NDT Technology for QA of Flexible Pavement Construction

Northeast Asphalt User/Producer Group
Annual Meeting
Mystic, Connecticut
October 17, 2007

Harold L. Von Quintus, P.E.
Presentation Outline

1. Overview Project
2. Candidate NDT Technologies
3. Unbound Materials/Soils
4. HMA Mixtures
5. Recommendations from Study

Sponsor:
NCHRP Project 10-65

Expanding the Realm of Possibility
Overview: The Team

Principal Investigator
Mr. H.L. Von Quintus
ARA, Inc.

Field Evaluations
Dr. C. Rao, ARA, Inc.
Dr. E. Minchin, UF

Lab Testing
Mr. B. Prowell
NCAT

FWD/LWD/DCP
Mr. J. Mallela
Mr. R. Stubstad
ARA, Inc.

GPR
Dr. K. Maser
Infrasense

Seismic Methods
Dr. S. Nazarian
UTEP

Statistician
Dr. Maghsoodloo
NCAT

ARA
Expanding the Realm of Possibility
<table>
<thead>
<tr>
<th>Part A – Confirm applicability of NDT test method</th>
<th>Completed June 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part B – Improve/Revise test protocol &amp; data interpretation procedures</td>
<td>Completed Fall 2006</td>
</tr>
<tr>
<td>Laboratory Testing, Modulus</td>
<td>Completed Summer 2007</td>
</tr>
<tr>
<td><strong>Final Report</strong></td>
<td><strong>Fall 2007</strong></td>
</tr>
</tbody>
</table>
Overview: The Objectives

1. Conduct field evaluation of Potential NDT technologies; their effectiveness & practicality for QA.

2. Recommend test protocols for NDT technologies for QA programs for:
   - Embankment Soils
   - Aggregate Base Materials
   - HMA Mixtures

= Practical & Effective tools for Routine use in QA Programs.
Overview: Project Locations

- Number of materials within a project.

3 - Number of materials within a project.
Overview: The Hypotheses

NDT Test Method:

2. Provides an accurate estimate of material-layer properties.
3. Provides an accurate measure of the mean & variance of lot.
4. Is insensitive to surface condition or texture of the surface.
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NDT Technologies: Deflection-Based Methods

Elastic Modulus
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NDT Technologies: Seismic-Based Methods

Seismic & Resilient Modulus
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NDT Technologies

Strength-Based Methods

Penetration Rate & Resilient Modulus

Penetration Rate & Penetration Rate & Resilient Modulus

- Elastic Modulus, ksi
- Average Depth, mm

- Section 94A
- Section 94B
- Section 94C
- Section 98A
- Section 98B
- Section 98C
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NDT Technologies
Volumetric-Based Methods
NDT Technologies

Compaction-Response Based Methods
NDT Technologies

Ground Truth = Existing QA Program

- Cores & Nuclear Gauge Readings
- Sand Cones & Nuclear Gauge Readings
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Testing Plan
Unbound Material/Soils Section

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### Success Rates In Identifying Anomalies

<table>
<thead>
<tr>
<th>NDT Device</th>
<th>Success Rate, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSPA</td>
<td>86</td>
</tr>
<tr>
<td>GeoGauge</td>
<td>79</td>
</tr>
<tr>
<td>Dynamic Cone Penetrometer</td>
<td>64</td>
</tr>
<tr>
<td>Deflection-Based Devices</td>
<td>64</td>
</tr>
<tr>
<td>Ground Penetrating Radar</td>
<td>43</td>
</tr>
<tr>
<td>Non-Nuclear Density Gauge</td>
<td>36</td>
</tr>
</tbody>
</table>
Repeated Load Resilient Modulus Testing of Unbound Materials

Confinement = 3 psi
Confinement = 6 psi
Confinement = 10 psi
Confinement = 15 psi
Confinement = 20 psi

Resilient Modulus, psi vs. Bulk Stress, psi

US-280 Crushed Stone
Adjustment to Laboratory Conditions

- Select stress state from lab tests
- Use average NDT modulus in areas without anomalies
- Determine average ratio of NDT to lab resilient modulus
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Lab. Versus NDT Values; Adjusted to Lab Condition
### Lab. Versus Adjusted NDT Modulus Values

<table>
<thead>
<tr>
<th>NDT Device</th>
<th>GeoGauge</th>
<th>DSPA</th>
<th>DCP</th>
<th>LWD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean Residual, ksi</strong></td>
<td>-0.117</td>
<td>0.149</td>
<td>-0.078</td>
<td>0.614</td>
</tr>
<tr>
<td><strong>Standard Error, ksi</strong></td>
<td>2.419</td>
<td>4.486</td>
<td>3.768</td>
<td>5.884</td>
</tr>
</tbody>
</table>
Effect of Physical Changes on Seismic Modulus

![Graph of Seismic Modulus vs. Moisture Content]

- *X* Sesimic Modulus, ksi
- ◆ Dry Density, pcf
- -- Poly. (Sesimic Modulus, ksi)
- --- Poly. (Dry Density, pcf)

Moisture Content, I-85 Embankment, percent

Dry Density, pcf

Sesimic Modulus, ksi

ARA

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Modulus Growth Curves for Base Material; Lower Quality Base

- **DCP**
- **GeoGauge**
- **Log. (GeoGauge)**
- **Log. (DCP)**

Graph showing resilient modulus from NDT devices (ksi) vs. number of roller passes.
GeoGauge is Recommended; Why?

