Minnesota Experience on RDM

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Acknowledgements

- FHWA/AASHTO
- GSSI
- MnDOT district materials and constructions
Why MnDOT is interested in?

- 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

\[ \varepsilon_{HMA} = \left( \frac{1 + \frac{A_0}{A_P}}{1 - \frac{A_0}{A_P}} \right)^2 \]
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?

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

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

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

Fr ~ 0.5 v (tr/fc)^{1/2}

D=12", Fr (Radius) ~ 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)
TH 52 – Longitudinal Joint

- 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%

10% 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

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

\[ R^2 = 0.97 \]

Measured Data
Regression Model

\[ t_0 \]
\[ t_2 \]
\[ d=6cm \ (2.36”) \]

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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
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.