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IMPROVED ROADWAY SUBSURFACE THICKNESS MEASUREMENTS AND ANOMALY IDENTIFICATION WITH GROUND PENETRATING RADAR (GPR)

PROBLEM STATEMENT

The Florida Department of Transportation (FDOT) and other DOTs have for some time recognized significant potential advantages of ground penetrating radar for nondestructive subsurface road measurement. These potential advantages include the ability of GPR to measure the thickness of thin overlays and subsurface layers, the reduction or elimination of destructive coring, and the identification of certain subsurface anomalies that may cause road surface failures. The result is significant potential cost savings through fewer corings, less road down-time, more accurate road inspections, and more informed maintenance and repair decisions.

The potential utility of GPR for roadway measurement has been only partially realized for both project and network level applications. Utility is limited as a result of the large quantity of data collected by the GPR for longer road sections, the significant amount of required operator interaction and interpretation, and the vast amount of required signal processing. These limitations have tended to make GPR under-utilized even in cases where adequate measurement accuracies have been possible.

OBJECTIVES

The overall goal of this project was to improve the accuracy of subsurface thickness measurements, anomaly identification, and techniques used to reduce operator interaction in GPR data collection and processing. Specific objectives included the following:

1. Establish a working multiple antenna GPR system using the current FDOT radar vehicle.

2. Obtain GPR data with accurate ground truthing using the implemented multiple antenna hardware.

3. Develop signal processing algorithms that fuse the data from the multiple antenna systems.

4. Develop signal processing algorithms to integrate the fused data into existing roadway GPR software for analysis.

5. Achieve signal processing capabilities on board the current FDOT radar vehicle to allow for in-the-field measurements and analysis of both roadway and geophysical GPR data.

6. Establish tests to verify the operation of the designs and to investigate techniques for thickness measurement, monitoring of void content, and anomaly identification.

FINDINGS AND CONCLUSIONS

This project resulted in a multi-system roadway analysis system, improved in-the-field data analysis capabilities, and an enhanced GPR evaluation software tool that organizes and processes multi-system GPR data for improved thickness measurements and roadway analysis capabilities. The operation of a dual-antenna, time-based processing scheme was verified for a range of depths and dielectric constant values. Results show high accuracy and low error variance. Timing problems in the ground-penetrating radar system have, however, been isolated as a considerable source of error in measurements. This critical issue and "radar board failure" errors experienced during the collection of verification data may indicate system problems that must be addressed by FDOT before the dual-antenna configuration will be capable of functioning to full capacity.

A limiting factor encountered in roadway analysis involves the radar resolution and the very thin layers sometimes found at the bottom of roadway cores. Radar resolution is limited by its bandwidth. This project has increased the bandwidth of the radar system with the addition of higher frequency antennas, which has improved the resolution of the system. However, layers on the order of approximately 1.5" and smaller, as seen in some collections, are not resolvable using the current system. Newer "super-resolution" algorithms are being researched throughout the scientific community. These algorithms hope to improve detectable resolution beyond that achievable using matched filter techniques for a given system bandwidth. Although application of such algorithms could constitute a separate study, modest attempts were made to utilize primitive super-resolution processing methods to improve GPR detection resolution. Development of super-resolution algorithms was not within the scope of the development of a total working implementation of the dual-antenna, multiple-radar system under this project, and the utility of such algorithms has yet to be determined. Matched filter techniques currently produce the best results.

Collection and processing speed limitations for the multiple system configuration place emphasis on project level roadway analysis. The outputs of the software include time location, depths, and dielectric constants to layer interfaces, in addition to various other subsurface characteristic indicators. This type of information can be of significant use to operators who assess the nature of subsurface pavement anomalies and potential problem areas.

The new GPR data collection configuration and the GPR software and analysis tool will improve FDOT capabilities for the non-destructive evaluation of potentially serious roadway problems—primarily at the project level so that they can be corrected before becoming costly. The software environment will also aid in future road design and improvement by providing a method for the rapid, non-invasive measurement of new subsurface roadway designs.

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