- Adequately identified anomalies.
- Adequately ranked the relative order of materials.
- Provides measure of resilient modulus.
- Output correlated to dry density.
- Coefficient of variation is less than other devices.
- Easily used to measure increasing resilient modulus with increasing compaction/density.

Moisture content and density must be measured with other devices.
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HMA Mixtures

US-280 HMA Base
Supplemental Testing

TH-23 HMA Base

SH-130 HMA Base

US-280 HMA Base Initial Testing

I-85 SMA Overlay
Section 1 to 3
Tested 1 day after paving

Section 4
Tested on day of paving

Low Asphalt Content
## Success Rates for Identifying Anomalies

<table>
<thead>
<tr>
<th>NDT Devices</th>
<th>Success Rate, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portable Seismic Pav’t. Analyzer</td>
<td>92</td>
</tr>
<tr>
<td>Non-Nuclear Gauge</td>
<td>77</td>
</tr>
<tr>
<td>Ground Penetrating Radar</td>
<td>50</td>
</tr>
<tr>
<td>Deflection-Based Device</td>
<td>50</td>
</tr>
</tbody>
</table>
Dynamic Modulus – HMA Mixes

US-280 HMA Base Mixture; Initial Mixture
# Adjustment to Laboratory Condition

<table>
<thead>
<tr>
<th>HMA Mixture</th>
<th>Dynamic E, ksi</th>
<th>Adjustment Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>PSPA</td>
</tr>
<tr>
<td>SMA Overlay</td>
<td>230</td>
<td>1.03</td>
</tr>
<tr>
<td>12.5 mm HMA Base Mix</td>
<td>440</td>
<td>1.11</td>
</tr>
<tr>
<td>19 mm HMA Base Mix</td>
<td>350</td>
<td>1.32</td>
</tr>
<tr>
<td>25 mm HMA Base Mix</td>
<td>600</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>950</td>
<td>0.36</td>
</tr>
</tbody>
</table>
### Lab Versus Adjusted NDT Modulus Values

<table>
<thead>
<tr>
<th>NDT Device</th>
<th>PSPA</th>
<th>FWD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Residual, ksi</td>
<td>13.5</td>
<td>39.0</td>
</tr>
<tr>
<td>Standard Error, ksi</td>
<td>76</td>
<td>87</td>
</tr>
</tbody>
</table>
HMA Mixture Testing; Comparisons with IC Rollers
PSPA is the Recommended NDT Device: Why?

- Provides measure of elastic or dynamic modulus.
- Adequately identified anomalies.
- Adequately ranked the relative order of materials.
- Elastic modulus correlated to HMA density.

Can not be used to establish roller pattering. Asphalt content & density measured with other devices.
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Recommended Devices

Unbound Materials

HMA Materials or Layers
## Summary of NDT Application to QA Programs

<table>
<thead>
<tr>
<th>QA Property</th>
<th>Unbound Materials</th>
<th>HMA Mixtures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulus</td>
<td>GeoGauge</td>
<td>PSPA</td>
</tr>
<tr>
<td>Thickness</td>
<td>GPR</td>
<td>GPR</td>
</tr>
<tr>
<td>Density</td>
<td>Nuclear/Sand Cone</td>
<td>1 – Cores/Nuclear</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 – Non-Nuclear</td>
</tr>
<tr>
<td>Fluids Content</td>
<td>Oven Dry</td>
<td>Ignition Oven</td>
</tr>
<tr>
<td>Air Voids, Saturation</td>
<td>---</td>
<td>GPR</td>
</tr>
</tbody>
</table>
Acknowledgements:

- Minnesota DOT; Skiekmier & Bolland
- Dunnick Brothers, Mn.
- Alabama DOT; Fuller
- Scott Bridge Company
- East Alabama Paving
- NCAT, Prowell
- Tx. Turnpike Authority, Wade
- Avlis Engineering, Tam
- Humboldt, Fielder
- CarlBro/Fugro
- Dynatest
- Salut, Horan
- BOMAG, Connelly
- Catepillar
- Ammann, Fox
- N. Dakota
- Ohio DOT
- Michigan DOT
- Missouri DOT
Thank you.
Any Questions?