Sub-Slab Concrete Investigations Using Ground Penetrating Radar to Identify Voids

2017 North Carolina Department of Transportation Geo3T2

Pyramid Geophysics

Presentation Overview

- Ground Penetration Radar (GPR)
  - Technical Background
  - Antenna Frequencies
  - GPR for voids
- Case Study 1 – High and Medium Resolution GPR to Identify Sub-Slab Voids
- Case Study 2 – Medium and Low Frequency Resolution GPR to Identify Sub-Slab Voids and Geologic Hazards
- Conclusions and Discussion of Limitations

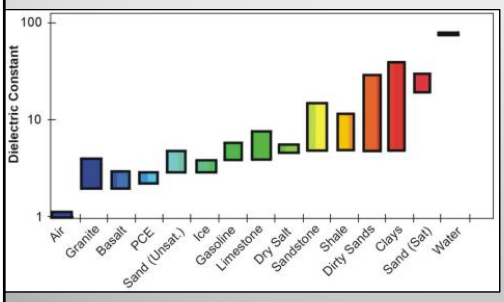
Ground Penetrating Radar (GPR)

- Geologic mapping (depth to rock, karst)
- Buried debris (landfill delineation)
- Concrete Inspections
- Underground Storage Tank (UST) locates
- Utility locates
- Buried remains (archaeology)

How Does GPR Work?

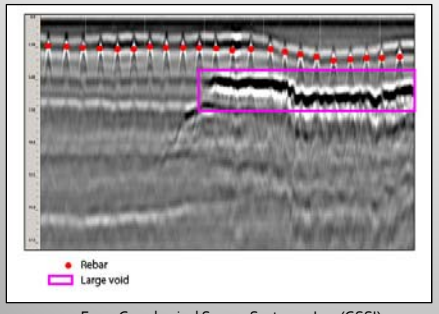
- Radio waves (microwave spectrum) are sent into the ground by a transmitter
- A receiver measures both the time it takes for the reflected wave to return, and its strength
- Changes in the subsurface (soil type, rock, saturation, and objects) create the reflections
- Electrical properties of subsurface soils and rock are the primary cause of GPR reflections

Dielectric Constant and GPR



- Strong reflections are produced by significant changes in the dielectric constant
- Weaker reflections produced as signal move through soils with similar electrical properties

Air-filled Voids

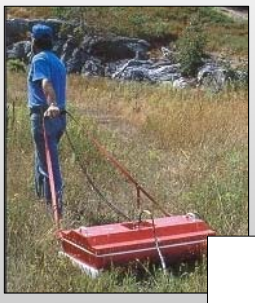


From Geophysical Survey Systems, Inc. (GSSI)

- Air has a dielectric value of 1
- Moving from soil or concrete to air creates a significant negative reflection
- Exhibited by sharp and isolated contrasting relflector

Not all Antennae Are Created Equal

- A variety of antenna frequencies are available (From 100 MHz to 2600 MHz)
- Frequency determines depth of penetration and resolution
- From 12 inches to 50+ feet

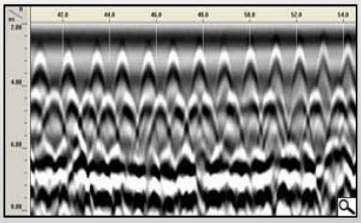


Applications of Different GPR Antennae

Appropriate Application	Primary Antenna Choice	Secondary Antenna Choice	Depth Range (Approximate)
Structural Concrete, Roadways, Bridge Decks	2600 MHz	1600 MHz	0-0.3 m (0-1.0 ft)
Structural Concrete, Roadways, Bridge Decks	1600 MHz	1000 MHz	0-0.45 m (0-1.5 ft)
Structural Concrete, Roadways, Bridge Decks	1000 MHz	900 MHz	0-0.6 m (0-2.0 ft)
Concrete, Shallow Soils, Archaeology	900 MHz	400 MHz	0-1 m (0-3 ft)
Shallow Geology, Utilities, UST's, Archaeology	400 MHz	270 MHz	0-4 m (0-12 ft)
Geology, Environmental, Utility, Archaeology	270 MHz	200 MHz	0-5.5 m (0-18 ft)
Geology, Environmental, Utility, Archaeology	200 MHz	100 MHz	0-9 m (0-30 ft)
Geologic Profiling	100 MHz	MLF (16-80 MHz)	0-30 m (0-90 ft)
Geologic Profiling	MLF (16-80 MHz)	None	Greater than 30 m (90 ft)

