Asphalt Compaction Evaluation using GPR: TH 52 and TH 14 Field Trial

Dr. Kyle Hoegh, MnDOT
Dr. Shongtao Dai, MnDOT
Pavement density has great effects on performance.

- Lack of density --- localized failure
- 1989 – “Effect of Compaction on Asphalt Concrete Performance” (Wash.DOT)
  Each 1% increase in air voids (over 7 percent) tends to produce ~10 percent loss in pavement life.

Core used to determine density

- At a particular location, does not represent the entire pavement density.
- Need a way to obtain full coverage of the surface
  - GPR is a potential tool: Continuous profile
  - Locate relative high or low density areas based on dielectric map
Equipment

Data Collection Video

3D Radar and Rolling Density Meter
Wave propagation in solids

Provides full coverage
Summer Testing Objectives

Selected TH52 (D6) and TH14 (D6)

- Validate calibration methodology on large scale pavements.
- Make recommendation for feasibility of implementation.
  - i.e. when it can and can’t be used
  - Assess repeatability of the method
- Gathering data necessary for specification development.
Project #1 (Summer 2016)

- **TH52 (D6):**
  - ~7 miles
  - M&O: Mill 1.5” and overlay 2x1.5”
  - 4 Test Sections (FHWA funding)
    - No added binder + 4 rollers (control)
    - Added binder (+0.3%) + 4 rollers
    - No added binder + 5 rollers
    - Added binder (+0.3%) + 5 roller
  - The entire 7 mile project was scanned
    - 30 scans per foot (10 scan-4 in. moving average used in analysis)
    - 3 antenna measurements per pass
    - Core calibrations along the entire project were used to develop a model relating RDM measurements to air void measurements
Project #2 (Summer 2016)

TH14 (D6):

- 14 miles
- M&O: Mill 2” and overlay 2” and 1.5”
- 4 Test Sections:
  - ¾” mix + 3 rollers (control)
  - ¾” mix + 4 rollers
  - ½” mix + 3 & 4 rollers
  - ½” mix (Evotherm) + 3 rollers
  - ¾” mix (Evotherm) + 3 rollers
- Scanned 11 Miles on Top lift
  - 30 scans per foot (10 scan-4 in. moving average used in analysis)
  - 3 antenna measurements per pass
  - Core calibrations along the entire project were used to develop a model relating RDM measurements to air void measurements
General Process

- On-Site Identification of high and low levels of compaction

5% Air Voids

10% Air Voids
Relating Dielectric Measurements to Air Void Content

$y = 15.652e^{-1.013x}$  
$R^2 = 0.6887$

Core Measured Air Voids

RDM Measured Dielectric

TH52

TH14
Relating Dielectric Measurements to Air Void Content

Lab Measured Air Voids vs. Dielectric

- Afton
- Monticello
- Power (Afton)
- Power (Monticello)

3D Radar

- UMN
- MN
- RDM

UMN Maine RDM

UMN Nebraska RDM
Uncertainty in Core Measured Air Voids

Hall, K. D., F. T. Griffith, and S. G. Williams. TRB Record No. 9 1761, pp. 81-85.
Highway 52 Findings - Histogram

- All Data Collected
  - Sampling Rate = 0.4 in/scan.
  - > 26 million measurements
  - Analysis based on 4 in. moving average
  - Equivalent to >1 million cores
- Summary Stats
  - 6.78% Median Air Voids
  - 97.5% locations less than 9% air voids
RDM Comparison of Test Sections

- Section with added binder + 5 rollers has highest density
## TH 52 – All Test Sections Cores

### Comparison of Test Sections

- Section with added binder + 5 rollers has highest density in both cores and RDM measurements
- Insignificant differences otherwise

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<th>Both Lanes</th>
<th>Control (4R+No Added Binder)</th>
<th>5 R on No Added Binder</th>
<th>4 R on Added Binder</th>
<th>5R on Added Binder</th>
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<tr>
<td>n Data</td>
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TH 52 - Sorted Histograms

- **Top lift Mainline Left and Right Lane Summary:**
  - 6.4% (R) and 6.6% (L) air voids respectively
  - **Density:**
    - Right: 93.6%
    - Left: 93.4%
  - **STD:** 1% and 0.9%
  - **97.5% locations below 8.4% air voids for both lanes**

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Blue – Right Lane (4’-8’)
Red – Left Lane (4’-8’)

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![Histogram](image-url)
Top lift Joint Unconfined and Confined Summary:
- 8.69% (UCJ) and 7.29% (CJ) air voids, respectively
- Density:
  - UCJ: 91.3%; CJ: 92.7%; R = 98.5%
- STD: 1.8% (UCJ) and 1.2% (CJ)
- 97.5% locations below 11.99% (UCJ) and 10.2% (CJ) air voids, respectively
Top lift Mainline and Confined Joint Summary:

- 6.59% (ML) and 7.29% (CJ) air voids, respectively
- Density:
  - CJ=92.7%; ML=93.4%; R=99.3%
- 97.5% locations below 8.37% and 9.69% air voids, respectively
TH 52 - Sorted Histograms

