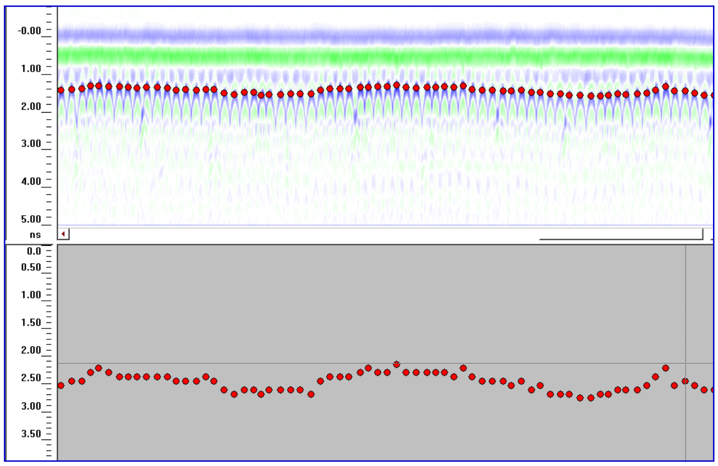
CONCRETE COVER DETERMINATION USING GROUND PENETRATING RADAR (GPR)



PRIORITY TECHNOLOGY PROGRAM Project No. NH1997-01

STATE OF NEW HAMPSHIRE
DEPARTMENT OF TRANSPORTATION
BUREAU OF MATERIALS & RESEARCH

Final Report
August, 1999

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16. Abstract

Since 1992, the New Hampshire Department of Transportation (NHDOT) has utilized a QC/QA specification for construction of new reinforced-concrete bridge decks. Under this specification, the Contractor's payment is based on certain measured attributes, including the depth to reinforcing steel (concrete cover). Originally, the Department utilized a limited-production device known as a rolling pachometer to measure the concrete cover. When this instrument was no longer serviceable, a need arose to find a suitable replacement device.

Ground penetrating radar (GPR) was identified as a potential measuring device for concrete cover. The Department partnered with Geophysical Survey Systems, Inc. of Salem, NH to develop a ground-coupled radar device for this use. To evaluate the effectiveness, accuracy and precision of the unit, the NHDOT collected GPR data from 53 locations at 12 sites and compared it to actual measurements obtained by drilling into the decks. After technicians gained experience using the device, all GPR predictions were accurate to within 3 mm of actual measured depths. The mean deviation between predicted and measured values was 1.95 mm for the study. The GPR data correlated with the actual measured depths with a correlation coefficient of 0.98 and a standard error of estimate of 2.2 mm. Multiple runs with the GPR device produced a maximum standard deviation of 2.15 mm. The Department believes that these data support the use of GPR for measuring concrete cover, and has implemented the technology through its QC/QA specification for concrete bridge decks.

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STANDARD CONVERSION TABLE - ENGLISH TO METRIC				
Symbol	To convert from	Multiply by	To determine	Symbol
		LENGTH		
IN	inch	25.4	millimeters	mm
FT	feet	0.3048	meters	m
YD	yards	0.9144	meters	m
MI	miles	1.609344	kilometers	km
		AREA		
SI	square inches	645.16	square millimeters	mm^2
SF	square feet	0.09290304	square meters	m^2
SY	square yards	0.83612736	square meters	m^2
A	acres	0.4046856	hectares	ha
MI^2	square miles	2.59	square kilometers	km^2
		VOLUME		
CI	cubic inches	16.387064	cubic centimeters	cm^3
CF	cubic feet	0.0283168	cubic meters	m^3
CY	cubic yards	0.764555	cubic meters	m^3
GAL	gallons	3.78541	liters	L
OZ	fluid ounces	0.0295735	liters	L
MBM	thousand board feet	2.35974	cubic meters	m^3
		MASS		
LB	pounds	0.4535924	kilograms	kg
TON	short tons (2000 lbs)	0.9071848	metric tonnes	t
		PRESSURE AND STRESS		
PSF	pounds per square foot	47.8803	pascals	Pa
PSI	pounds per square inch	6.89476	kilopascals	kPa
PSI	pounds per square inch	0.00689476	megapascals	MPa
		DISCHARGE		
CFS	cubic feet per second	0.02831	cubic meters per second	m^3/s
		VELOCITY		
FT/SEC	feet per second	0.3048	meters per second	m/s
		INTENSITY		
IN/HR	inch per hour	25.4	millimeters per hour	mm/hr
		FORCE		
LB	pound (force)	4.448222	newtons	N
		POWER		
HP	horsepower	746.0	watts	W
		TEMPERATURE		
°F	degrees Fahrenheit	5 X (°F - 32)/9	degrees Celsius	°C
		DENSITY		
lb/ft^3	pounds per cubic foot	16.01846	kilograms per cubic meter	kg/m^3
		ACCELERATION		
g	freefall,standard	9.807	meters per second squared	m/s^2

TO CONVERT FROM METRIC TO ENGLISH, DIVIDE BY THE ABOVE CONVERSION FACTORS.

