PROJECT SUMMARY REPORT

Subsurface Sensing Lab
University of Houston

**SUBSURFACE SENSING LAB**
**UNIVERSITY OF HOUSTON**

Project Summary Report 0-4414-S
Project 0-4414 Development of a Thickness Measurement Device for Steel Reinforced Concrete Pavement

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# Development of Thickness Measurement Device for Steel Reinforced Concrete Pavement: Summary Report

Research Project 0-4172 "Development of a Thickness Measurement Device for Steel Reinforced Concrete Pavement" provided a rudimentary radar system that was able to measure concrete pavement thickness, for pavement without steel reinforcement, up to 18 inches. In this project, the GPR system developed in Project 0-4172 is further improved to measure concrete thickness with steel reinforcement. A prototype GPR system was manufactured and an efficient thickness computation algorithm is implemented. The developed GPR thickness measurement system was both lab-and field-tested. This GPR system is mounted on a pushcart for easy operation. There are two display screens mounted on the GPR: one displays the GPR traces in color map formats and the other displays thickness and distance in text format. Field tests were done on the construction site of US Highway 59 south in the Sugarland area. Field test results showed that the GPR is able to measure the thickness of steel reinforced concrete up to 16 inches with an average error of 2%. Additionally, the location and diameter of the steel rebar can be obtained. This system also measures the dielectric constant of the concrete automatically. The dielectric constant may be useful in estimating concrete maturity.

## *What We Did …*

The GPR system developed in this project is shown in Figure 1 and Figure 2. Inside the box shown in the figures, there is a transmitter, transmitter antenna, receiver, receiver antenna, control circuits, and power supplies. The system is powered by single rechargeable battery (5"x2.5"x2.5"). The power consumption is about 6 watts. The output signal is digitized and displayed on a notebook computer external to the GPR system.

In order to obtain more accurate measurement of the pavement thickness in the presence of steel rebars, both the hardware and software of the GPR system have been greatly improved in this research. The hardware and software improvements are as follows:

### (1) Increasing GPR's Sampling Point

In this project, the sampling circuits are modified in order to increase the spatial resolution. The original 256 sampling point is increased to 512 data points by completely redesigning the sampling circuit and time-delay circuit.

### (2) Reducing Direct Couplings

To cut off the paths of direct couplings, all the wires including the common ground lines, power-supply cables and trigger cables, should be shielded from passing high-frequency currents. It was found that ferrite materials are especially effective in suppressing high-frequency currents on wires.

### (3) Increasing Dynamic Range

The larger the dynamic range is, the higher the resolution the radar can obtain. However, the dynamic range depends on the properties of the electronic components applied and the design of the circuits. In this research, the dynamic range has been improved to +/-5V from the original +/-2.5V.

### (4) Distance Measurements

In order to make the thickness measurement and the position recording

Figure 1. The finalized GPR thickness measurement system

Figure 2. Field test of the developed thickness radar over new pavement with steel rebar (Picture taken by Ed Oshinsky).

simultaneous and automatic, a distance-measurement device is provided based on an optical shaft encoder.

### (5) LCD Display

Though the computer monitor is a good device for displaying measured radar data, it is power-consuming and not bright enough under strong sunlight. Hence LCD was developed as an alternative displaying device.

### (6) Using the Short Time Fourier Transform (STFT) to extract the Reflected Signal

The improvements on hardware significantly increased the signal-to-noise ratio of the radar data. However, there is always a part of the direct wave (feed-through wave from the transmitting antenna to the receiving antenna) arriving at the receiving antenna at the same time as the subsurface reflections. The signals picked up by the receiving antenna are actually a superposition of the direct wave and the subsurface reflected wave. Since the direct wave has much larger amplitude than the reflected wave, special software is needed to extract the reflected wave from the received signal. In this project, STFT is applied to process the measured signals.

## *What We Found…*

The electromagnetic response from the rebar-reinforced pavement is quite different from that of plain pavements, because electromagnetic waves are more sensitive to the metal rebar than to the underground dielectric interfaces.

