Ground Penetrating Radar (GPR) Applications in Kentucky

3 case studies
By: Brad Rister P.E./MSCE
Overview

Case study #1

Using GPR to determine why a concrete pavement (PCCP) has been settling on I-265 in Louisville, Kentucky and how it has changed the project design

Case study #2

Using GPR to determine the size and location of a sinkhole on US 27 in hopes of preventing a catastrophic pavement collapse in Summerset, Kentucky

Case study #3

Using GPR to detect void areas beneath the concrete pavement in the Cumberland Gap Tunnel in Middlesboro, Kentucky

Questions
Case Study: #1
Using GPR to identify why a PCCP pavement has been settling

Project background

- 3-mile long project on I-265 in Louisville, KY. Mileposts 15 to 18
- 10 inch concrete pavement that was constructed in 1987
- Right driving lane has differentially settled approximately 1 to 2 inches from the shoulder and the left driving lanes
- Urgency for inspection: 2003, one motorcycle fatality had occurred due to the pavement settlement
What did we use and how did we use it?

Ground Penetrating Radar

Equipment
900 MHz. antenna
Approx. depth 3 ft.

Data collection location
1 pass per lane
CWP

Data collection density
3 scans per foot

Data collection speed
20 m.p.h. (3 hrs.)
First: used GPR to locate different degrees of saturated sub-base beneath PCCP

Degree of saturation scale

- severe
- moderate
- minimum
Moderate water beneath PCCP

Degree of saturation scale

severe moderate minimum
Minimum water beneath PCCP

Degree of saturation scale

severe
moderate
minimum
Second: used GPR to locate tie bars between lanes

1.25” Lane Drop
Shoulder Side
Driving Lane Side
Shoulder Side
Threaded Connection at Shoulder
Third: used GPR to locate dowel bars at the transverse joint
Fourth: GPR was used to find clay layer between D.G.A. and apparent rock roadbed.  

Core Information
Station 1582+43
Approx. 2” between lane faulting
PCCP: 9.75” - 10.25”
DGA: 5.75” – 6.25”
Clay soil: 8” – 10”

Core Information
Station 1699+73
No between lane faulting
PCCP: 10.00” - 10.25”
DGA: 4.75” – 5.25”
Apparent rock roadbed:
1” or more settlement, less than 50% load transfer, & moderate to severe water 

1” settlement and severe water

1” settlement (possible slab jacking)

Less than 50% load transfer, some settlement and/or water
Presence of Clay layer (yes/no)
KYDOT compared information provided by GPR to initial design proposals
Originally design firm proposed 7 different pavement rehabilitation designs

- $6,710,373  remove right driving lane slab/replace, rework D.G.A. shoulders
- $6,055,364  remove right driving lane slab/replace, rework D.G.A. shoulders
- $8,260,344  remove right driving lane slab/replace, weekend work, rework D.G.A. shoulders
- $13,196,072 remove all slabs/replace, install edge-drains, rework D.G.A. shoulders
- $10,959,017 1” bond breaker—9” PCC overlay, rework D.G.A. shoulders
- $8,258,970  break and seat existing pavement—10” asphalt overlay, rework D.G.A. shoulders
- $17,476,275 remove all slabs/replace, install edge-drains, concrete shoulders
Additional GeoTech. work eastbound (boring log)
A new pavement design was created

- Break and remove existing concrete pavement, excavate sub-grade (clay layer), replace with number 2 size stone, place new concrete pavement, and install edge-drains

- Project currently under construction approx. $14 million
I-265 pavement structure after excavation
Why the pavement has settled

- Provided that traffic predominately travels in the right driving lane, over time the saturated clay beneath the DGA layer has compressed thus allowing for differential settlement of the right driving lane.
Summary of I-265 pavement settlement project using GPR

After reviewing GPR results, 6 out of the 7 initial rehabilitation designs were discarded
  – Remaining one was determined not to be the best design

GPR results prompted engineers to perform a more thorough geotechnical investigation

Ultimately GPR results helped engineers design a more appropriate pavement design to fix the settling pavement
Case Study: #2
Sinkhole
Somerset, Ky
US 27 southbound lane
between mile-point 14.5 and 15.5
What has taken place since Feb. 2001

200 Tons of rock material: volume 3200 c.f.

22 Tons of cement grout
General Site Photo
(US 27 southbound)
Surveyed Sinkhole with GPR
GPR equipment for sinkhole survey

- **200 MHz.**
  - 300 ns (approx. 50 ft.)
  - 1024 samples/scan
  - 5 gain points

- **400 MHz.**
  - 80 ns (approx. 12 ft.)
  - 512 samples/scan
  - 5 gain points
Middle Lane
Right Lane
Sinkhole Area
Contour Map
Sinkhole Area
(disturbance below surface)
What we don’t want to happen
Summary Sinkhole project

Sinkhole: GPR assisted in identifying the size and location of a sinkhole in southern Kentucky on US 27
Case study #3:
Cumberland Gap Tunnel Inspection
May 2005
Overview