CONCRETE COVER DETERMINATION USING GROUND PENETRATING RADAR (GPR)

By:

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Prepared in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

PRIORITY TECHNOLOGY PROGRAM Project No. NH1997-01

STATE OF NEW HAMPSHIRE
DEPARTMENT OF TRANSPORTATION
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CONCRETE COVER DETERMINATION USING GROUND PENETRATING RADAR (GPR)

I. Introduction

Section 6005 of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 established "an applied research and technology program for the purpose of accelerating testing, evaluation, and implementation of technologies which are designed to improve the durability, efficiency, environmental impact, productivity, and safety of highway, transit, and intermodal transportation systems." The Priority Technology Program (PTP) is one element used to implement this section of ISTEA. This report summarizes a PTP study in which the New Hampshire Department of Transportation (NHDOT) evaluated ground-penetrating radar (GPR) for measuring concrete cover on bridge decks.

II. Background

In 1992, NHDOT began implementation of a performance-based, quality control/quality assurance (QC/QA) specification for concrete bridge decks. By 1995, all NHDOT bridge decks were constructed under this specification. The specification includes provisions for measuring selected attributes affecting the durability and serviceability of the structure. The Contractor's payment is subject to bonus or penalty adjustments based on the measured quality of the deck.

The concrete cover over the deck's upper reinforcing mat is one of the measured attributes in the specification. Adequate concrete cover is essential in protecting the reinforcing steel from the adverse effects of environment, de-icing chemicals and traffic. Excessive cover is wasteful and can create problems as well, such as increased dead load and problems associated with finished grades.

Traditionally, depth to reinforcing steel has been measured by coring or drilling into the concrete, or by utilization of an instrument known as a *pachometer*. This device is a calibrated metal detector that examines embedded steel reinforcement by changes in electric inductance of the ferromagnetic material. NHDOT utilized a James Instruments *rolling pachometer*, manufactured in the mid-1970's, to measure concrete cover prior to 1996. However, the Department began to experience problems with the reliability of the instrument, reducing its effectiveness to unacceptable levels for use in a QC/QA specification. Because the limited-production rolling pachometer was no longer manufactured and parts were unavailable, NHDOT was faced with finding a suitable replacement device. An interim pay factor of 1.0 (i.e. no bonus nor penalty) was assigned to the concrete cover portion of the specification at that time.

The Department evaluated a number of handheld pachometers in 1996 and 1997. The precision and bias of these instruments was not acceptable for the required use and they were therefore eliminated from further consideration. During this investigation, ground-penetrating radar (GPR) emerged as an innovative and potentially effective replacement tool for measuring concrete cover. NHDOT's willingness to pursue GPR technology for use with the QC/QA specification was enhanced by its positive experience with GPR for determining repair quantities on existing bridges and for measuring pavement thickness in the early 1990's.

III. Objectives

The objectives of this study were to determine the effectiveness, accuracy and repeatability of ground penetrating radar for determining concrete cover on new bridge decks. It was hoped that the study would validate the use of radar as a measuring tool for the Department's QC/QA specification for concrete bridge decks and that future measurements could be used to compute pay factors on associated projects. Successful implementation of this technology would provide benefits to the transportation community by promoting quality, reducing variability of test results, and minimizing field data acquisition time.

IV. SIR® System-2 Ground Penetrating Radar

Geophysical Survey Systems, Inc. (GSSI), of Salem, NH is a leading manufacturer of ground penetrating radar. GSSI's Subsurface Interface Radar (SIR®) systems are used worldwide for a broad range of applications in mining and civil engineering, and have proven to be effective in archaeological, geological and hydrogeological investigations. In addition to locating and identifying underground objects, a number of prior field tests had been performed to locate and measure objects embedded near the surface in concrete.

Around the time NHDOT was seeking a new concrete cover measuring device, GSSI was working with the Department to evaluate the condition of several existing bridge decks using GPR. Preliminary discussions indicated that it would be feasible for GSSI to develop a new data processing module to meet NHDOT's concrete cover needs using their existing hardware and software shells. GSSI began to work informally with the Department to develop its GPR technology for this use. As NHDOT pursued funding through the Priority Technology Program, GSSI agreed to contribute system development costs for the proposed application.

