Premature Pavement Failure
The Use of GPR and a Case Study

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Uses of GPR in Pavement Design

- Determine pavement layer thickness
- Detect stripping
GPR and Pavement Thickness Survey

GPR Pavement Thickness Survey

- FWD data analysis
- Rehabilitation design
- Pavement management decisions
Mapping Thickness Data
Asphalt Pavement Stripping

Defined as moisture-related mechanism

- Deteriorates bond between asphalt and aggregate
- Results in low-density zone
- Detected as out-of-phase reflection peak
Typical Out-of-Phase Reflection Peaks
Mapping of Stripping Data
Case Study

- Rii was retained by the Client to perform GPR scans for use in pavement rehabilitation program on major toll road (ADT = 234,400)
  - Locate areas of high moisture content
  - Determine thickness of existing layers
  - Identify/locate voids
  - Detect areas of stripping
- Used non-contact horn antenna with center frequency of 1 GHz
- Data collected from right wheel path of each lane
- Project included 44.71 Km of toll road with up to 8 to 10 lanes of traffic
GPR System Used During Data Collection
GPR Findings

- Rii determined that the existing asphalt was severely stripped in many areas indicated by out-of-phase reflection peak
  - Radar wave travels from higher to lower dielectric material
  - Low dielectric a function of low density of the stripped material
Figure 1. Detection of stripping
Premature Pavement Failure

- As a result of the GPR findings, Client further retained Rii to evaluate premature pavement failure of recent rehabilitation.

<table>
<thead>
<tr>
<th>Toll Road</th>
<th>Section (Km)</th>
<th>Section Total (Km)</th>
<th># of Lanes</th>
<th>Pavement Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR-22</td>
<td>1.00</td>
<td>7.61</td>
<td>6.61</td>
<td>Flexible</td>
</tr>
<tr>
<td>PR-22</td>
<td>13.60</td>
<td>22.60</td>
<td>9.00</td>
<td>Flexible</td>
</tr>
<tr>
<td>PR-5</td>
<td>5.75</td>
<td>9.75</td>
<td>4.00</td>
<td>Flexible</td>
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<td>71.00</td>
<td>72.00</td>
<td>1.00</td>
<td>Flexible</td>
</tr>
<tr>
<td>PR-22</td>
<td>83.40</td>
<td>85.00</td>
<td>1.60</td>
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<td>PR-22</td>
<td>33.00</td>
<td>45.00</td>
<td>12.00</td>
<td>Rigid</td>
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<tr>
<td>PR-22</td>
<td>64.00</td>
<td>71.00</td>
<td>7.00</td>
<td>Rigid</td>
</tr>
<tr>
<td>PR-22</td>
<td>80.00</td>
<td>83.50</td>
<td>3.50</td>
<td>Rigid</td>
</tr>
</tbody>
</table>
Premature Pavement Failure

- Client began to report premature pavement failures within 2 to 3 months following the final pavement placement
- Potholes, delamination and staining reported
- Failures continued to occur
Premature Pavement Failure

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Premature Pavement Failure

Potholes, delamination and staining reported
Pavement Staining

Potholes, delamination and staining reported
Rii’s Investigative Approach

- Review construction, materials, and testing records
- Site visit, and interviews with owner and consultants
- Obtain pavement cores and test for specific parameters
  - Conformance to mix design
  - Potential for stripping
Construction Review

- Three types of treatments
  - Cold milling and overlay (2”) – used most extensively throughout the project
  - Cold milling and overlay with geogrid (3”)
  - Full depth repair and overlay
- Most work performed at night
- Tropical climate (rain, high temps, humidity)
- Warm Mix Asphalt
  - Rediset® WMX with anti-stripping agent
- Construction August 2012 – March 2013
Construction Review

- Construction records indicate there were areas of unsound pavement after cold milling
  - These were addressed by additional milling

- Milled pavement left open to traffic for up to 25 days (3 to 5 typical)

- Surface cleaned and tacked prior to paving - tack pick up noted in project photos

- MTV used with standard paver - most work at night

- Mix temps were within specification

- Rain reported in 10 of 41 paving lots
Suspect area after milling

Typical night paving operation—note the paver tire track pick up
Construction Review

- Generally the mix was reported as acceptable in field.
- Air voids were reported to generally be in specification:
  - Ave. in-place compaction of 92% to 97% met in all but 2 lots.
  - Some individual in-place compaction less than spec.
Post Construction Testing Review

- Contractor performed testing of pavement cores
- Determined:
  - Permeability of overlay was very low
  - Saturation of cores 58% to 75% in new surface and existing asphalt in distressed areas
  - Potential for stripping based on TSR was low (AASHTO T-283) in new overlay with no distress; but high in areas of distress
Post Construction Testing Review

- Contractor in-situ moisture (% Saturation) was inconsistent with the results of the GPR testing performed by Rii
- Rii evaluated the dielectric constants in 2 distressed areas to assess moisture conditions in the asphalt layers
Overall the GPR test data indicated that the asphalt material (new and existing) generally had low moisture content and the aggregate base material was generally dry.

