Summary of Final Report, BB-884
March 2002

DEVELOPMENT OF AN AUTOMATIC DETECTION SYSTEM FOR MEASURING PAVEMENT CRACK DEPTH ON FLORIDA ROADWAYS

PROBLEM STATEMENT

Since Pavement Management Systems (PMS) began to be implemented in the 1970s, one of their key components has been the pavement surface condition survey. Cracking has an adverse effect on pavement performance, which makes it an important criterion for maintenance intervention. Once initiated, cracking increases in severity and extent, and allows water to penetrate the pavement. The water, in turn, accelerates the rate of pavement deterioration. Thus, to determine the appropriate timing and expected cost of pavement maintenance, information on pavement crack condition is necessary.

Cracking data is difficult and time consuming to collect because a manual survey must be conducted. The subjective nature of the survey renders obtaining accurate, repeatable, and reproducible results difficult. However, automating the cracking survey process can result in improved safety and increased objectivity and consistency in data collection. Crack surveys are performed to characterize crack conditions in terms of type, severity, and extent. Compared with other crack characteristics, such as location, length, and width, crack depth is the most difficult one to be detected. On the other hand, the most serious problem affecting the service life of a pavement is the formation of cracks due to disruptive stresses from the original design or from unexpected chemical, physical, or mechanical loading. Thus, crack depth is a frequently used factor when reconstruction is performed on pavement surfaces. The assessment technique used to detect crack depth is vital to provide effective maintenance of pavements.

The techniques used to detect pavement cracks fall into two primary categories: destructive testing (DT) and nondestructive testing (NDT). The DT method (i.e., core sampling) is both costly and time consuming, but it continues to be the primary method utilized by state DOTs that use crack depth as a factor to evaluate pavement performance. NDT methods have significantly progressed since late 1980s, and they have been implemented on a production basis in the last four to five years. The majority of the production work to date has been performed by Roadwave Corp.'s ARAN/Wise Crax system, IMS's PAVUE system, SES's ROSAN system, and GIE's LASER VISION system. However, the main measurements of these systems only focus on crack location, crack length, and crack width. Although some systems can perform crack depth measurement, few can effectively measure the real depth of cracks that are not vertical to the pavement surface.

OBJECTIVES

The main purpose of this project was to develop an automatic system to estimate pavement crack depth on Florida roadways. Specific objectives included the following:

- to search and review the existing literature databases to identify technologies and methodologies that have the potential for automatic pavement crack depth measurement
- to perform laboratory and field experiments to further prove the feasibility of selected technologies
- to develop a prototype that can be used to measure pavement crack depth on Florida roadways.

FINDINGS AND CONCLUSIONS

To determine crack depth, two steps are needed: crack identification and crack depth estimation. At the early stage of this project, several approaches were proposed, including the following methods: static ultrasonic, dynamic ultrasonic sensor, radar sensor, ground penetrating radar. Preliminary laboratory experiments and the literature search and review suggested that these methods were not able to detect crack depth with statistically reliable accuracy or practical applicability. However, researchers determined that a combination of high-accuracy laser sensors and estimating models could produce satisfactory results.

To dynamically identify a crack, two laser sensors were used to minimize detection errors. An algorithm called Partial Cross Correlation (PCC) was developed to enhance crack detection ability. PCC was evaluated in field experiments, and its detection performance proved to be much better for identifying pavement cracks than previously studied approaches.

A key element in the automatic measurement of the crack opening geometric is the measurement of longitudinal displacement of the measuring system, for which purpose a distance sensor was employed. Field tests revealed that the sampling rate of the distance sensor affected measurement accuracy. Consequently, a scan-rate-effect-canceling model was developed, based on field experimental data and modeling results, that significantly improved the accuracy of the longitudinal displacement measurement.

With the obtained crack opening geometric characteristics and the information on the pavement section such as the average daily traffic, pavement life cycle, pavement age, and other pavement related information, researchers used a neural network model to estimate the crack depth. The database used to develop the neural network model was comprised of two parts: (1) the distance sensor reading, including the geometric characteristics of the crack, (2) data including pavement related variables. The crack information data were obtained from 95 pavement sections utilizing the system developed in the project and a static ultrasonic measuring system that can statically measure crack depth with reliable accuracy. The pavement related information data were obtained from a database provided by FDOT. Different network architectures and different training algorithms were investigated and tested during model development. Based on the tests of different model architectures, researchers established an optimal architecture.

The system, implemented and installed in a manually operated push-car, now can measure crack depth at a walking speed. The current system consists of two high-accuracy laser sensors, a longitudinal distance measuring sensor, a portable computer with an interface to communicate with the sensors, and a comprehensive model software used to estimate pavement crack depth using the readings from these sensors and the pavement section related information. The system can only be used to measure transverse crack depth since the developed neural network model was based on field data of transverse cracks. To measure longitudinal crack depth, longitudinal crack data are needed for modeling. Further, if adequate modifications are implemented to increase the sampling interval and the sampling rate by using a more powerful computer, such as an industry computer, the system could be operated at speeds of up to almost 55 mph.

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