Upon award of the PTP grant, NHDOT purchased a SIR® System-2 ground-coupled radar system from GSSI with a Model 5100, 1.5 GHz center frequency antenna (Figure 1). The SIR® System-2 radar device is a low power GPR system that transmits electromagnetic energy in the form of radio waves into the concrete subsurface. The antenna is mounted in an enclosure on a bracket attached to a fiberglass tube with a handle to allow the operator to walk while collecting data. A distance encoder attached to the mounting bracket provides distance-based scan control. Data are obtained at a density of 80 scans per meter. Reflections occur in the subsurface at boundaries of dielectric contrast. A receiver in the antenna detects the returning signal and sends it to a control unit, which processes and displays the signal as a graph of amplitude versus time. The waveforms from a series of pulses can be "stacked" to display a plot of time versus distance along a particular run made by the radar device. The integrated software of NHDOT's system then provides a depth of concrete cover for each reinforcing bar surveyed.

Figure 1 - SIR® System-2 GPR w/1.5 GHz Antenna

The purchase price of the SIR® System-2 was approximately $34,000. In addition, a laptop to facilitate field manipulation of data and computation of pay factors was purchased with accessories for approximately $7,000. NHDOT took possession of the radar equipment during the Fall of 1997. With the assistance of GSSI, personnel from the NHDOT Bureau of Materials and Research familiarized themselves with the equipment. The radar was generally easy to use, and technicians were quickly able to master its operation.

While the control unit can be attached to the body with a harness as shown in Figure 1, operators soon determined that it was more practical to leave the unit on the deck and utilize the system's 30 meter control cable (Figure 2).

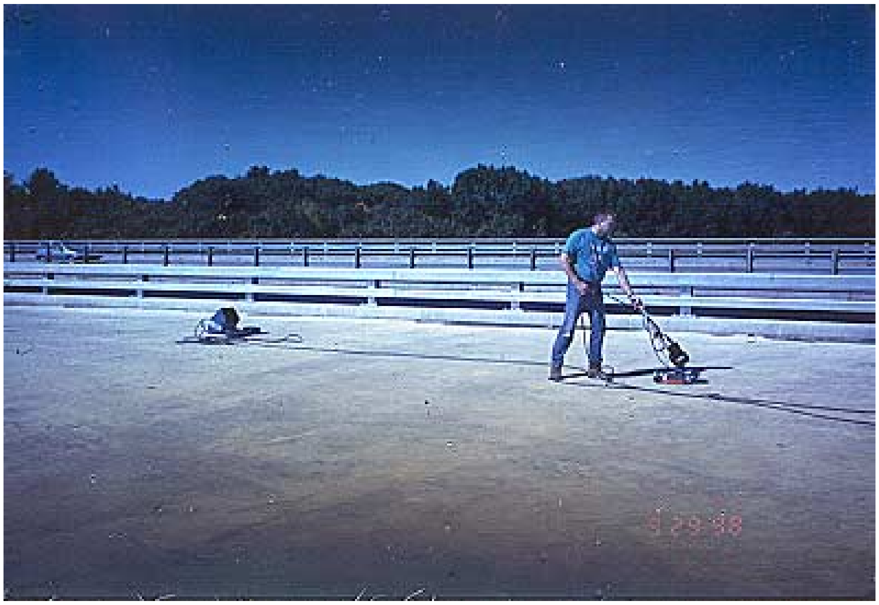

Figure 2 - Data Collection

A description of the data collection procedure established for the GPR follows:

A. Layout reference lines on the deck surface.
   1. Per specification, one run is made per lane per lot of concrete, avoiding girders and crowns. A lot is normally a single placement.

B. Turn on SIR® System-2.
   1. Set up header.
   2. Check for signal.
   3. Adjust "gain" or scale of signal.

C. Acclimate device to ambient conditions for 30 minutes.
   1. Prepare sketch of testing pattern
   2. Mark calibration hole

D. Collect data
   1. Mark "events" such as location of piers, visible change in concrete, calibration hole location, etc.

E. Drill calibration hole and measure depth to reinforcing steel. The purpose of the calibration hole is to calculate the propagation velocity in the concrete (see G.1 below).

F. Download data into laptop computer.

G. Process data.

1. Input velocity of signal through concrete or input calibration hole depth at corresponding distance (preferred).
2. Output cover over each bar, mean, and standard deviation.

