Analysis of Debonding Effects on Vibration Propagation in Composite Pavement Structures

Yifeng Lu, Yinhong Cao, J. Gregory McDaniel, Ming L. Wang, Northeastern University

This work was performed under the support of the U.S. Department of Commerce, National Institute of Standards and Technology, Technology Innovation Program, Cooperative Agreement Number 70NANB9H0012

INTRODUCTION

Detection of the subsurface delamination of asphalt pavements, referred to as "debondings," is a principal design goal for the Tire Excited Acoustic Sensors (TEASe) subsystem because no current non-contacting measurement system is able of detecting them. This analysis is motivated by the desire to create a non-contacting method that mimics current contact techniques for measuring changes in pavement vibration propagation that can be related to important pavement characteristics such as pavement layer density, modulus and thickness. The core concept of TEASe is to measure the propagation characteristics of vehicle-generated pavement vibration. A vehicle creates vibration in the pavement that travels along its surface layers, which are referred to as "surface waves." As surface wave propagation relies in part on energy storage in shear, debondings, and their inherent lack of shear stiffness, change the propagation characteristics of surface waves significantly.

To demonstrate this, a finite element model was developed. A four-layer pavement structure, both with and without a finite-sized debonding between the first and second pavement layers, was modeled in COMSOL. An impact force was applied alongside the debonding to simulate force transmitted through the vehicle suspension and tire. Based on this FEM forward modeling, debondings could be identified due to their resonant characteristics as sensed by an air-coupled acoustic sensor above the pavement. Distinctions between "healthy" and "debonding" pavement propagation results were achieved using multiple-channel spectral analysis with help of custom signal processing algorithms. To compare this method to currently accepted contacting methods, the difference between an acoustic sensor and accelerometers bonded to the pavement were calculated.

RESULTS & ACHIEVEMENTS

Comparison of debonded and healthy pavement, near ground surface and 0.7m from impact horizontally. The sound pressure level (SPL, dB re 20 Pa) for the debonded case is calculated to 44 dB SPL, which is 2 times the response associated with intact pavement.

MULTIPLE-CHANNEL ACOUSTIC SENSING

A 7-channel microphone array with a 5cm spacing is positioned 2cm above the pavement surface, where it mimics the response of a ground attached accelerometer array. Meanwhile, multiple-channel sensing is expected to separate the response due to multiple subsurface wave propagation modes.

SUMMARY OF RESULTS

In order to predict the dynamic response of complex pavement structures, the finite element model is a valid approach when there is neither a closed-form analytical solution nor an existing pavement test bed whose materials parameters are known. A finite element model of regular highway pavement with large scale size and high mesh resolution was built up with the help of a finite element software. In order to improve the coherence of different receiver and channels and generally reduce noise, a floating window is employed in the processing. Multiple channel signal processing is based on the phase-shift algorithm. It has the potential to separate multiple solid wave propagation modes to improve the accuracy of the inversion. The model has been checked by comparison with coupling waveforms and other critical parameters produced using semi-analytical methods.

The predicted coupling between the pavement and the air above indicates that at low frequencies recording acoustic signals above the pavement should provide virtually the same information as that produced using accelerometers bonded to the pavement. The comparison of acoustic signals produced for the debonded and healthy casesthagrams suggests that there is an opportunity to detect subsurface anomaly through measurement of their resonant characteristics.

Research to Reality

This analysis will be used in the design of a non-contacting, vehicle-based method that produces information similar to that of traditional, contacting methods (SASW). The product (TEASe) will be integrated with SOTA radar, optical measurement and advanced GPS systems to create a vehicle-based measurement system that can assess surface and subsurface conditions of roads and bridges at traffic speeds. This effort is being carried out as part of a NIST/TIP funded joint venture between Northeastern University, Trilion Quality Systems, the University of Vermont, and the University of Massachusetts at Lowell, and will be commercialized as part of the effort.