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Executive Summary Report

An Efficient and Accurate Genetic Algorithm for Backcalculation of Flexible Pavement Layer Moduli

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Project Background

Backcalculation of pavement moduli has been an intensively researched subject for more than four decades. Despite the existence of many backcalculation programs employing different backcalculation procedures and algorithms, accurate inverse of the layer moduli is still very challenging. Genetic algorithm (GA) is a robust and randomized search algorithm which can be employed to optimize the search domain for backcalculation. The use of GAs in pavement engineering is relatively new and thus no thorough investigation has been carried out to address all aspects and challenges associated with the backcalculation procedure. Most programs can only perform backcalculation for up to 20 layers of pavement due to the limitations associated with the mathematical formulation of their analytical solutions. This limitation restricts the modeling of pavement structures where the temperature variation along the depth is observed. *BackGenetic3D* is a program developed by The University of Akron group which uses GA and the efficient and accurate forward calculation program *MultiSmart3D* to backcalculate the layer moduli as well as the thickness of any pavement structure with no restrictions regarding the number of layers, thickness, location of the response points, and number of loading locations.

Study Objectives

The objectives of this work are to study the GA-based backcalculation method in pavement materials, to optimize the objective function in backcalculation procedure, to develop a new user-friendly backcalculation program (*BackGenetic3D*), to generalize the backcalculation procedure to include arbitrary number of pavement layers, loading conditions, and number of sensors, and last but not least to validate the performance and accuracy of the new method using several real pavement structures.

Description of Work

A detailed study has been conducted on the backcalculation of pavement layer elastic modulus and thickness using *BackGenetic3D*, a program developed by the University of Akron's Computer Modeling and Simulation Group. The importance of the measurement errors is illustrated clearly by a real pavement example. Besides root mean square (RMS), an efficient and accurate objective function, called area value with correction factor (AVCF), is proposed for accurate backcalculation of pavement modulus and thickness. The accuracy of the backcalculated results from these two functions are analyzed and compared. Numerical results have been presented for one-, three-, and twenty-three-layer pavement structures.

Research Findings & Conclusions

Backcalculation of layer moduli and thickness based on the common root mean square (RMS) as objective function has been presented in this work. Besides RMS, an efficient and accurate objective function, called area value with correction factor (AVCF), is proposed for accurate backcalculation of pavement modulus and thickness. The accuracy of the backcalculated results based on these two functions are analyzed and compared. Numerical results have been carried out for one-, three-, and twenty-three-layer pavement structures. Our results showed that while RMS was sensitive to measurement errors, AVCF was very accurate even when there were measurement errors. Thus, even though RMS is a commonly used goodness-of-fit function in existing backcalculation procedures, the backcalculated results based on RMS can be sensitive to the measurement errors. It means that even a slight change in measured deflections could result in a significant variation in backcalculated layer modulus and thickness. On the other hand, AVCF can make the backcalculated result close to the measured value independent of the backcalculation algorithm used. Thus, this new objective function AVCF would be remarkably helpful in future backcalculation of pavement properties. The proposed backcalculation method can backcalculate the modulus and thickness simultaneously for any number of pavement layers. The new backcalculation method derived from the improved GA and the efficient and accurate forward program *MultiSmart3D* has been incorporated into a simple, user-friendly, comprehensive GUI (*BackGenetic3D*).

Implementation Recommendations

The potential important influence of the parameters in genetic algorithm on the backcalculation procedure is an interesting topic for future study. Recently, there are a variety of optimization techniques with several advantages and disadvantages. A comparative study on the merits of these techniques can help us to better understand the moduli optimization in pavement engineering and to improve the backcalculation method. In addition, the current *BackGenetic3D* program assumes linear elastic pavement layers. The nonlinearity of the stresses in the pavement layers should be considered in the backcalculation procedure especially under high surface loads. The software can be developed to consider the thermal effect in the future versions. The improved genetic algorithm in this study can be used in combination with other advanced numerical simulation tools to increase the accuracy and efficiency in backcalculation of pavement properties.

With good seed values for the moduli and thicknesses, the *BackGenetic3D* can be implemented. If the measured deflections are reasonably free from errors, the simple objective function RMS can be selected; otherwise, it is better to run the program with the objective function AVCF. Due to the searching method used, *BackGenetic3D* could take more time to run, as compared to MODULUS 6.0. Thus continued study is needed on reducing the run time of the program.