H. Calculate pay factor.

1. Input mean and standard deviation of cover measurements.
2. Calculate upper and lower quality indices.
3. Calculate percent within limits.
4. Calculate pay adjustment. Concrete cover currently makes up 40% of the *composite* pay factor (along with water/cement ratio and percent air).

Figure 3 represents processed data from a new bridge deck surface. In the top panel, red circles overlay the reinforcing steel reflection picks. The picks are located automatically by the system software through an algorithm that searches for the peak of each hyperbolic reflection in the data. In the bottom panel, horizontal position and depth to top of rebar are displayed with the results output to ASCII database.

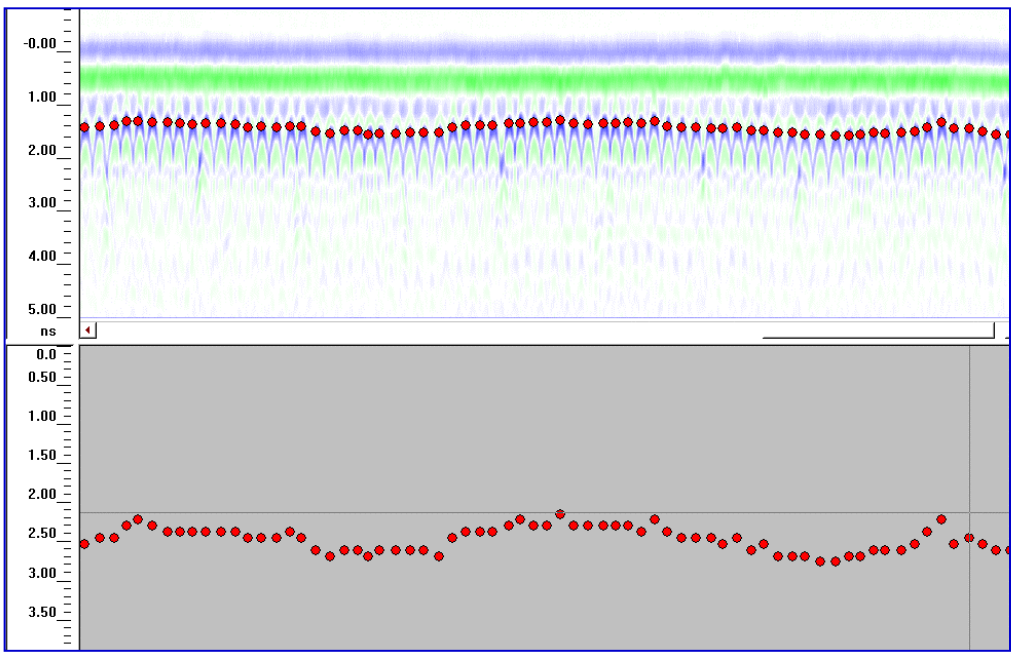

Figure 3 - Processed GPR Data from New Bridge Deck Surface

V. Control Devices

For comparison purposes, two types of control were utilized during this study. The first control consisted of two different commercially available portable pachometers. As discussed earlier, NHDOT had not been successful in its earlier attempts to identify such a device capable of providing measurements with the accuracy and precision needed for use with the QC/QA specification. Other pachometers were later identified. The Rebar Datascan, manufactured by James Instruments, Inc. was selected for comparison to the GPR device because it had the features considered essential for the required use. These features included the ability to measure in either English or metric units, the use of a single sensor head or probe, and the ability to store up to 1000 data points which later could be downloaded to a PC. The device includes a separate control box with a liquid crystal display and weighs less than 5 kg. Scanning is enhanced by an audible output and the analog meter on the probe. The manufacturer literature claimed a measurement range accuracy of between 2 and 5 percent, depending on the depth of the reinforcing steel and the size of the bar. The instrument was purchased at a cost of approximately $2,600.

During the study, the Rebar Datascan was found to be impractical for the required use. When the meter was in test mode, it displayed a number five digits long. This in itself was not a problem; however, even when the probe was moved across the surface very slowly, the last two digits changed so rapidly that the probe had to be stopped before a reading could be taken. Several stop and start attempts were required to find the top of the reinforcing bar, adding time to the process. Another drawback involved the 178 mm (7 in.) probe length. Most transverse bar spacing is designed to be 150 mm (6 in.); therefore, when attempting to locate longitudinal bars, the probe was always affected to some degree by the transverse bars. This resulted in inconsistent readings over the longitudinal bars. Furthermore, there are no lines or markings to indicate the exact reading location across the 64 mm (2.5 in.) probe width.