Figure 3 is a multi-trace chart that was measured on US Highway 59 near Sugarland while the pavement was under

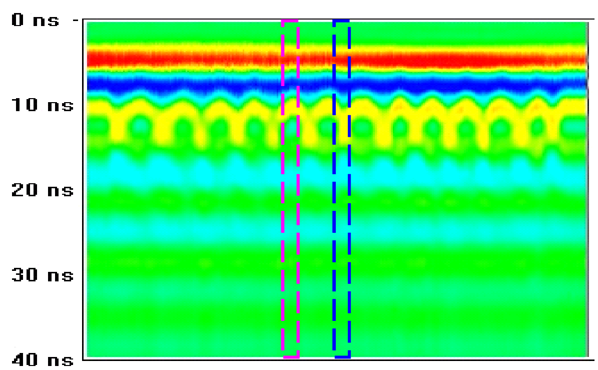


Figure 3 Multi-trace chart on highway pavement

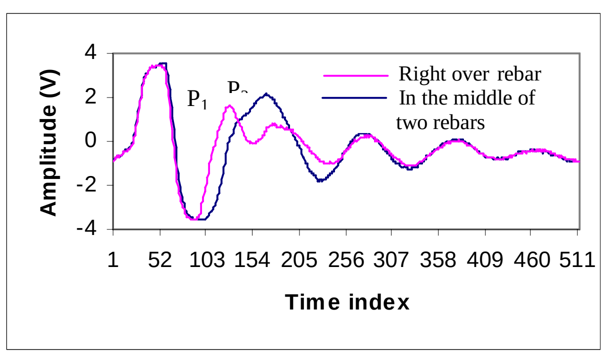


Figure 4 Traces measured over and off the rebar

construction. This chart contains three-dimensional information. The color represents the signal amplitude, the horizontal axis denotes a trace index that relates to the distance of radar movement, and the vertical axis is the travel time of the GPR waves going down and coming back.

The traces are displayed in Figure 3 from left to right according to the time order of the trace acquisition. The color pattern in the above chart changes periodically, which corresponds to the subsurface structures. By eye (visually) observing from the side trans-section of the pavement, the traces inside the red rectangle in Figure 3 are recorded while the radar is over a rebar. The traces inside the blue rectangle are recorded at the middle of two transverse rebars. Figure 4 gives two typical traces selected from Figure 3, one from the red-line-rectangle area and the other from the blue-line-rectangle area.

When the radar scans over the pavement, the second largest peak of each graph in Figure 4 swings between $P_1$ and $P_2$. The arrival time of rebar reflection and the bottom reflection can be found by the STFT technique.

In January 2002, a field test was carried out on US Highway 59 at Williams Trace in Sugarland. During the measurement, the project director and university research supervisor were invited for the field test. Figure 2 shows the field condition. The pavement is a continuously reinforced concrete pavement (CRCP).

Besides the researchers, the project director (Dr. Moon Won), the program coordinator (Ed Oshinsky), and Dr. German Claros participated in the field test. The field test was done on February 7, 2002, on US Highway 59 North at Williams Trace Boulevard in Sugarland, Texas. The pavement thickness is an 11-inch CRCP. GPR thickness measurement was conducted at the same time with a ruler measurement. In Figure 2, Dr. Claros measures the pavement thickness using a ruler.

This section of pavement was newly constructed and we were able to measure the thickness using a ruler at the side of the road.

During the test, the GPR on the pavement measures a thickness at a point and stores the data. This process is automatic and does not need the operator to input any prior knowledge of the pavement. At the same spot, Dr. Claros measured a thickness using a ruler at the side of the road (as shown in Figure 2).

Table 1 shows statistical data for this test.

## *The Researchers Recommend…*

- This thickness measurement radar can be easily implemented for TxDOT's routine pavement thickness monitoring. The cost of this system is very low (less than $10k each unit). The researchers strongly recommend that TxDOT implement several of these radar units to replace thickness measurement by coring every 1000 feet.
- The researchers also recommend that TxDOT investigate implementing similar units for vehicle-mount thickness measurement. In this way, network-level thickness information can be obtained.
- The network-level thickness information can be input into PMIS for TxDOT engineers to use in pavement design and maintenance.
- Similar technology can also be applied to measure asphalt pavement for thickness measurement. Since asphalt pavement is easier to be penetrated by radar waves, multi-layer thickness information can be obtained. Research in this area is recommended.
- We also recommend further development of the automatic thickness computation algorithm so that it can be applied to multi-layer cases.
- The thickness radar also extracts the dielectric constant of the concrete. Therefore, the moisture content of the pavement can be obtained because of the strong dependence of the dielectric constant on the moisture content of the pavement. Currently, this information is not being used. Further study of the relationship between the moisture content in concrete and the dielectric constant is recommended.

Table 1 Average measurement errors by GPR

| Average thickness by GPR | Average Thickness by ruler | Average difference | Relative average error |
|---|---|---|---|
| 10.82181818 | 10.60727273 | 0.214545455 | 2.0226% |

## For More Details…


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## TxDOT IMPLEMENTATION STATUS DECEMBER 2005

A pilot implementation project, 5-4414 has been completed with implementation of 3 devices.

For more information, please contact Dr. German Claros, P. E., Reasearch and Technology Implementation Office, (512) 465-7403 or email: gclaros@dot.state.tx.us.

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