From Geophysical Survey Systems, Inc. (GSSI)

Example of StructureScan GPR – Concrete Mapping of Rebar

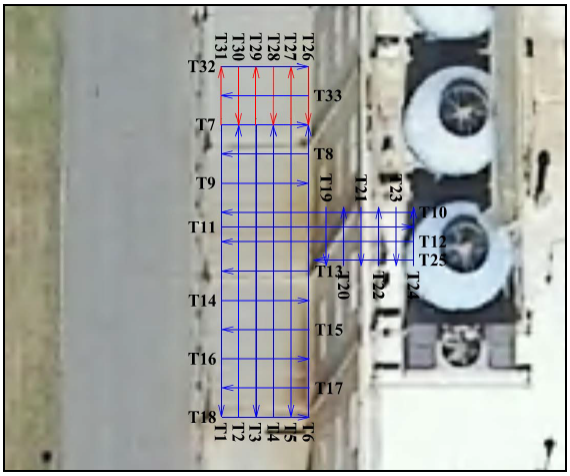


Case Study: GPR for Voids Under Concrete – High and Medium Frequency

Project Approach

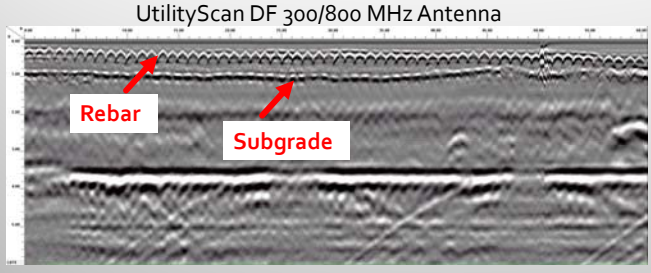
- Establish a grid across the area suspected to contain sub-slab voids
- Perform a high frequency GPR survey using GSSI StructureScan Mini 1600 MHz antenna
- Perform medium frequency GPR survey using GSSI UtilityScan DF (300/800 MHz)
- Examine data for both voids and evidence of slumping/failing soils