A Micro-Covermeter, manufactured by ELE/Soiltest, was also purchased during the study. A nearly identical device had been obtained on loan from the Federal Highway Administration in 1994 following participation in FHWA's Demonstration Project DP-84. NHDOT technicians were therefore very familiar with the instrument. Although the device was used primarily for *locating* rebar prior to coring, it had also shown some ability in measuring concrete cover depths. The Micro-Covermeter utilizes two different probes, depending on the depth of the reinforcing steel, and is available at a cost of approximately $2,900.

By comparison to the Rebar Datascan described above, the Micro-Covermeter's three digit display is easily read while moving the probe along the concrete surface. The device is also more effective at locating the edge and center of the rebar. The majority of pachometer data collected during this study were collected by one or both of the Micro-Covermeters.

The second type of control utilized for the study consisted of direct concrete cover measurements. These measurements were made by drilling or coring down to the top of the reinforcing steel and measuring the actual depth of cover. While this is the most direct measurement, it must be noted that some degree of variability is inherent even with this process. Potential variability is associated with the concrete surface texture, deformations on the reinforcing steel, damage to the reinforcing steel during drilling, precision of the measuring ruler, human error, and other factors. However, when due care is taken, it is believed that these direct measurements are a proper control for evaluation of the pachometers and the GPR device. For the remainder of this report, these measurements will be referred to as the "actual" depth.

VI. Testing Program and Results

The testing program utilized by NHDOT during this evaluation is summarized as follows:

- Data were collected on new bridge decks using GPR and compared to actual concrete cover depths. Data from the pachometers were collected at selected sites.
- Multiple sites and various concrete mixes were used.
- All decks were constructed under the Department's QC/QA specification for concrete bridge decks.
- Radar data were collected with assistance from the manufacturer to insure correct operational procedures. Prior to delivery of the NHDOT device, a SIR® System-2/ Model 5100 system

owned by GSSI was utilized along with the prototype data processing module developed for the project.

- Results were compared and correlated.
- An assessment was made of the accuracy and precision of the GPR device and the traditional pachometers.

Data were collected from 53 test locations at 12 sites. Table 1 includes early test results from six locations surveyed at a site in Exeter. Multiple GPR measurements were obtained to evaluate the repeatability (precision) of the device. The difference between actual measurements and GPR predictions was also computed. Mean GPR results were within 3.1 mm (1/8 inch) of the actual measured depths. The maximum difference between a single GPR measurement and an actual measured depth was 5.1 mm (7/32 inch).

Location #	Actual Depth, mm	GPR Prediction, mm (3 runs)	Mean GPR Prediction, mm (Std. Deviation, mm)	Difference between Actual Depth & Mean GPR Prediction, mm	Maximum Difference between Actual Depth & Single GPR Prediction (Absolute), mm
1	63.5	59.9, 61.9, 59.9	60.6	2.9	3.6
			(1.17)		
2	58.6	57.9, 59.9, 60.9	59.6	-1.0	2.3
			(1.55)		
3	69.8	71.1, 72.8, 74.9	72.9	-3.1	5.1
			(1.90)		
4	58.6	56.9, 56.9, 57.9	57.2	1.4	1.8
			(0.59)		
5	73.0	72.8, 71.8, 70.1	71.6	1.4	2.9
			(1.41)		
6	66.6	62.9, 65.0, 62.9	63.6	3.0	3.7
			(1.17)		

Table 1. Exeter, NH Route 101 over Little River, 1997

Table 2 includes test results from a bridge in Brentwood. At this location, only one set of GPR measurements was made, along with measurements from both pachometers. GPR predictions were within 2.8 mm (1/8 inch) at all locations. Pachometer readings varied by as much as 12 mm (1/2 inch). In general, pachometer readings tended to over-predict the concrete cover, especially where the reinforcing steel was relatively deep.

Location #	Actual Depth, mm	GPR Prediction, mm	Pachometer #1 Depth, mm	Pachometer #2 Depth, mm
1	50.8	48.0 (2.8)	49.5 (1.3)	49.5 (1.3)
2	79.4	79.9 (0.5)	91.4 (12.0)	86.3 (6.9)
3	69.8	71.8 (2.0)	76.1 (6.3)	72.3 (2.5)
4	68.3	69.0 (0.7)	-	77.4 (9.1)
5	67.5	66.0 (1.5)	-	66.0 (1.5)
		Values in parenthesis indicate the (absolute) difference from actual depths.		

