Project Summary Report 7-3969-S
Project 7-3969 Investigation of Short-Range Sensing Devices for Use in Non-Destructive Pavement Evaluation
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PROJECT SUMMARY REPORT

Investigation of Short-Range Sensing Devices for Use in Non-Destructive Pavement Evaluation: Summary Report

Highway skid number is largely dependent on the texture of the pavement. For many years, TxDOT has used a skid truck to measure skid number directly. The skid truck is a trailer with a standard weight. During the skid measurement, the brake is applied to the trailer. This measurement is direct and accurate. However, the measurement speed is limited, and frequent traffic slowdown is inevitable.

For years, TxDOT has been pursuing alternative skid measurement methods using laser and other NDT tools such as microwave. Two major components are included in order to achieve a non-contact skid measurement. The first component is to investigate short-range sensors that are sensitive to micro and macro texture. The second is to relate the skid number to the measured data. In this project, the emphasis is on the texture sensor development. A commercial laser is expensive and measurement speed is limited to 40 – 55 miles per hour. A high speed and low-cost laser system is desired for network level skid measurement. In this project, we have investigated several texture sensing devices including a high speed and low cost laser sensor for micro and macro texture detection, and a microwave sensor for macro texture measurement.

This research has produced two prototype pavement texture measurement devices: a laser texture sensor which runs at 178 kHz allowing highway speed measurement, and a microwave macro texture sensor that is sensitive to macro texture. We have also investigated the relations between texture data with skid number. Preliminary results show that the skid number is a non-linear function of the texture parameters.

What We Did …

Development of a high speed laser texture sensor

Due to the high cost and low speed of commercial laser texture sensor, researchers in this project developed a low cost, high speed texture radar system. This system is based on laser triangulation technology. An advanced PID feedback control is used to reduce the influence of pavement surface condition on the measurement results. The developed laser texture system has been prototyped, lab tested, and field tested. Test results show that the new texture sensor is able to measure pavement textures at an accuracy of 0.02 mm at the speed of 178 kHz. The cost of the laser system is only one-third that of the commercial devices. The new laser system makes it possible to measure pavement texture at highway speed.

The laser texture sensor is composed of a laser source, optical system, laser detector, processing circuits, data acquisition, and corresponding software. The data acquisition

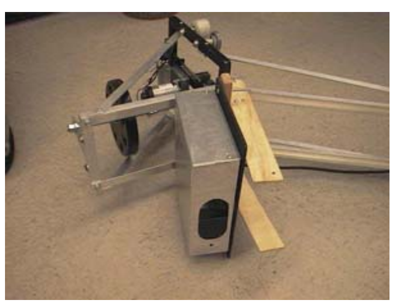

Figure 1. Laser texture sensor with mounting hardware

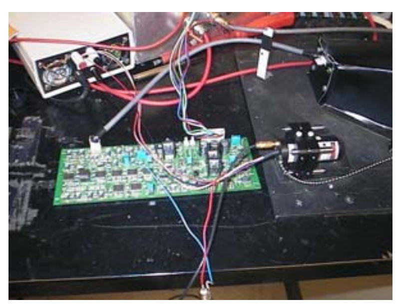

Figure 2. Circuit board under test

device is directly connected to a computer, and the measured data is stored in the computer. The processing and display software is used to process and store the measured data. Figure 1 shows a boxed laser texture sensor developed in this project. Figure 2 shows the electronic circuits of the laser sensor.

Development of microwave texture sensors

Any interface separating two media with different electric or magnetic properties will affect an electromagnetic wave incident on it. The microwave is reflected according to well-known laws: the reflected field depends on the wavelength, the angle of incidence, and the electrical properties (permittivity, permeability and conductivity) of two media.

What will happen if we apply the electromagnetic wave to the irregular or random variations of height measured from a certain mean plane surface, or simply to a rough surface? Usually, the difference in the behavior of a smooth versus a rough surface is the fact that a smooth surface (of sufficiently large dimensions) will reflect the incident wave in a single direction, while a rough surface will scatter it into various directions, though certain privileged directions may receive more energy than others (Figure 3).

The goal of our project is to develop a method to detect the texture and the dielectric constant (related to the material properties and moisture content) of the pavement surface. Since the surface roughness is on the order of millimeters, millimeter electromagnetic waves are used. We have developed an algorithm to calculate the roughness and the dielectric constant if the scattering data is available. Figure 4 is a photograph of the device used in the lab for surface texture measurement.

What We Found...

1) The development efforts were very succesful. The developed laser texture reaches an accuracy of 0.02 mm at 178 kHz. Figure 5 shows measured data at 60 miles per hour. The measured voltage is dirrectly proportional to the texture hight. The waveforms shown represent the raw data without any stacking or filtering.

2) The prototype laser texture device was field tested and found to be aplicable to the field measurement. The cost of the system is much less than the cost of similar commercial devices, which have a much lower sampling frequency than that of the device developed in this project.

3) The laser texture sensor is not sensitive to the color changes of the pavement surface. This feature makes the sensor more flexible. It can not only be applied to concrete pavement, but can also be applied to asphalt pavement without any changes in circuits.

4) The millimeter wave texture sensor is sensitive to the pavement macro texture. At 88 GHz, the detectable particle size is about 0.8 mm. The spot size of the millimeter wave is about 30 cm at a distance of 30 cm from antenna to pavement surface.

5) X band (10 GHz) radar is sensitive to pavement surface texture with particle size about 2-3 mm. If a focus dielectric lens is used, the spot size can be reduced from about 0.5 m to 20 mm. This radar is found to be sensitive to the voids and cracks under the pavement surface.

