Application of Ground Penetrating Radar for Civil Infrastructure Assessment

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Research Thrusts / Talk Outline

There are five thrusts to the current GPR research effort:

1. Familiarization with the operation of the GPR instrument and antennas at hand.
2. Development of software tools to read and process raw data.
3. Application to problems of interest (e.g., barrier rail).
4. Developing and testing pulse/echo and pitch/catch methods to measure material properties which influence GPR inspections, such as electromagnetic wave speed and attenuation.
5. Developing forward models of the GPR inspection process capable of predicting time-domain responses from buried objects.
GPR Equipment at CNDE

- 1600 MHz Antenna
- Encoder attached to rear wheels relays position info to computer
- 18-inch ruler
- 200-MHz antenna
- 400-MHz antenna
- Computer and Pulser/Receiver
- 1600 MHz Antenna
GPR Operation and Line Scan Display

- Pulser / Receiver
- Antenna
- Computer
- Soil
- Antenna field extent
- Path followed by a short duration EM pulse
- Buried Object

Arrival Time \( t \)

Response

Front wall response

Object response

A-scan (fixed \( X \))

B-scan

Max pos. response

Max neg. response

Arrival Time (nsec)
Application to Bridge Barrier Rail Inspection

Rebar anchor the retaining wall to the roadbed. Water infiltration can cause rebar corrosion and thinning.

“Cold joint” between road bed and wall

Thinning near level of roadbed

Center for Nondestructive Evaluation
Field Trial at a Local Highway Bridge

GPR Equipment setup with 2 x 4 spacer

1.6 GHz antenna   Laptop with Pulser/Reciever

Sections of bridge inspected
Field Trial at a Local Highway Bridge

- Rebar responses
- Positive amplitude response versus distance
Field Trial at a Local Highway Bridge

Scanned section of 210 bridge illustrating the differences between “on-roadbed” and “elevated” responses.
Field Trial at a Local Highway Bridge

Suspect rebar with abnormally low responses

Average Amplitude / Time

Rebar GPR Time

Rebar GPR Amplitude
Transition to Further Research

• Our long-range plan is to simulate such inspections with computer models.
• Inputs into such simulators will include: antenna properties, and the EM properties of the materials being inspected.
• Work has begun exploring different ways of measuring EM wave speed and attenuation for different materials.
• Work has begun on simulation model development.
EM Property Measurement: Pitch/Catch Method

- From time delay between 1 & 2 can infer soil wave speed if soil thickness is known.
- From relative strengths of 1 & 2 can infer soil attenuation.
EM Property Measurement: Pulse/Echo Method

- From time delay between ① & ② can infer soil thickness.
- From time delay between ① & ③ can infer soil wave speed once thickness is known.
- From relative strengths of ① & ③ can infer soil attenuation.
Feasibility Studies for Property Measurements

Pitch/Catch Method

1.6 GHz antenna supported by wooden rails

Pulse/Echo Method

Soil bags

Metal plate

From time delay between & can infer soil thickness.
From time delay between & can infer soil wave speed once thickness is known.
From relative strengths of & can infer soil attenuation.

Measured Average Values

<table>
<thead>
<tr>
<th>Soil thickness (per bag)</th>
<th>EM wave speed in soil</th>
<th>EM attenuation in soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 inches</td>
<td>2.3 inch/nsec</td>
<td>1.1 dB of loss per inch of travel</td>
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One Bag of Soil Present

No Soil Present
Property Measurements: Example Results

Deduced Soil Attenuation

\[ y = 2.84x \]
General Modeling Approach

Four physical phenomena affect the output GPR signal.

1. EM Field Generation (What is the outgoing antenna radiation pattern in air?)
2. EM Field Propagation (How is the radiation pattern affected by soil?)
3. Reflector Response (How does the object scatter the incident EM field?)
4. Propagation back to the antenna and reception. (What is the received response?)
Simulation Example: Input and Output GPR Signals

Given:
- 1.6 GHz antenna
- 22.5" Metal plate
- air

Predict:
- 1.6 GHz antenna
- Z = 4.0"
- 2”-diameter steel rod
- soil

Response (Vpp for Ref.)

Time (nanoseconds)

3 4 5 6 7 8
Our Unique Test Levee at CNDE will be used to validate simulation models in the future.
Summary

At the Center for Nondestructive Evaluation (CNDE) work is in progress to develop a more quantitative understanding of GPR inspections of embedded objects.

Guided by analogous work in ultrasonic inspection, there are five main thrusts to our effort, focusing on:

- Familiarization with the capabilities of the equipment on hand.
- Development of data analysis tools.
- Applications to problems of interest.
- Development of EM property measurement tools.
- Development of Inspection simulation tools.

Our past work was primarily directed at inspections of deteriorating rebar in concrete bridge structures. Future work will focus in part on the inspection of earthen dams and levees. A novel “test levee” that has been constructed at CNDE will serve as a valuable testing facility.