Table 2. Brentwood, NH Route 101 over Pine Road, 1997

With increased technician experience, both the accuracy and precision of the GPR device improved during the study. All GPR predictions evaluated during the 1998 and early 1999 seasons were accurate to within 3 mm of the actual measured depth. At one site in Lebanon, the GPR survey revealed that the concrete cover was significantly below the limits of the specification. The contractor disputed the output, which indicated that cover depths were as low as 11 mm (7/16 inch). An NHDOT technician, with a single blow from a hammer and chisel, exposed the reinforcing steel at precisely the depth predicted by the GPR. The repeatability of the GPR prediction was also tested under actual construction conditions as illustrated in Table 3, which contains data from a deck in Hanover. At this site, the contractor also challenged the survey results obtained with the GPR. For each sublot, an overall mean and standard deviation for bar depth is shown, which would then be input into the equation contained in the specification to calculate the price adjustment. The right column shows the results from a repeated survey, which ended the dispute.

	RUN 1 Mean Bar Depth, mm (Standard Deviation)	RUN 2 Mean Bar Depth, mm (Standard Deviation)
Sublot 1	73.6 (6.6)	73.6 (6.4)
Sublot 2	72.3 (8.7)	72.1 (8.7)
Sublot 3	82.7 (7.2)	82.7 (6.9)

Table 3 - Hanover-Norwich, NH Route 10A over Connecticut River, 1998

Figure 4 represents a scatterplot of GPR predictions versus actual measured depths collected at all sites during the study. A best fit straight line regression analysis was performed on the data, producing a correlation coefficient of 0.98 and a standard error of estimate of 2.2 mm (0.09 in).

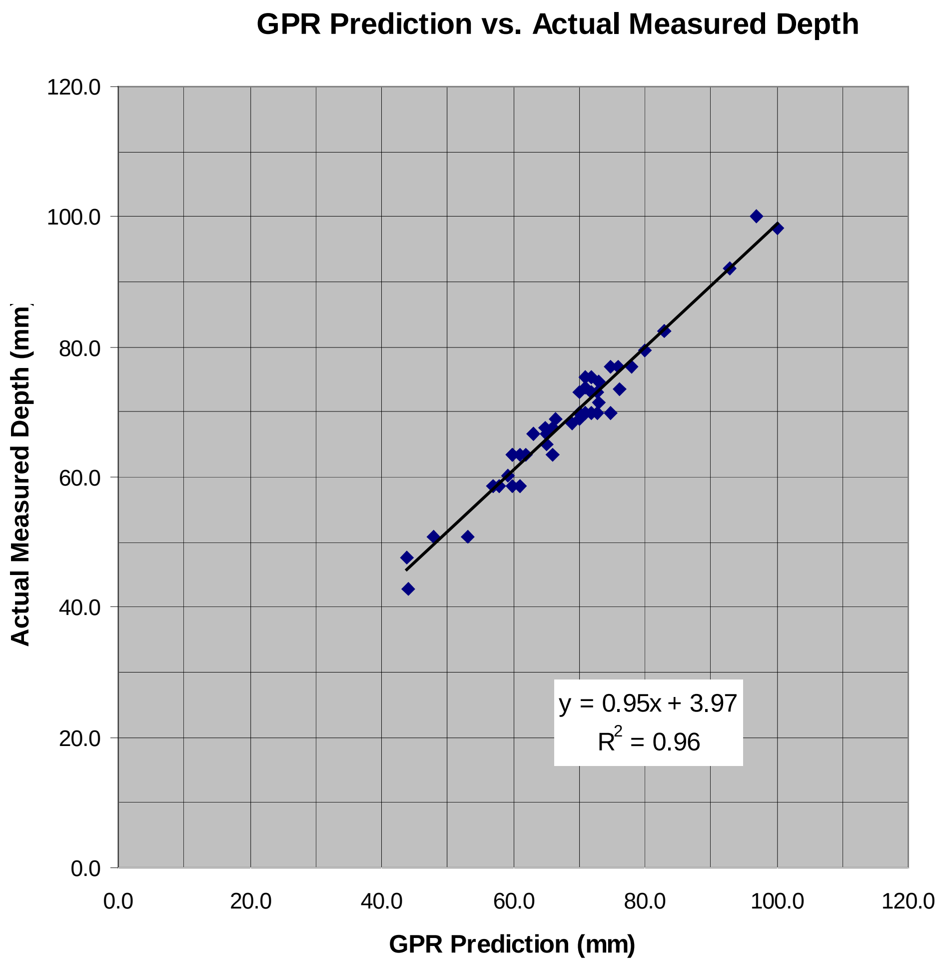

Figure 4 - Comparison of GPR Predictions versus Actual Measured Depth (53 test locations at 12 sites)

Figure 5 represents a scatterplot of pachometer data versus actual measured depths collected during the study. A best fit straight line regression analysis was performed on the data, producing a correlation coefficient of 0.85 and a standard error of estimate of 5.3 mm (0.21 in).

