures were investigated in this paper including:

- Witczak model [1];
- Modified Witczak model [2].

3. Experimental Work

In this research, ten flexible pavement sites were selected in Khuzestan and Kerman provinces in Iran. The sites were selected from different roads having pavements with different characteristics concerning their thickness, number of layers, ages, and types of base and subbase layers. Falling Weight Deflectometer (FWD) testing was conducted ("Fig. 1") and core samples were taken at each site. These were then tested for volumetric analysis. The results of the tests were used as input parameters in dynamic modulus predictive models.

Fig. 1. FWD testing on a site

4. Prediction of Dynamic Modulus of Asphalt Layers

Predicted dynamic moduli for all samples at different temperatures using original predictive models as well as FWD back-calculated ones are shown in "Fig. 2". As can be seen in

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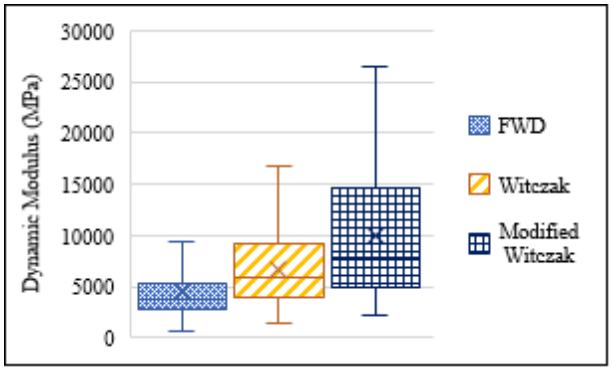

Fig. 2. FWD back-calculated and predicted dynamic moduli for all samples at different temperatures using original predictive models.

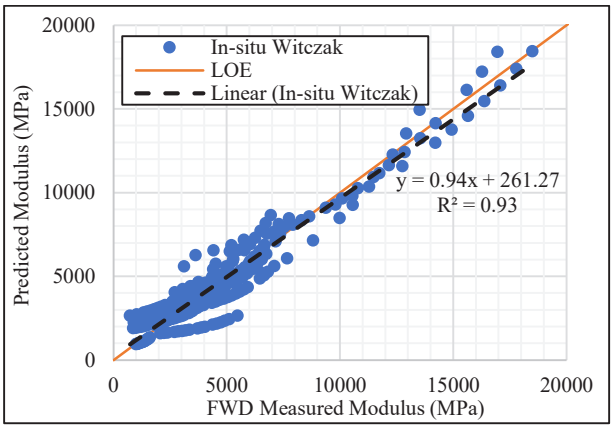

Fig. 4. Predicted dynamic moduli using In-situ Witczak model versus FWD back-calculated values.

this figure, the moduli predicted with Witczak and Modified Witczak models are greater than the back-calculated values. In addition, moduli predicted with the Modified Witczak model has shown a large difference with the back-calculated ones.

5. Development of In-situ Predictive Models

Nonlinear regression analysis was employed and two new in-situ predictive models were developed based on calibration of the original models. Newly developed models were named "In-situ Witczak" and "In-situ Modified Witczak" models. The predicted dynamic moduli using these new in-situ models as well as FWD back-calculated ones are shown in "Fig. 3". As it can be seen in this figure, in-situ models could predict dynamic moduli at a similar range of the back-calculated values and this shows the capability of the newly proposed models in predicting dynamic modulus of in-service asphalt layers.

6. Performance of New Models

Goodness-of-fit and bias were the two parameters that were used to evaluate the prediction performance of the new models. "Fig. 4" and "Fig. 5" show the predicted moduli versus FWD back-calculated values using In-situ Witczak and In-situ Modified Witczak models, respectively. As can be seen in these figures, the newly developed models could predict the dynamic modulus of in-service asphalt layers very close to the line of equality.

7. Conclusions

In this research, field and laboratory testing were carried out to predict the dynamic modulus of in-service asphalt layers in some flexible pavements in Iran. Two conventional dynamic modulus predictive models were utilized and the following findings were obtained:

• Feasibility investigation of using two dynamic modulus predictive models including Witczak and Modified Witczak models showed that it is possible to predict dynamic moduli of in-service asphalt layers using these models, although improvement of prediction accuracy is necessary.

• New in-situ predictive models with calibration of the above two original models were developed and their prediction performance was evaluated. Results showed that proposed models could predict the dynamic modulus of in-service asphalt layers with high accuracy and low bias, especially in the temperature range of this study.

• Directly prediction of dynamic modulus of in-service asphalt layers using mixture volumetric properties and asphalt

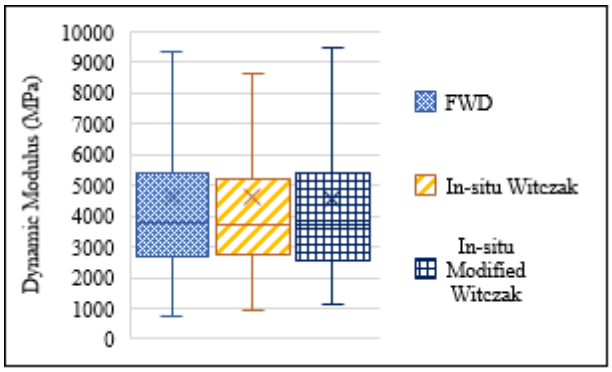

Fig. 3. FWD back-calculated and predicted dynamic moduli using new in-situ models.

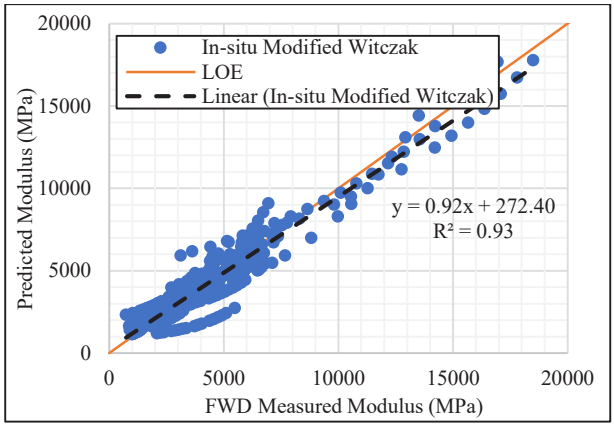

Fig. 5. Predicted dynamic moduli using In-situ Modified Witczak model versus FWD back-calculated values.

binder characteristics without the need for FWD testing is the main advantage of new developed in-situ predictive models.

• The best prediction performance belonged to the "In-situ Witczak model" with an R2 of 0.93.

References

[1] Andrei, D., Witczak, M. W. and Mirza, M. W. (1999). "Development of a Revised Predictive Model for the Dynamic (Complex) Modulus of Asphalt Mixtures", Inter Team Technical Rep. prepared for the NCHRP 1-37A Project, University of Maryland, College Park, MD.

[2] Bari, J. and Witczak, M. W. (2006). "Development of a New Revised Version of the Witczak E* Predictive Model for Hot Mix Asphalt Mixtures", Journal of the Association of Asphalt Paving Technologists, Vol. 75, pp. 381-423.

HOW TO CITE THIS ARTICLE

N. Solatifar, Calibration of Witczak and Modified Witczak Models for Prediction of Dynamic Modulus of In-Service Asphalt Layers, Amirkabir J. Civil Eng., 53(3) (2021) 183-186.

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