HMA COMPACTION ASSESSMENT USING GPR ROLLING DENSITY METER

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The Importance of Density

- Optimum density provides:
  - Reduced oxidation
  - Reduced moisture damage
  - Decreased rutting potential
  - Improved fatigue life
  - Increased load bearing capacity

- Past studies relating density to pavement life
  - Rule of thumb: 1 % decrease below minimum results in 10% loss of life

Uniform density throughout the pavement layer is critical
Enemy of Density: Segregation

- Two main types of segregation
  - Mechanical (aka physical or gradation)
  - Thermal
- Often identified visually; subjective
- May not be apparent at time of construction
- Difficult to quantify
- Very difficult to enforce contractually
- Major cause of premature pavement failures
Rapid Technologies to Enhance Quality Control on Asphalt Pavements (R06C)

Two non-destructive techniques for evaluating asphalt pavements during construction

- Infrared thermal scanning
- Ground Penetrating Radar

- Measures uniformity and potential defect areas in asphalt pavements during construction.
- Offers real-time testing of potentially 100 percent of the pavement area.
Current Density Tests

Density gauge (Nuclear or electrical)

Core samples

Typical random sampling measures ≈ 0.003 % of pavement area
• Widely used for many applications
  – Utility location
  – Pavement thickness
  – Bridge deck deterioration

• Uses electromagnetic wave reflection to “see” through materials

• Research for decades to use for pavement density
  – Accuracy never achieved
• Measures dielectric properties of asphalt surface
• Dielectric constant - ability of a substance to store electrical energy in an electric field
  – Air dielectric: 1.00059
  – Asphalt, aggregate ≈ 3 to 6
  – Water: 80
  – New pavement: mixture is uniform; dielectric variation primarily caused by % air voids – directly relates to density
• Based on ratio of reflection from asphalt surface to reflection from metal plate
  – Approximately 1” -1.5” into layer – not reading entire layer thickness
GSSI PaveScan RDM

• Three – 2GHz antenna
• Portable push cart
• Capable of scanning 6’ width
• Onboard computer
  – Captures dielectric values
  – Can be correlated to core densities
Metal plate calibration
Correlation procedure

- Scan a pavement section
- Device identifies high, low, median density locations
- Take static reading directly over each location
- Obtain cores at each location
- Test cores; enter results in software

Correlation accuracy depends on obtaining core densities over entire range of measured dielectric values
Typical density profile
Limitations

Affected by:
- Surface moisture
- Temps below 40 F
- Mix constituents (change in aggregate source, etc.)

Layers < 1”: accuracy affected by underlying layer

Layers > 2.5” – 3”: affected by density gradients within layer

Density varies with depth

< 1”

> 3”
Further enhancements

- Some users are adapting with vehicle mounts
- Minnesota DOT – leaders in data analysis
- Single antenna cart units - lower price
- Being investigated for longitudinal joint use
- Incorporation into VETA software
  - Data analysis of Intelligent compaction, thermal profile, and (soon) GPR density
Minnesota Experience on RDM

• Shongtao Dai, MnDOT
• Kyle Hoegh, MnDOT
Acknowledgements

- FHWA/AASHTO
- GSSI
- MnDOT district materials and constructions
MnDOT Uses Cores Density for Acceptance

Need a tool for continuous assessment: RDM

Longitudinal Joint deterioration

IC and IR Implementation

IC&IR are QC tools

RDM (GPR) can be a QA tool

RDM in 2015
MnDOT Equipment

- Push Cart Type RDM
- Vehicle Mounted RDM
RDM Principal

- Mainline Survey: multiple passes

- Joint Survey: one antenna close to joint
Equipment Calibration

- High Density Polyethylene (HDPE)
- Reported dielectric: 2.3-2.35
Underlying layer effect on surface measurement?

- How thick does the HMA layer need to be so that the underlying layer (agg. base) has no effects?

\[ h_1 = \frac{v^* \Delta t_1}{2} \]

\[ v = \frac{c}{\sqrt{\varepsilon_1}} \]

\[ dT \sim 0.439 \text{us} \]
Footprint area of an antenna (Fresnel Zone)?

Fr \sim 0.5 v (\text{tr/fc})^{1/2}

D=12"", Fr (Radius) \sim 3.6"" (for 2.7Ghz-RDM)
Use histogram to assess uniformity and quality.

- 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
  - 93.2% median density
  - STD: 1.18
  - 97.5% locations density > 90.8%
Examples: TH 52 – Left and Right Mainline

- Median Density
  - Right: 93.4%
  - Left: 93.1%

- STD: 0.92(R) and 0.96(L)

- 97.5% locations:
  - > 91.6% (R)
  - > 91.2% (L)
TOP LIFT MAINLINE VS CONFINED AND UNCONFINED JOINTS SUMMARY:

- 93.5% (ML), 92.6% (CJ) and 91.4% (UCJ)
- SD: 0.94 (ML); 1.22 (CJ); 1.8 (UCJ)
- Density:
  - UCJ/ML = 97.7%; CJ/ML = 99%
  - Core data: UCJ/ML = 95.1%
    CJ/ML = 99.1%
- 97.5% locations:
  - > 91.6% (ML),
  - > 90.2% (CJ)
  - > 87.8% (UCJ)
TH 14 – Mainline

- Comparison of Test Sections
  - Mix B (3/4-) to A(1/2-): not much difference on compaction.
  - Adding a roller: density slightly increased on this project.
  
  - Median Density:
    - Blue: 94.1%
    - Red: 94.2%
    - Yellow: 93.5%
    - Green: 93.3%
Core Locator for Implementation

- Automatic to identify core locations at the end of each paving day
  - At low and high dielectric locations
  - Ex: 10% and 90%
Generate core location text file and load to a GPS device to automatically guide field person to the core location for obtaining the core.

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- Measure dielectric constant on a gyratory specimen?
  - Establish Calibration Curve in Lab & Sensitivity Study
    - Currently use field cores for calibration: ex: 10% and 90%
    - Hope to establish calibration curve at lab in future
  - How does each component in a mixture affect dielectric constant, such as aggregate type, gradation, binder type and content?
Core Locator Application

Delrin
d=6cm (2.36")

Gyratory Measured Air voids versus Surface Dielectric

\[ AV = \exp \left(-7.53 \left(3.40 \left| e^{-7.97 \frac{1}{1-7.97}} - \frac{1}{1-7.97} \right| - 1\right)\right) \]

\[ R^2 = 0.97 \]

d=6cm (2.36")
Activities

- **Calibration of Equipment**
- **Field Testing:**
  - 2016: TH52 and TH14: Surveyed about 18 miles.
  - 2017: I35; TH52; Th22; Th60; CR86; Th110; CSAH13 and MnROAD
    - Hired American Engineering Testing (AET) to collect data
      - Educating consultant and contractors on this new technology
      - Testing application feasibility of vehicle mounted RDM system on construction projects.
  - 2018: “Ghost” specification and core locator – 1 or 2 projects
    - TH47, TH14, TH109 and TH50 so far
    - Work with GSSI on software improvements
- **Research on Laboratory Calibration**
  - **Gyratory Specimen**
Summary

- RDM is a good tool for mapping 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 density and 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.
For more information on improving the quality of asphalt pavements through SHRP2 products:

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For more information on Maine’s experience:

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