- **Top lift Mainline vs Confined and Unconfined Joints**
  - 6.59% (ML), 7.29%(CJ) and 8.69(UCJ) air voids, respectively
  - **Density:**
    - CJ=92.7%; UCJ=91.3%; ML=93.4%
    - UCJ/ML=97.7% (ML-UCJ=2.1%); CJ/ML=99.3% (ML-CJ=0.7%)
  - 97.5% locations below 8.11%(ML), 9.89%(CJ) and 10.7(UCJ) air voids, respectively
TH 52 - Sorted Plots

Break data down by location

Red = Left Lane Mainline
Green = Right Lane Mainline
Yellow = Confined Joint
Blue = Unconfined Joint
TH 52: Comparison with other Factors

Import RDM data into Veta for comparison with IC and other data.
TH 52 – Experimental Design

Results in Left Lane Mainline

No significant difference in control mix from 4 rollers (red) to 5 rollers (blue), except initial jump.
TH 52 – Comparison with other Factors

Import RDM data into Veta for comparison with IC and other data

Local decreases (blue) at unconfined edges

Local Increase after Added Roller

dielectric
• 3D Radar can provide better coverage and precision at a tighter spacing. However RDM has advantages too:
  • Less Expensive
  • Requires less user expertise (ex. Antenna Correction)
  • RDM is easier to operate close to joints when adjacent lanes are open to traffic
  • Real time results (easier for providing on-site feedback)
TH 14 – All Test Sections

Comparison of Test Sections

- Adding a roller: compaction density increase on this project.
- Adding Evotherm: not much difference on compaction.
- Mix B (3/4-) to A(1/2-): not much difference on compaction.
TH 14 – All Test Sections

- Comparison of Test Sections (Core data)
Percent within limits (PWL) implications

- Good measure if enough data: takes into account magnitude and spread in data
- < 10 data points for each QA Core assessment:
  - Core PWL st.dev > 10 percent
- >150,000 data points for each RDM assessment
TH 14 -Sorted Histograms

- 3 Roller on ¾” Mix: Confined Joint and Mainline.

- Summary Stats
  - 5.23 (ML) and 5.06 (CJ) dielectric, respectively
  - STD: 0.11 and 0.11, respectively
  - 3.6% higher dielectric in mainline
  - CJ/ML = 96.7%
TH 14 - Sorted Histograms

- 3 Roller on ¾” mix (Evotherm): Confined Joint and Mainline.

Summary Stats
- 5.22 (ML) and 5.20 (CJ) dielectric, respectively
- STD: 0.10 and 0.09, respectively
- 0.4% higher dielectric in mainline
  - CJ/ML = 99.6%
TH 14 - Sorted Histograms

4 Roller on ¾” Mix: Confined Joint and Mainline.

- Summary Stats
  - 5.40 (ML) and 5.29 (CJ) dielectric, respectively
  - STD: 0.10 and 0.12, respectively
  - 2.1% higher dielectric in mainline
  - CL/ML = 97.9%
TH 14 - Sorted Histograms

4 Roller on ½” Mix: Confined Joint and Mainline.

Summary Stats

- 5.38 (ML) and 5.35 (CJ) dielectric, respectively
- STD: 0.09 and 0.09, respectively
- 0.6% higher dielectric in mainline
  ✶ CJ/ML=99.4%
Implementation Recommendations:

**Longitudinal Joint (RDM)**
Recommendation #1 - LJ:

Require dielectric distribution readings from RDM per 500ft.

Ex: Require E of 5.31 \(\geq\) 90% density?

E of 5.31 includes > 95% data

Take cores at E=5.31, Then measure density
Recommendation #2 - LJ:

Require RDM readings at the longitudinal Joint and X distance away from the Joint, use % difference of dielectric.  

(No cores required)

Ex: Require Joint E >= 92% of mainline E ?

91.45% different
Implementation Recommendations:

Mainline – 3D GPR
Recommendation #3A - M(3DGPR)

Survey the whole project surface
Require dielectric distribution from 3DGPR every 500ft.
Example A: Require E of 5.2 = 92% density?
E of 5.2 includes > 95% data
take cores at E=5.2,
then measure density

Dielectric Map

Surface Arrival Amplitude
Longitudinal Distance from Starting Point, feet
Transverse Distance from the Longitudinal Joint, feet
Recommendation #3B - Mainline (3DGPR):

Require a test strip to establish the dielectric histogram and establish E and density relationship

Example B: E of 5.2 = 92% density

E of 5.2 includes > 95% data

take cores at E=5.2, then measure density

Require to construct test strip where material changes

Then use established histogram for project acceptance: dielectric distribution on mainline should be similar. 95% data should > 5.2.

(No cores required)
Summary

- GPR can provide a continuous coverage of the relative compaction levels (higher dielectric = higher compaction)

- Histograms and general statistics can be used to give a complete assessments of the in-place compaction

- Potential Uses:
  - Assess compaction uniformity for QC/QA.
  - Provide on-site feedback to contractor of high and low compaction locations that they can cross-check with differences in mix or paving strategies in those locations to determine optimal construction procedures
  - Identification of trends in the air void content maps that can be cross-checked with IC and other data to determine the most critical factors in achieving higher density