Ground-Penetrating Radar Applications for the Assessment of Pavements

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Capabilities of GPR

- Layer thicknesses
- Void location
- Stripping in asphalt layers
- Presence of moisture
- Detection/locate subsurface anomalies

GPR contributes to the structural assessment of pavements

- Predict pavement performance
- Determine upgrade requirements
- Prevent unforeseen pavement failures

GPR is nondestructive

- Quicker results
- Fewer delays and interference
ERDC GPR Applications

- **Airfield evaluations**
  - Current pavement condition
  - Layer thicknesses can be used with falling weight deflectometer (FWD) data to backcalculate layer moduli

- **Road structures**
  - Maintenance and repair
  - Future design

- **Test sections at ERDC**
  - Quality assurance tool
Pulse Radar System

- Developed under Small Business Innovative Research (SBIR) with Pulse Radar (Houston, TX)
- Multi-Antenna
  - 1 GHz (1 meter)
  - 500 MHz (2 meters)
  - 250 MHz (3 meters)
  - 100 MHz (5-10 meters)
- Operates at highway speeds
Note: Requires dielectric discontinuity at layer interfaces
GPR Equations

- **Layer thickness**
  
  \[ h = \frac{c \times \Delta t}{2\sqrt{\varepsilon}} \]
  
  - \( h \) = layer thickness
  - \( c \) = speed of light
  - \( \Delta t \) = two way travel time
  - \( \varepsilon \) = dielectric

- **Dielectric values**
  
  - Use assumed value (typically 6.0 for asphalt, 8.0 for concrete)
  - Backcalculate dielectric from core
  - Use equations

\[
\begin{align*}
\varepsilon_a &= \left[1 + \frac{A_0}{A_m}\right]^2 \\
\sqrt{\varepsilon_b} &= \sqrt{\varepsilon_a} \left[1 - \left(\frac{A_0}{A_m}\right)^2 \right]^2 + \left(\frac{A_1}{A_m}\right) \\
\varepsilon_a &= \text{dielectric of first layer} \\
\varepsilon_b &= \text{dielectric of base layer} \\
A_m &= \text{metal reflection amplitude} \\
A_0 &= \text{surface reflection amplitude} \\
A_1 &= \text{base reflection amplitude}
\end{align*}
\]

*Scullion et al, 1994*
Layer interfaces (signal peaks) are found using a cross-correlation technique.

Layer thickness are calculated using the locations of the signal peaks and the previous equations.

Layer thickness measurements improve when calibrated/corrected with a thickness value from a single core (“ground truth”).
GPR Display
Detection of Subsurface Utilities

Pipe
Utility
Layer 1 original and corrected thicknesses as determined from the 1 GHz antenna on the ERDC asphalt test pavement
Differences/Errors

Asphalt test pavement – Asphalt, layer 1 (1 GHz)

Asphalt test pavement – Base, layer 2 (1 GHz)
Verification – Rigid Pavement

Layer 1 original and corrected thicknesses as determined from the 1 GHz antenna on the Portland Cement Concrete (PCC) airfield pavement
Differences/Errors

PCC airfield pavement – layer 1 (1 GHz)

PCC airfield pavement – layer 1 (500 MHz)
Summary and Conclusions

- Continuous thickness measurements along the entire length of the pavement ensure that changes in layer structure will be detected.

- Combination of the 1GHz and 500 MHz antenna appears to provide both the resolution and penetration necessary for sampling most typical pavement structures.

- At least one core is required to calibrate GPR thicknesses:
  - Flexible pavement - error is reduced from an average of 1.04 inches to 0.42 inches.
  - Rigid pavement – error is reduced from an average of 1.59 inches to 0.19 inches.
Summary and Conclusions

- Measuring layer thicknesses with GPR has the potential to minimize time required for pavement evaluations by optimizing coring and DCP testing.

- GPR is useful for detecting utilities.

- Using layer thicknesses from GPR along with FWD data results in more accurate backcalculated moduli, and therefore, more reliable predictions of structural capacity.