The Researchers Recommend...

- TxDOT can implement the developed laser device for network level texture measurement. More work must be done to relate the texture information measured from the laser texture sensor to the skid number.

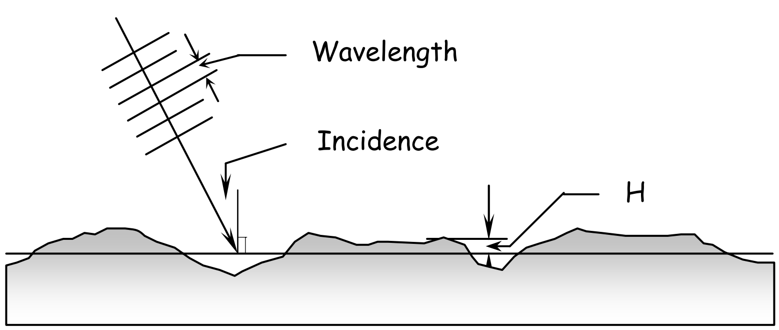

Figure 3. Microwave texture sensor schematic

Figure 4. Lab test setup for the measurement of concrete texure using a network analyzer and millimeter wave

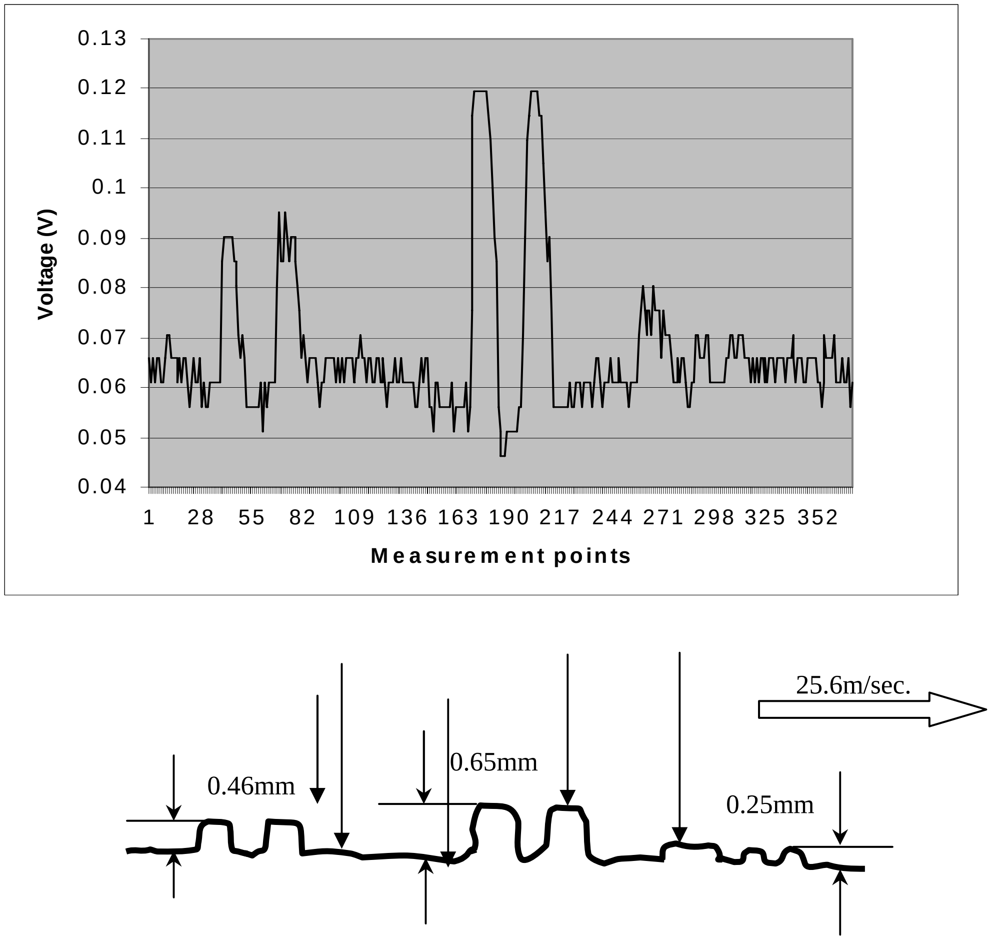

Figure 5. Measurements on different height surfaces

- To implement the texture sensor, more work must be done on the casing for the device so that it is strong enough to survive in all field conditions.
- More research must be done to make the microwave sensor practical. The microwave texture sensor is sensitive to the surface texture but measures only the macro texture. On the other hand, the laser texture sensor is sensitive to micro texture. Combining the data from both the laser and microwave texture sensors will result in reliable information to be used in the computation of skid number.
- The standoff distance of the laser should be increased to at least 15 cm to avoid the laser being damaged during field applications.
- Integration of the data acquisition and control computer with the laser elelctronics is necessary for practical measurement.
- Data acquisition and system control should be performed via Internet to simplify the field operation.

For More Details...

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TxDOT IMPLEMENTATION STATUS
October 2001

The 178 kHz laser developed under this research project is being implemented on a pilot basis through an implementation project, IPR 5-3969. This IPR covers the construction of five units to measure texture with this laser. Validation of the correlation between Skid Numbers and texture measurements is also included in this IPR. The other devices developed under this project may be used in the future for identification of segregation in asphalt mixtures. The Construction Division is the Office of Primary Responsibility (OPR) of this project.

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation and the U. S. Department of Transportation, Federal Highway Administration. The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TXDOT. This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. Trade names were used solely for information and not for product endorsement. The engineer in charge was Dr. Richard C. Liu.