



The Ohio Department of Transportation Office of Research & Development Executive Summary Report

An Exploratory Study on Functionally Graded Materials with Applications to Multilayered Pavement Design

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Problem

Response of a flexible pavement is directly related to the elastic modulus of the pavement. During the construction of the flexible pavement, the elastic moduli will be gradually changed and be different along the depth due to the influence of construction methods and environmental factors. Actually, it is well known that the properties of asphalt concrete can be significantly affected by temperature and time, leading to the temperature- and aging-related stiffness gradients. Thus, the response of a flexible pavement will be substantially influenced by the potential elastic moduli gradient, which was listed by the FHWA as the most urgent needed research. A closely associated issue is on the back-calculation of the elastic moduli of the layered pavement. However, it is found that only very limited studies are documented on elastic moduli gradients, and the research on the effect of the elastic moduli gradients on the response of the asphalt concrete pavement has not been carried out yet. Therefore, this exploratory and innovative study is to investigate how the material property gradients affect the load response of the flexible pavement and to provide guidance to pavement engineers on the design of pavement material properties.

Objectives

The objective of this exploratory and high-risk study is to investigate how the gradually varied elastic moduli affect the load response of the flexible pavement.

Description

Instead of using the average moduli, the elastic moduli of each layer in a pavement structure are modeled to be gradually varied within the layer. To consider the elastic moduli gradients, the layer is subdivided into many sublayers with every sublayer having a constant modulus. Therefore the conventional 2-3 layers pavement is modeled by a multi-layered structure, with up to 100 sublayers. For such multilayered pavement, a unique, fast and innovative program, named *MultiSmart3D*, was developed.

Conclusions & Recommendations

Practical pavement engineering problems have been discussed and analyzed taking into consideration of the modulus variation with depth. Our analysis is carried out by utilizing the *MultiSmart3D* program, a powerful and innovative computer software product coded by the PI's group. This is a practical and fast program for studying and predicting the pavement response with elastic moduli gradients in each layer. It is found that stress jumps and strains jumps can be reduced greatly and the predicted life time of the pavement can be increased or decreased by a factor more than two if the modulus of elasticity variation with depth is taken into consideration, which could provide direct guidance for future pavement analysis and design.

Implementation Potential

The relationship between the functionally graded moduli and load response from this research will be useful in the design of flexible pavement. The corresponding *MultiSmart3D* software will be used to analyze permit applications for overloaded vehicles and forensic analysis of pavement sections. This exploratory study will also build up the foundation for the future modulus backcalculation analysis where modulus gradient needs to be included.