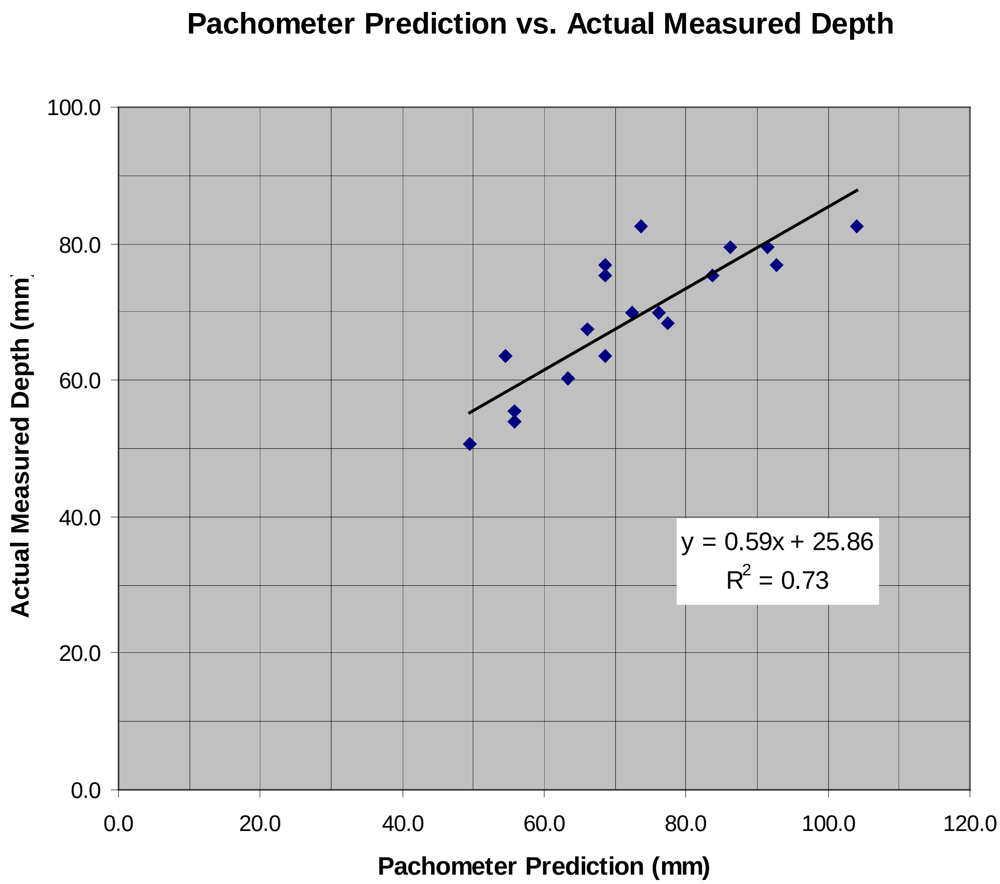

Figure 5 - Comparison of Pachometer Predictions versus Actual Measured Depth

Reliability issues surfaced during the evaluation of the pachometers, as devices were susceptible to lock-up and occasional inoperability. In addition, multiple pachometer measurements at the same location sometimes produced widely varying results.

VII. Conclusions and Recommendations

1. Commercially available magnetic rebar locators (pachometers) are portable and relatively inexpensive. Convenience and practical features vary significantly between models. The importance of these features is influenced by the desired use. Evaluated devices lacked the necessary accuracy, precision, and reliability for use with a QC/QA specification.

2. Individual Ground Penetrating Radar (GPR) predictions were accurate in all cases to within 5.1 mm of actual measured cover depths. With increased technician experience, the recorded accuracy later in the study was reduced to within 3 mm. The mean deviation between individual GPR predicted values and actual measured depths was 1.95 mm for the study.

3. “Actual” measured cover depths can be variable due to concrete surface texture, deformations on the reinforcing steel, damage to the reinforcing steel during drilling, precision of the measuring ruler, human error and other factors.

4. Multiple runs with the GPR device produced a maximum standard deviation of 2.15 mm. The repeatability (precision) of GPR test results also improved with increased technician experience.

5. The SIR® System-2 radar system utilized during this study is easy to use and was quickly mastered by NHDOT technicians. Data acquisition time is considered reasonable for the intended use.