- Background of Cumberland Gap Tunnel
- History of problems encountered to the pavement structure
- Survey of tunnel with GPR
- Areas of concern (CP 3, 5, 8 ½)
- 2 minute video of inspection
- Summary
Background of Cumberland Gap Tunnel

- 4-lane twin-bore mountain tunnel
- 4600 feet long
- Carries US-25-E under Cumberland Gap between Kentucky and Tennessee
- Completed in October 1996
- Costs of Construction $280 million
- Currently operated and maintained by the Cumberland Gap Tunnel Authority (CGTA) a subsidiary of Vaughn and Melton Consulting Engineers
History of problems encountered to the pavement structure and inspections performed

- 2001 (CGTA) requested a pavement inspection due to possible slab settlement
  - FWD testing CP 5 and 8 ½
  - Drainage inspection of tunnel drains
- 2002 (URETEK placed at CP 5 and 8 ½)
  - FWD testing after URETEK CP 5 and 8 1/2
- 2003
  - FWD testing throughout tunnel (50 ft. spacing) to develop trend line of pavement subgrade strength
- 2005
  - Surveyed tunnel using Ground Penetrating Radar (GPR)
Visual slab settlement at CP 3
(water ponding after tunnel washing)

southbound
2005: Survey of tunnel with ground penetrating radar (GPR)

| Equipment               | 900 MHz. antenna                   |
|                        | Approx. depth 3 ft.                |
| Data collection location| 3 passes per lane                  |
|                        | CWP, RWP                           |
|                        | LWP                                |
| Data collection density | 1 scan every inch                  |
| Data collection speed   | 5 m.p.h. (3 hrs.)                  |
Good GPR data showing pavement layers
Good GPR data showing re-bar
Void area beneath concrete pavement
southbound tunnel

GPR signal has negative amplitude (noted as black space) because it doesn’t have anything to bounce off of (namely air).
Multiple void areas beneath concrete pavement northbound tunnel
Void length RLRWP 79 feet

Void length RLRWP 27 feet
Void depth beneath 10 inch concrete pavement CP 3

### Southbound

<table>
<thead>
<tr>
<th>Sta. #</th>
<th>Lane</th>
<th>Void depth inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>122+77</td>
<td>R cwp</td>
<td>8</td>
</tr>
<tr>
<td>122+80</td>
<td>R cwp</td>
<td>7 5/8</td>
</tr>
<tr>
<td>123+00</td>
<td>L cwp</td>
<td>5 7/8</td>
</tr>
</tbody>
</table>

### Northbound

<table>
<thead>
<tr>
<th>Sta. #</th>
<th>Lane</th>
<th>Void depth inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>122+72</td>
<td>L cwp</td>
<td>2 1/4</td>
</tr>
</tbody>
</table>
CP 5
tested area
126+00 to 130+00
Mapped void area CP 5

Void length RLRWP 41 feet

Void length LLLLWP 65 feet

SB  NB
**Void depth beneath 10 inch concrete pavement CP 5**

### Southbound

<table>
<thead>
<tr>
<th>Sta. #</th>
<th>Lane</th>
<th>Void depth inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>128+67</td>
<td>L cwp</td>
<td>4 3/4</td>
</tr>
</tbody>
</table>

Void area under URETEK

### Northbound

<table>
<thead>
<tr>
<th>Sta. #</th>
<th>Lane</th>
<th>Void depth inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>127+35</td>
<td>L cwp</td>
<td>6 3/4</td>
</tr>
</tbody>
</table>
CP 8 1/2
tested area
137+00 to 140+50
Void length LLLLWP 56 feet

Void length LLLWP 43 feet
# Void depth beneath 10 inch concrete pavement CP 8 1/2

### Southbound

<table>
<thead>
<tr>
<th>Sta. #</th>
<th>Lane</th>
<th>Void depth inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>138+98</td>
<td>L cwp</td>
<td>21 7/8</td>
</tr>
<tr>
<td>139+02</td>
<td>L cwp</td>
<td>29 3/8</td>
</tr>
</tbody>
</table>

### Northbound

<table>
<thead>
<tr>
<th>Sta. #</th>
<th>Lane</th>
<th>Void depth inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>139+14</td>
<td>L cwp</td>
<td>7 1/8</td>
</tr>
</tbody>
</table>

URETEK material
Video of inspection of void area
Case Study # 1:
- GPR prompted a more thorough geotechnical investigation on I-265 that ultimately lead to a more appropriate pavement design to fix the underlying problem causing the concrete pavement to settle

Case study # 2:
- GPR assisted in identifying the size and location of a sinkhole in southern Kentucky on US 27

Case study # 3:
- GPR used to detect void areas beneath the concrete pavement in the Cumberland Gap Tunnel in Middlesboro, Kentucky
Questions?
Thank You

Our Mission
We provide services to the transportation community through research, technology transfer and education. We create and participate in partnerships to promote safe and effective transportation systems.

We Value...
Teamwork -- Listening and Communicating, Along with Courtesy and Respect for Others

Honesty and Ethical Behavior

Delivering the Highest Quality Products and Services

Continuous Improvement in All That We Do

The University of Kentucky is an Equal Opportunity Organization