TECHSUMMARY December 2011

State Project No. 736-99-1405 / LTRC Project No. 07-1P

Finite Element Simulation of Structural Performance on Flexible Pavements with Stabilized Base/Treated Subbase Materials under Accelerated Loading

INTRODUCTION

Accelerated pavement testing (APT) has been increasingly used by state highway agencies in recent years for evaluating pavement design and performance through applying a simulative heavy vehicular load to the pavement section under controlled field conditions in a compressed time period. However, running an APT experiment is expensive. It requires costly accelerated loading devices, constructing full-scale pavement structures, and operator resources. It is obviously impractical to test all potential pavement structures under APT. In order to maximize the benefit from an APT study and utilize APT results to evaluate other pavements with similar structural configurations, a finite element predictive model that can simulate the APT tests is an essential tool in which pavement distress prediction functions as well as laboratory material models can be calibrated and verified directly based on field APT test results.

OBJECTIVE AND SCOPE

The objective of this study was to develop a finite element (FE) analysis model(s) to simulate pavement structural performance of stabilized base and treated subbase materials under accelerated loading, so the performance of pavement structures with other stabilized base and subbase materials can be predicted without running additional APT tests. FE modeling of the permanent deformation behavior of various pavement materials was investigated. The accuracy and efficiency of different types of FE models were compared, including a 3-D model with a moving load, a 3-D model with a repeated load, and an axisymmetric model with a repeated load. The developed finite element model was validated and calibrated using the test results obtained from LTRC Project No. 03-2GT, or ALF Experiment 4: Accelerated Loading Evaluation of a Sub-base Layer on Pavement Performance.

LTRC Report 452

Read online summary or final report:
www.ltrc.lsu.edu/publications.html

PRINCIPAL INVESTIGATOR:
Zhong Wu, Ph.D., P.E.

LTRC CONTACT:
Zhongjie "Doc" Zhang, Ph.D., P.E.
225-767-9106

Louisiana Transportation Research Center

4101 Gourrier Ave
Baton Rouge, LA 70808-4443

www.ltrc.lsu.edu

METHODOLOGY

A permanent deformation (P-D) material model was proposed in this study to simulate the permanent deformation behavior of pavement base/subbase and subgrade materials under repeated loading. As shown in Figure 1, this model was modified from a conventional elastoplastic model with a linear strain hardening. All model parameters can be obtained from a laboratory P-D test. A P-D test data analysis spreadsheet by Excel Macro was developed to obtain parameters for the proposed P-D model. The P-D material model was implemented into a commercial FE program, ABAQUS through a user-defined UMAT subroutine. The P-D model was verified by simulating laboratory P-D tests for eight pavement base and subbase/subgrade materials. In addition, a sensitivity analysis was conducted to evaluate the effect of the material model parameters, pavement structures, and load configurations on the permanent deformation of pavement structures.

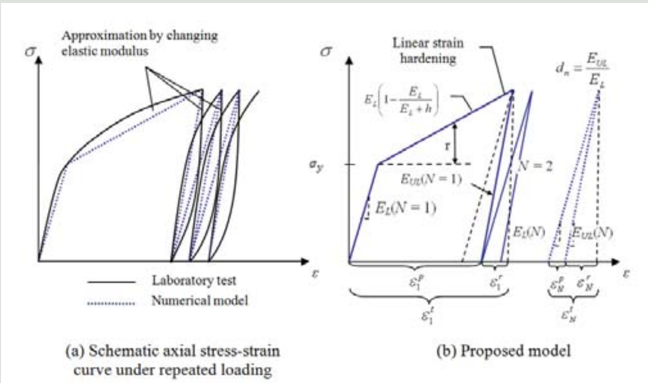

Figure 1. Concept of the proposed P-D model

Three FE models for APT were preliminarily developed to investigate the dimensionality effect: a 3-D model with a moving load, a 3-D model with a repeated load, and an axisymmetric model with a repeated load. Considering the computational efficiency, the axisymmetric model was finally selected in this study. Six APT tests were simulated to calibrate the FE model. In the FE analysis, the load wander effect and the temperature change in the pavement was considered. An accelerated analysis procedure was adopted. The calibrated FE model was validated by predicting the permanent deformation of two typical low volume pavement structures used in Louisiana.

Finally, the APT test calibrated FE model was used to develop P-D prediction models (transfer function) for pavement base/subbase and subgrade materials. These materials were classified into four categories: stabilized base materials (e.g., stabilized blended calcium sulfate [BCS] materials); unbound base materials (e.g., crushed limestone); treated subbase/subgrade materials (e.g., lime, lime/fly ash, and cement treated soils); and untreated subgrade soils. The developed P-D transfer functions were verified by predicting the permanent deformation of six APT sections and two typical low volume pavement structures.

CONCLUSIONS

Comparisons with the laboratory test data indicated that the proposed P-D model can successfully simulate the permanent deformation behavior of various base/subbase and subgrade materials under repeated loading. The developed axisymmetric FE model was used to simulate the permanent deformation of the six ALF Experiment 4 test sections. Based on the FE results, a shift factor of 1.13 was calibrated to account for the condition differences between the laboratory P-D test and the field. In addition, the calibrated FE model was applied to predict the permanent deformation of two typical low volume pavement structures used in Louisiana. Overall, the predicted permanent deformations matched well with the measured data.

The developed FE model was also used to predict an APT test section with a lime/fly ash treated subbase. FE analysis results indicated that the performance of 2.6 percent lime/6 percent fly ash treated subbase would be similar to that of 3.5 percent cement treated subbase, while the material linear foot costs were similar for these two sets of materials as well. The analysis showed that lime/fly ash treated soil could be a viable alternative to cement treated soil.

As an alternative of running the FE simulation, P-D transfer functions were developed for four categories of pavement materials. The developed P-D transfer functions were verified by predicting the six APT sections and two typical low volume pavement structures. The predicted permanent deformations based on transfer functions also matched well with the field measured data.

RECOMMENDATIONS

Both the FE method with the proposed P-D material model and transfer function method could be used to predict the permanent deformation of pavement structures, especially for those with stabilized base and subbase materials. The developed FE model could be a viable tool that can be used to predict the permanent performance deformation performance of various pavement structures without running additional APT tests. Further research efforts are recommended to determine P-D model parameters for various pavement materials used in Louisiana under different stress levels and environmental conditions. The proposed P-D model could be further evaluated by field measured rutting data from Louisiana pavement management systems (LAPMS). The calibration constants of developed P-D prediction models (transfer functions) for pavement base and subbase/subgrade materials are recommended to be further calibrated by more field projects.

Louisiana Transportation Research Center sponsored jointly by the Louisiana Department of Transportation & Development and Louisiana State University