GPR Survey Setup

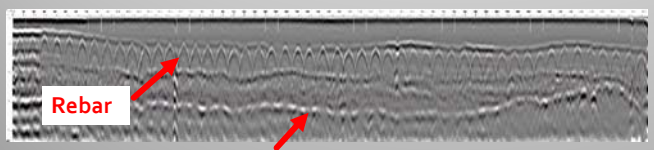


High vs. "Medium" Frequency Results

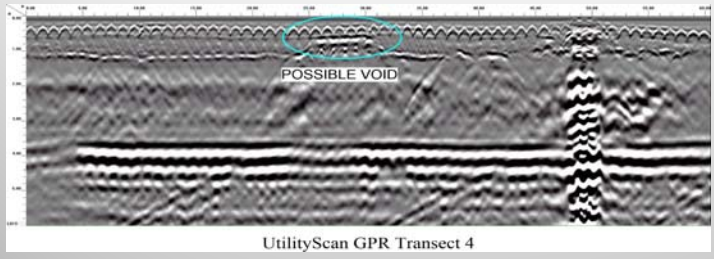
UtilityScan DF 300/800 MHz Antenna



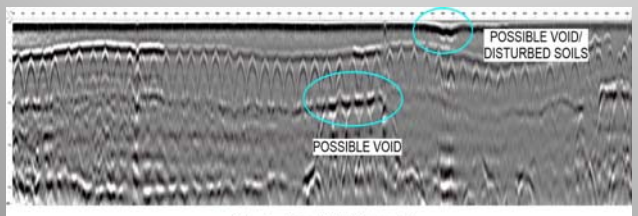
StructureScan Mini 1600 MHz Antenna



Evidence of Possible Voids



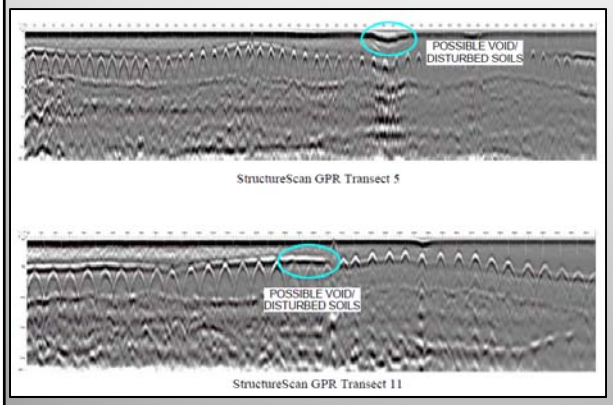
UtilityScan GPR Transect 4



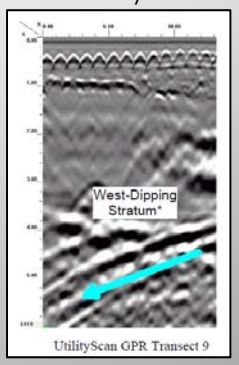
StructureScan GPR Transect 4

Additional Evidence of Voids and Down-Dipping Strata

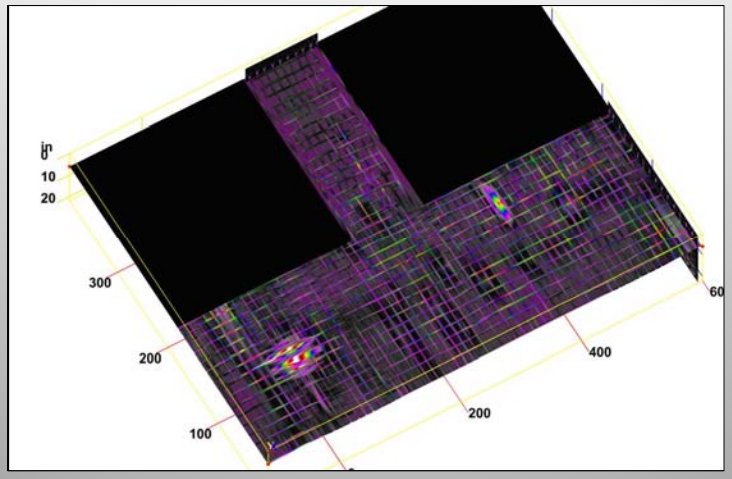
StructureScan Mini Scans – Additional Voids



