Implementation of Electro-Magnetic Gauge Readings for Assessing Hot Mix Asphalt Quality

R. Christopher Williams
Matt Mason
Andrea Kvasnak

SEAUPG Meeting
November 18, 2008

Quality Assurance

• Varies from one agency to the another
• Density often an indicator
• Traditionally:
  – Cores pulled from multiple locations
  – Density checked by contractor or owner/agency
• Other methods
  – Nuclear Gauges
  – Non-Nuclear Gauges

Quality Assurance

• Bulk Specific Gravity
  – Air Voids (AV)
  – Voids in the Mineral Aggregate (VMA)
  – Voids Filled with Asphalt (VFA)
  – Density (% Gmm)

• While only 1 of 31 states directly specifies Bulk Specific Gravity, all but 2 of 31 use it by specifying AV, VMA, or Density (Burati et al., 1999).

Saturated Surface Dry

• AASHTO T 166 or ASTM D 2726
• Most common method for determining the bulk specific gravity
• Dry weight, submerged weight, and saturated surface dry weight
• Not appropriate for coarse mixes
  – Interconnected air voids
  – Significant surface irregularities

Paraffin and Parafilm Method

• AASHTO T 275 and ASTM D 1188
• Samples with open or interconnected air voids
• Weight of uncoated in air, coated in air, and coated in water
• Film/Wax prevents future use of specimen
• Film/Wax is messy

Vacuum Sealing Method

• ASTM D 6752
• Weight of specimen in air, bag, sealed specimen in air, and sealed specimen in submerged
• Good for coarse mixes
Nuclear Gauges

- Most common non-destructive method
- Not as accurate as core densities
- Quick and limited human interaction
- Special training and certification
- Many studies concluded only good for quality control

Non-Nuclear Gauges

- Electro-magnetic
- Non-destructive devices
- Commercially available 1998
- Pavement Quality Indicator (PQI)
- PaveTracker
- No special training or certification

Pavement Quality Indicator

- Trans-Tech Systems
- Measures changes in electrical impedance of material
  - Function of composite resistivity and dielectric constant of material
- Electrical field produced by electrical charge
- Measure strength of electric field

Concept Behind Non-Nuclear Gauges

- As pavements become more dense:
  - ↓ air volume: other components volume
  - Δ dielectric constant
  - Δ electrical signal
- Only component changing is air

PaveTracker

- Troxler Electronics Lab

Field Sites- 2006 Paving Season

- 15 field sites
- 3 Aggregate types
  - 2 slag/limestone
  - 2 quartzite
  - 11 limestone
- 12.5 or 19.0mm NMAS
- Low and high volume traffic levels
- 2" to 6" lifts
Field Sites, Cont.

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Paving Contractor</th>
<th>Aggregate</th>
<th>Binder (500 kg/m³)</th>
<th>Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Limebacker</td>
<td>4.34</td>
<td>10.0</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Limebacker</td>
<td>4.34</td>
<td>10.0</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>Limebacker</td>
<td>5.30</td>
<td>12.5</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>Limebacker</td>
<td>5.81</td>
<td>12.5</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>Limebacker</td>
<td>5.47</td>
<td>12.5</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>Limebacker</td>
<td>4.94</td>
<td>12.5</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>Limebacker</td>
<td>5.00</td>
<td>12.5</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>Limebacker</td>
<td>5.39</td>
<td>17.5</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>Quartz</td>
<td>4.65</td>
<td>12.5</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>Limebacker</td>
<td>5.60</td>
<td>12.5</td>
</tr>
<tr>
<td>11</td>
<td>4</td>
<td>Limebacker</td>
<td>6.30</td>
<td>18.5</td>
</tr>
<tr>
<td>12</td>
<td>4</td>
<td>Limebacker</td>
<td>5.89</td>
<td>12.5</td>
</tr>
<tr>
<td>13</td>
<td>1</td>
<td>Limebacker</td>
<td>6.16</td>
<td>12.5</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>Blain, Ltd.</td>
<td>5.61</td>
<td>12.5</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>Quartz</td>
<td>5.10</td>
<td>18.0</td>
</tr>
</tbody>
</table>

Pavement Quality Indicator

- Single readings every 1 ft
- 1 Random reading per location (cloverleaf)
- All readings dry except for final random reading per station
- PaveTracker
  - Four readings every 1 ft
  - All readings dry except a random wet reading per station

Reading Locations

PaveTracker

Paving Condition

- Most readings were dry
- Wet readings were collected last
- Approximately 10 oz. poured on pavement
Readings

- PQI
  - Cloverleaf
  - Four overhangs
- PaveTracker
  - Four turns
  - No overhangs

What is of Interest?

- Sensitive to roller passes?
- Sensitive to the presence of moisture?
- Sensitive to aggregate?
- Similar to cores?
- Similar to one another?
- Same mixes passing as cores?

Analysis Tools, Cont.

- Why look at ANOVA and Regression?
  - ANOVA evaluates class variables
  - Regression relates significance and relationship of class and continuous variables
  - Class variables are easier for contractor to control or know ahead of time
  - Example: Aggregate type is known before paving begins, however, asphalt content could vary from JMF

Analysis Tools, Cont.