<table>
<thead>
<tr>
<th>Location</th>
<th>Lane</th>
<th>LPN</th>
<th>Average Dielectric Constant - Surface</th>
<th>Average Dielectric Constant – Existing Base Asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Km 3.389 – 3.438 EB</td>
<td>3</td>
<td>14</td>
<td>6.02</td>
<td>6.53</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>6</td>
<td>6.83</td>
<td>7.31</td>
</tr>
<tr>
<td></td>
<td>Ramp Lane</td>
<td>6</td>
<td>6.70</td>
<td>7.10</td>
</tr>
</tbody>
</table>
Post Construction Testing Review

- Contractor determined:
  - Water was infiltrating up through base material from bottom or sides and through cracks in the old asphalt
  - Temperature fluctuations and traffic action caused pore water pressure in old damaged asphalt to fracture the asphalt-aggregate bond in the new overlay
Site Visit - Observations

- Potholes were observed in lower elevation areas and at higher elevations such as on ramp embankments.
- Many potholes appeared in wheel paths.
- Potholes appeared to be depth of overlay:
  - Overlay material appeared delaminated from the milled surface with loose material in the associated pothole.
  - Distresses appeared consistent with stripping, either a cohesion failure between the aggregate surface and asphalt binder, or an adhesion failure within the asphalt binder itself.
- Project area is in coastal plane.
- During rainfall event lower elevation areas showed evidence of ponding water in ditches.
Rii Testing

- Cores obtained from 1 production lot represented distressed and non-distressed areas:
  - **Area A** with visible distress at a relatively low pavement elevation area
  - **Area B** with visible distress at a relatively higher pavement elevation area
  - **Area C** without visible distress
Rii Testing

- Gradation & Percent passing sieve #200
- Percent binder (asphalt) content
- In-place air void content
- Moisture susceptibility testing (AASHTO T 283), Tensile Splitting Ratio (TSR)
A. Area with visible distress at a relatively low pavement elevation area

Cold mill to ~3” inches; ~1-inch WMA leveling course; geogrid; and ~2” inches of WMA surface course
A. Area with visible distress at a relatively low pavement elevation area

Cold mill to ~3” inches; ~1-inch WMA leveling course; geogrid; and ~2” inches of WMA surface course
B. Area with visible distress at a relatively higher pavement elevation area

Cold mill to ~3” inches; ~1-inch WMA leveling course; geogrid; and ~2” inches of WMA surface course
B. Area with visible distress at a relatively higher pavement elevation area

Cold mill to ~3” inches; ~1-inch WMA leveling course; geogrid; ~2” inches of WMA surface course
C. Area without visible distress

Cold mill and place ~2” of WMA surface course
C. Area without visible distress

Cold mill and place ~2” of WMA surface course
Gradation tests indicated that the mixes in all 3 areas (A, B and C) had similar gradation characteristics with little or no variability.

There was not excessive material passing the #200 sieve.
Rii Testing – Binder Content

- Percent Binder (Asphalt) Content of the new surface mix ranged from 5.9 to 6.7 as compared to the JMF of 5.52
Rii Testing – In place AVs – New Surface Course

- **Average** percent air voids ranged from 4.823 to 6.421
  - Area A with **visible failures** and relatively low elevation had lowest average air voids (highest average in-place compaction of 95.2%)
  - Area C with **no visible failures** had the highest average air voids (lowest average in-place compaction of 93.6%)
  - All within specification and not statistically different
Rii Testing – In place AVs – Existing Asphalt Base Course

- **Average** percent air voids ranged from 10.125 to 6.284 (89.9 % to 93.7% **average** in-place compaction)
  - Area A with visible failures had the lowest average in-place compaction of 89.9%
  - Area C with no visible failures had the highest average in-place compaction of 93.7%
### Rii Testing - TSR

<table>
<thead>
<tr>
<th>Test Area</th>
<th>Average Strength, Unconditioned (Dry) Samples, psi</th>
<th>Average Strength, Conditioned (Wet) Samples, psi</th>
<th>Strength Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-Top</td>
<td>120.5</td>
<td>105.1</td>
<td>0.87</td>
</tr>
<tr>
<td>B-Top</td>
<td>104.5</td>
<td>77.5</td>
<td>0.74</td>
</tr>
<tr>
<td>C-Top</td>
<td>104.2</td>
<td>87.5</td>
<td>0.84</td>
</tr>
<tr>
<td>JMF</td>
<td>130.9</td>
<td>130.7</td>
<td>0.969</td>
</tr>
<tr>
<td>Spec</td>
<td>80</td>
<td>80</td>
<td>0.75</td>
</tr>
<tr>
<td>A-Bottom</td>
<td>126.6</td>
<td>71.55</td>
<td>0.56</td>
</tr>
<tr>
<td>B-Bottom</td>
<td>121.3</td>
<td>77.44</td>
<td>0.64</td>
</tr>
<tr>
<td>C-Bottom</td>
<td>153.4</td>
<td>102.97</td>
<td>0.67</td>
</tr>
</tbody>
</table>

**Contractor’s testing** of new surface had TSR results of 0.33 to 0.51 in distressed area; and 0.96 to 1.05 in non-distressed area; and TSR of 0.75 of existing asphalt for both distressed and non-distressed areas.
Rii Determination

- Mix was not the issue; the new asphalt overlay:
  - Was within specification for gradation, binder content, and TSR
  - Field compaction was within specification

- Existing asphalt had areas of stripping
  - Evidenced using GPR and confirmed with cores
Rii Determination

- Construction practices suspect
  - Cold milled surface left open to rain and traffic
  - LPN 15 left open from 6 to 11 days
Rii Determination

- Water entered old stripped asphalt matrix and was trapped when overlay was placed.
- Trapped water can condense causing pressure in matrix in turn causing potholes in new asphalt course.
Pink highlights indicate areas of stripping detected by GPR
Pink highlights indicate areas of stripping detected by GPR.
Rii Determination

• Tack pick up during paving operation can contribute to pavement delamination
Summary

- Rii determined mechanisms of premature failure were:
  - Milled surface open to rain and traffic for long periods coupled with questionable structural integrity of existing asphalt
  - Additional delamination/de-bonding due to tack placement issues
  - Could not corroborate that moisture was coming from subgrade
  - The use of GPR was very effective in determining stripped areas that likely contributed to premature failure
Thank You

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