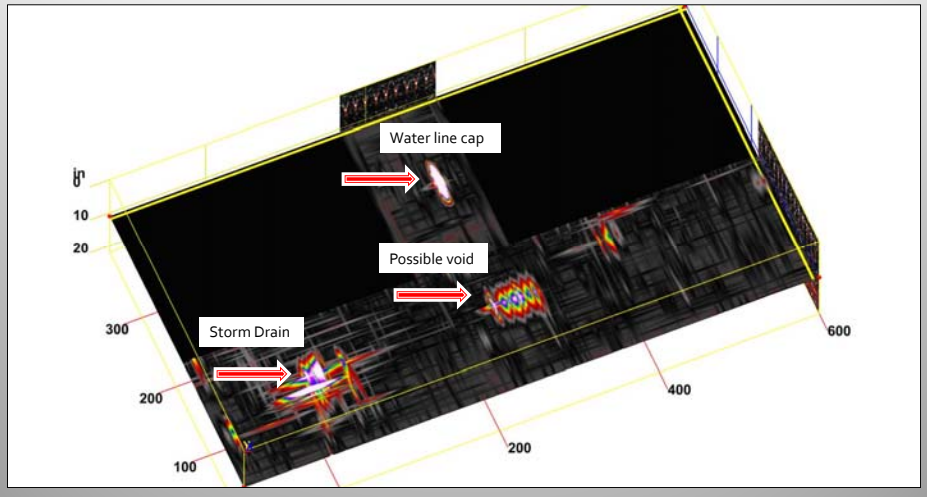
UtilityScan – Dipping Soil Layers



StructureScan Mini 3D Survey

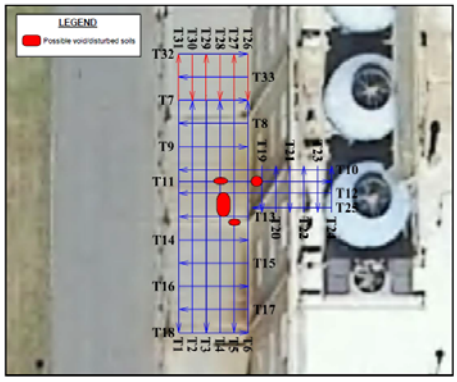


Evidence of Possible Voids

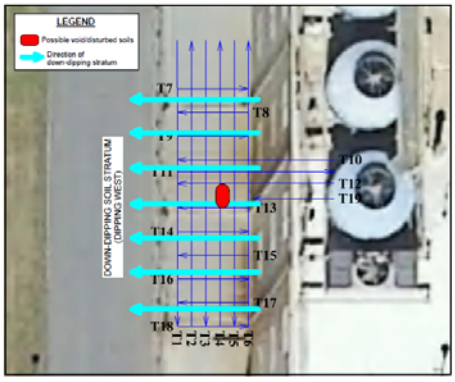


Summary of Possible Voids and Slumping Soils

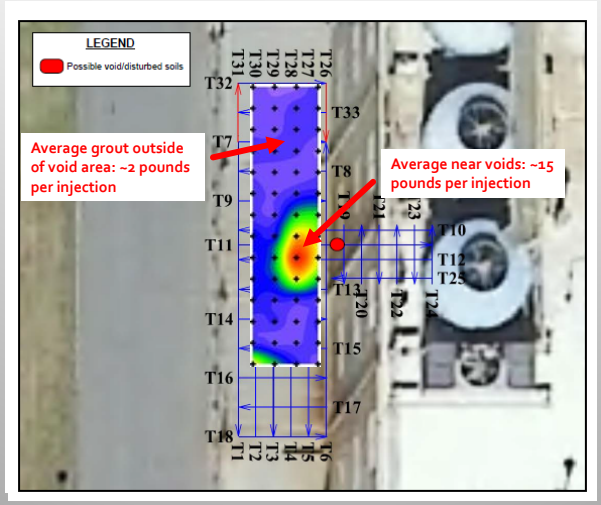
StructureScan Mini 1600 MHz Antenna



UtilityScan DF 300/800 MHz Antenna



Grout Injection To Stabilize Slab



Case Study 1 - Summary

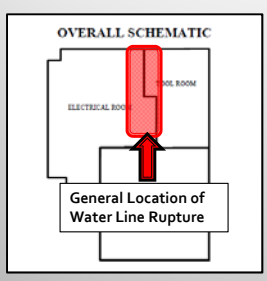
- High frequency (1600 MHz) GPR was effective in identifying possible void spaces directly beneath slab
- "Medium" (300 MHz) frequency GPR provided correlating data for significant voids
- 300 MHz GPR also provided evidence of potential hazardous geologic conditions deeper in subsurface
- Grouting volumes correlated with geophysical interpretations

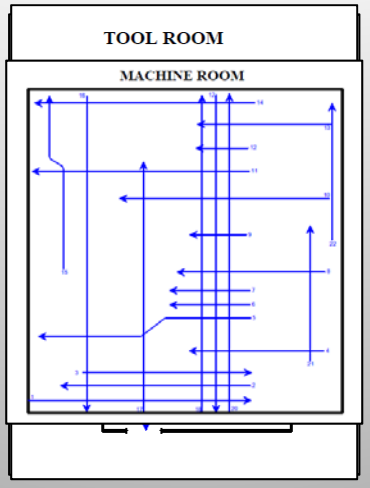
Case Study: GPR for Voids Under Concrete –Medium and Low Frequency

Project Approach

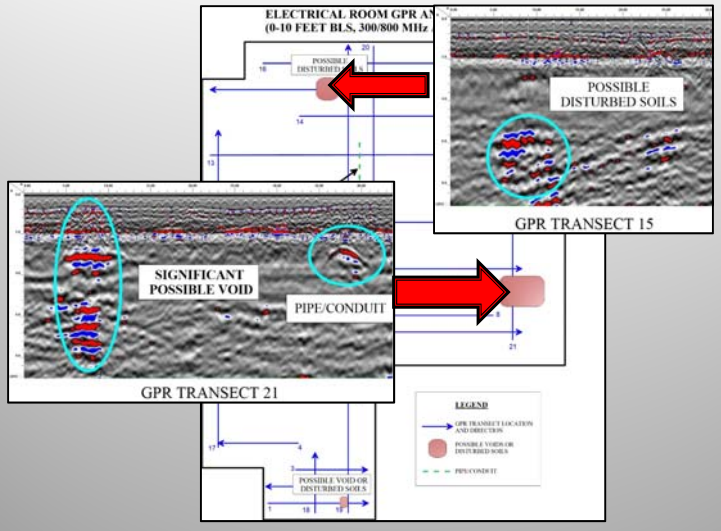
- Establish "grids" within three rooms for GPR surveys
- Perform a "medium" frequency GPR survey using GSSI GSSI UtilityScan DF (300/800 MHz)antenna to examine upper 10 feet
- Perform low frequency GPR survey usinga GSSI 100 MHz antenna to image down to 30 feet*
- Examine data for both voids and evidence of slumping/failing soils