6. GPR predictions correlated to the actual measured cover depths with a correlation coefficient of 0.98 and a standard error of estimate of 2.2 mm. These statistics support the use of GPR for implementation of the Department’s QC/QA specification for concrete bridge decks. By comparison, pachometer predictions correlated to actual measured cover depths with a correlation coefficient of 0.85 and a standard error of estimate of 5.3 mm.

7. The Department’s QC/QA specification was easily adapted to the use of GPR as a concrete cover measuring device. The Department has now fully implemented this technology.

8. The design value for concrete cover on bridge decks included in this study was 63.5 mm (2.5 in). Actual measurements varied between 42.9 mm (1.7 in) and 100.0 mm (3.9 in). The mean cover was 68.6 mm, with a standard deviation of 10.8 mm. These data justify the continued verification of concrete cover as outlined in the specification.

9. An available software module for performing condition surveys on existing (older) bridge decks enhances the value of the GPR device to the Department.

Acknowledgments

The authors would like to thank Rick Lalumiere, former Concrete Inspector for NHDOT, and Roger Roberts, GSSI, for their contributions to the project.

Appendix - Summary of Data Collected During Study

X GPR (Inches)	Y Actual (Inches)	X GPR (mm)	Y Actual (mm)	
Brentwood 101/Pine Rd. (4/97)				
1.890	2.000	48.0	50.8	
3.150	3.130	79.9	79.4	
2.560	2.560	65.0	65.0	
2.560	2.630	65.0	66.8	
2.830	2.750	71.8	69.8	
2.720	2.690	69.0	68.3	
2.600	2.660	66.0	67.5	
1.730	1.880	43.9	47.7	
Exeter 101/Little R. (6/97)				
2.360	2.500	59.9	63.5	Run 1
2.440	2.500	61.9	63.5	Run 2
2.360	2.500	59.9	63.5	Run 3
2.280	2.310	57.9	58.6	Run 1
2.360	2.310	59.9	58.6	Run 2
2.400	2.310	60.9	58.6	Run 3
2.800	2.750	71.1	69.8	Run 1
2.870	2.750	72.8	69.8	Run 2
2.950	2.750	74.9	69.8	Run 3
2.240	2.310	56.9	58.6	Run 1
2.240	2.310	56.9	58.6	Run 2
2.280	2.310	57.9	58.6	Run 3
2.870	2.875	72.8	73.0	Run 1
2.830	2.875	71.8	73.0	Run 2
2.760	2.875	70.1	73.0	Run 3
2.480	2.625	62.9	66.6	Run 1
2.560	2.625	65.0	66.6	Run 2
2.480	2.625	62.9	66.6	Run 3
Concord, US3/Merrimack R (7/97)				
2.876	2.813	73.0	71.4	
1.734	1.690	44.0	42.9	
2.403	2.313	61.0	58.7	
2.088	2.002	53.0	50.8	

X GPR (Inches)	Y Actual (Inches)	X GPR (mm)	Y Actual (mm)	
Exeter, WB 101/Bloody Brook (10/97)				
2.800	2.970	71.1	75.4	Run1
2.830	2.970	71.8	75.4	Run 2
3.270	3.250	83.0	82.5	Run1
3.270	3.250	83.0	82.5	Run 2
2.400	2.500	60.9	63.5	Run1
2.360	2.500	59.9	63.5	Run 2
3.070	3.030	77.9	76.9	Run1
2.950	3.030	74.9	76.9	Run 2
Derry 12158-B, 6/12/98				
2.756	2.750	69.9	69.8	
Rumney 12079, 6/25/98				
2.756	2.750	69.9	69.8	
Manchester-Hooksett, 8/10/98				
2.800	2.906	71.1	73.8	
3.660	3.625	92.9	92.0	
3.940	3.875	100.0	98.4	
2.874	2.937	72.9	74.5	**Nashua 10625-C (9/98)**
2.756	2.718	69.9	69.0	**Nashua 10625-C (9/98)**
2.598	2.500	65.9	63.5	**Nashua 10625-C (10/98)**
2.559	2.660	64.9	67.5	**Haverhill-Bath 10340 (10/98)**
2.990	3.030	75.9	76.9	**Lebanon 11699 (10/98)**
2.795	2.750	70.9	69.8	**Hanover-Norwich 10029-A (11/98)**
3.820	3.940	97.0	100.0	**Haverhill-Bath 10340 (11/98)**
2.330	2.375	59.1	60.3	**Haverhill-Bath 10340 (4/99)**
2.614	2.720	66.3	69.0	**Haverhill 10662 (5/99)**
3.000	2.900	76.1	73.6	**Lebanon 11699 (5/99)**