- Difference between regression/ANOVA and mean comparisons:
  - Regression and ANOVA evaluate the significance of a variable
  - Mean comparisons evaluate differences between levels within a variable
  - Example: Regression/ANOVA deems density device significant, but mean comparisons relates which density devices yield statistically different results

PaveTracker ANOVA

- Data collected every foot
- Affect density readings?
  - Site
  - Random Station
  - Pavement Condition
  - Contractor
  - Aggregate Type
  - NMAS
  - Roller Pass
  - Distance Across Pavement

PaveTracker Regression

<table>
<thead>
<tr>
<th>Important</th>
<th>Not Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station</td>
<td>Site</td>
</tr>
<tr>
<td>Pavement Condition</td>
<td>Traffic Level</td>
</tr>
<tr>
<td>Contractor</td>
<td>Pavement Width</td>
</tr>
<tr>
<td>Aggregate</td>
<td>Transverse location</td>
</tr>
<tr>
<td>Binder Content</td>
<td></td>
</tr>
<tr>
<td>NMAS</td>
<td></td>
</tr>
<tr>
<td>Roller Pass</td>
<td></td>
</tr>
</tbody>
</table>

2008 SEAUPG CONFERENCE-BIRMINGHAM, ALABAMA
PaveTracker Field Mean Comparisons

- Site (15 Levels)
- Pavement Condition (2 Levels)
- Contractor (7 Levels)
- NMAS (2 Levels)
- Traffic Level (5 Levels)
- Aggregate Type (3 Levels)
- Roller Pass (3 Levels)

PaveTracker Field Mean Comparisons, Cont.

- Site
  - 3 sites significantly different
  - Failing subgrade (1), slag (1), ? (1)
- Pavement Condition
  - Wet significantly different than dry
- Contractor
  - 2 significantly different
  - Slag (1), only 1 mix collected (1)

- NMAS
  - No differences
- Traffic Levels
  - All different
  - Related to gradation perhaps
- Roller Pass
  - All different
  - Gauges sensitive to changes in density

Single Mode PQI Field Regression

Important
- Station
- Pavement Width
- Distance Across Pavement
- Pavement Temperature

Not Important
- Site
- Contractor
- Aggregate Type
- Binder Content
- NMAS
- Traffic Level
- Roller Pass

Single Mode PQI Field Mean Comparisons

- Site
  - Slag (2) and sampled once (2)
- Contractor
  - Almost all
- NMAS
  - None
- Traffic Level
  - Almost all
- Aggregate Type
  - Slag
- Roller Pass
  - All
Multi-Mode PQI Field Regression

**Important**
- Site
- Width
- Contractor
- Aggregate Type
- Binder Content
- Roller Pass
- Distance Across

**Not Important**
- Station
- Condition
- NMAS
- Traffic Level

Multi-Mode PQI Field Mean Comparisons

- Site
  - Slag: 4 significantly different
- Contractor
  - Most
- NMAS
  - None
- Traffic Level
  - Most
- Aggregate Type
  - No difference
- Roller Pass
  - All but Final and 2nd to last
- Pavement Condition
  - Wet different than dry

Significant Variables for Both Single and Multi-Mode PQI Field

- ANOVA
  - Site, station, roller pass, and distance across a pavement
- Regression
  - Station, pavement width, and distance across a pavement

Significantly Different Levels

- Site
  - 3 sites deemed statistically different than the others
  - Additional uncommon sites were identified
- Contractors
  - Single Mode: Almost all
  - Multi-Mode: 3 different
- NMAS
  - Single and Multi-Mode: None
- Aggregate Type
  - Single Mode: Slag different
  - Multi-Mode: None

Reason for Differences

- Multi-Mode only looked at one spot per station
  - Compared to 12-24 locations per stations for single mode
- Single mode has more data
  - Outliers less likely to affect analysis and quality/density assessment

Core Readings

- Typically 7 cores pulled per site
- Compared core densities to gauge densities
- Core density used as control
Mean Density Comparison

Coefficient of Variation

Analysis

- PQI almost always the most variable
- PQI yielded the highest values in most cases
- PaveTracker almost always the lowest values
- Coefficient of variations are the most similar for cores and PaveTracker

Field Conclusions

- PQI yields higher mean densities
- PQI yields higher standard deviation
- Sensitive to roller passes
- Both PQI and PaveTracker have issues with pooled water

Quality Assurance Conclusions

- PQI resulted in passing almost all of the same sites as cores without a correction factor
  - Not PaveTracker
- PaveTracker agreed with cores once correction factor applied
  - Not PQI
- Gauges will need to be calibrated against field cores.

2nd Phase- 2007 Paving Season

- Evaluate core and electro-magnetic gauge adjustment factors
  - Are the adjustment factors the same from one paving day to the next?
  - How improved are the latest electro-magnetic gauges?
- We are confident the technology can be implemented for QA/QC
  - How many readings are needed to represent at least the same assessment of quality as cores?
  - What is the trigger for re-establishing the adjustment factor?
Outcomes of Phase 2 Work

- We can overcome issues identified in the 1st phase by calibrating gauges with cores from first day of production and use on ensuing days of production.
- Two options:
  - Gauge identifies non-compliance- verify with cores.
  - Calibrate gauge with reduced number of cores daily and use more gauge readings for quality assurance program.
- PaveTracker appears to be preferred over the PQI.

Next Steps

- Developing shadow specification for use in the upcoming construction season in existing QC/QA program
- Updated for inclusion in percent within limit specifications

Other Technologies Being Considered by DOTs

- Corelok for density testing
- Permeability
  - NCAT permeameter
  - Falling head permeameter (Karol-Warner)
  - ROMUS permeameter

Acknowledgements

- Iowa Department of Transportation
  - John Hinrichsen, Mike Heitzman & field personnel
- Asphalt Paving Association of Iowa and its members
  - Mike Kvach, Steve Sorenson, George Jessen