GPR Survey Areas

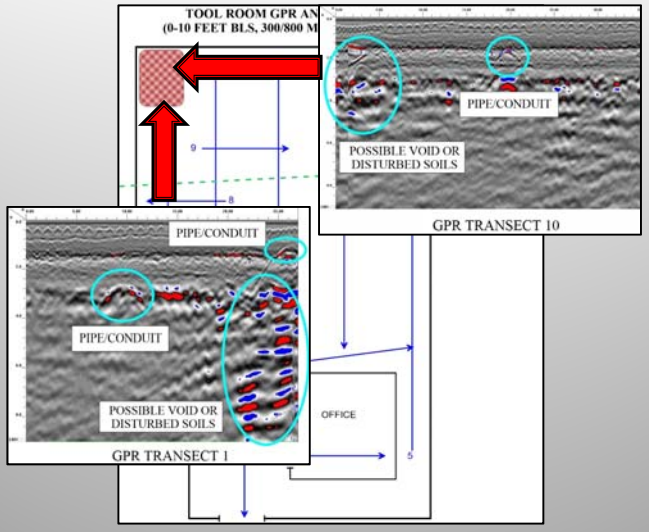




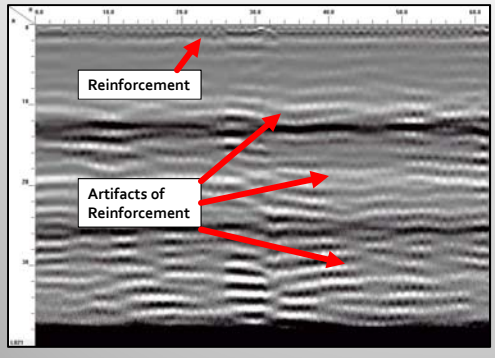
Electrical Room GPR Results

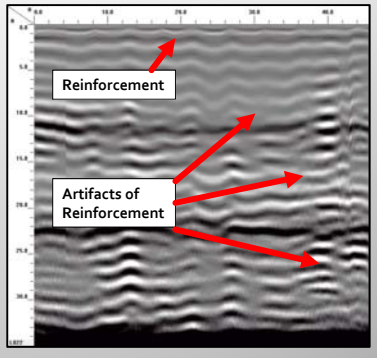


Tool Room GPR Results

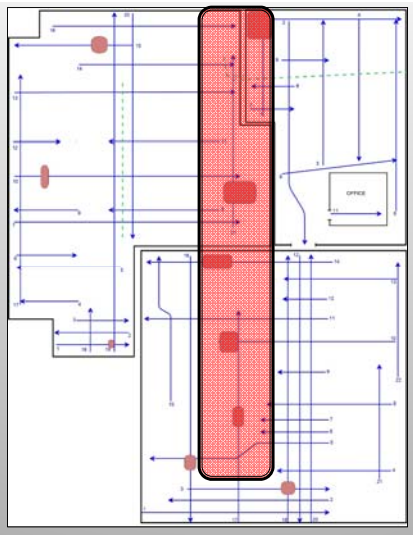


Limitations of Low Frequency GPR Survey





Locations of all GPR Features



Case Study 2 - Summary

- 300/800 MHz "medium" frequency GPR was effective in identifying shallow possible voids and hazards
- 200 MHz frequency GPR could not effectively image subsurface in detail due to shallow metal reinforcement
- Voids and disturbed soils correlated to location of ruptured water line

Summary – Sub-Slab GPR Investigations

- GPR can be an effective tool to examine conditions underlying concrete slabs
- Antenna frequency choice is critical
- Interpretation of voids and disturbed soils can be highly subjective
- Site factors such as reinforced concrete and working indoors (ceilings) can affect results
- Groundtruth data provide additional verification of interpretations

If only we had used Geophysics!