



SHRP2 SOLUTIONS
TOOLS FOR THE ROAD AHEAD

Minnesota Experience on RDM

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U.S. Department of Transportation
Federal Highway Administration

American Association of State Highway and Transportation Officials
AASHTO

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

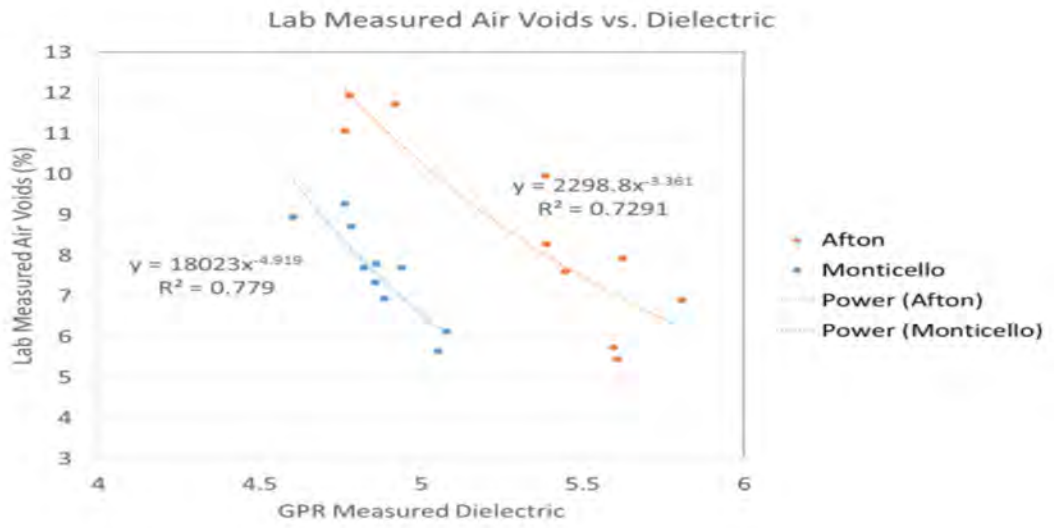
MnDOT Equipment

- Push Cart Type RDM

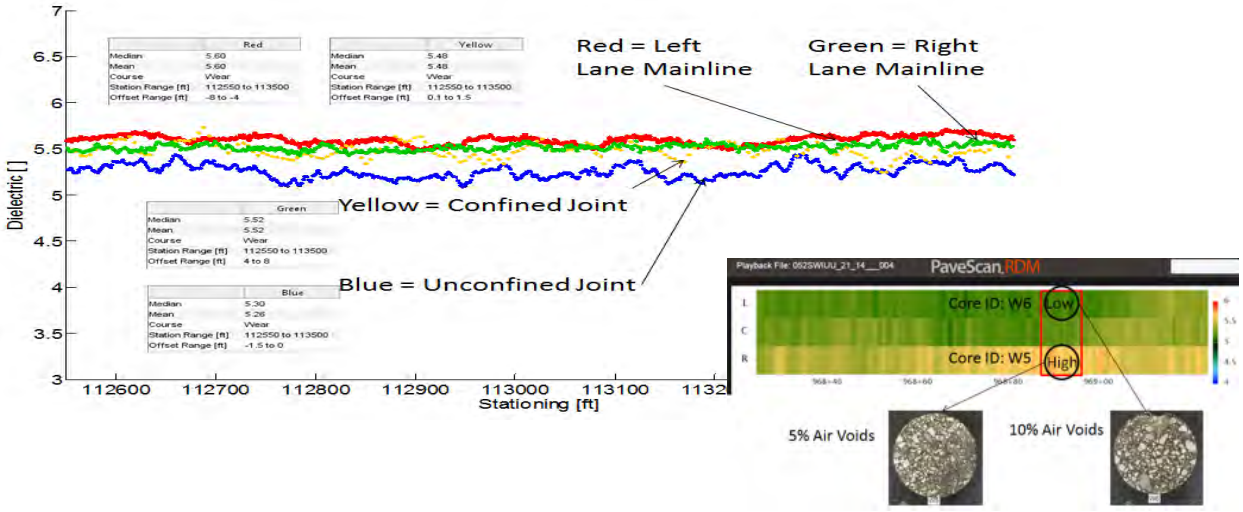
- Vehicle Mounted RDM

RDM Principal

- **Mainline Survey: multiple passes**



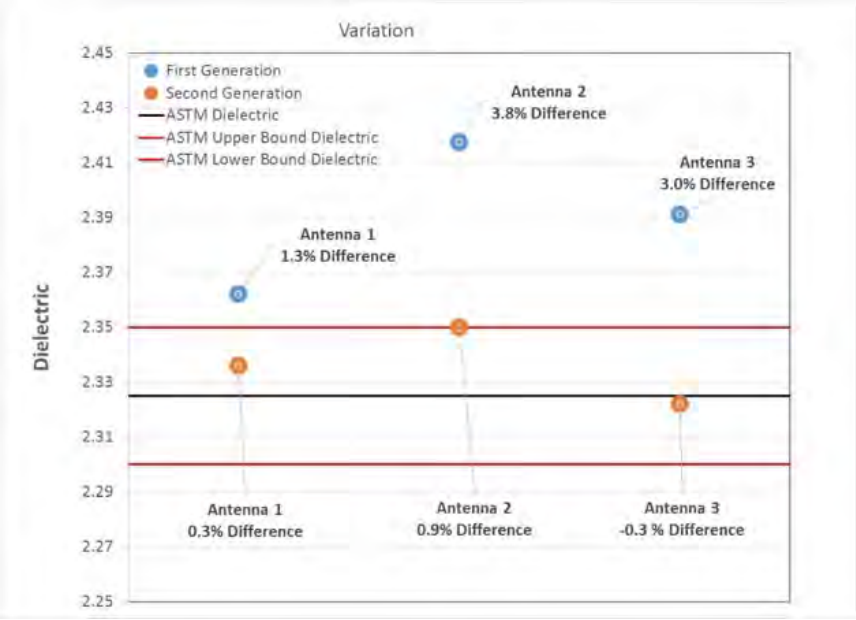
- **Joint Survey: one antenna close to joint**

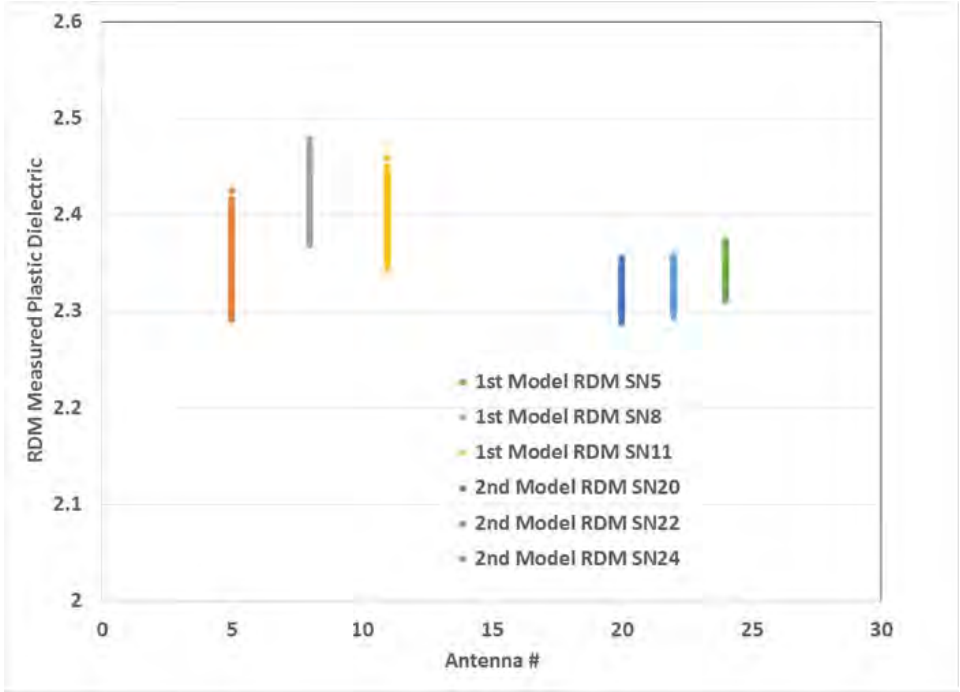


Equipment Calibration

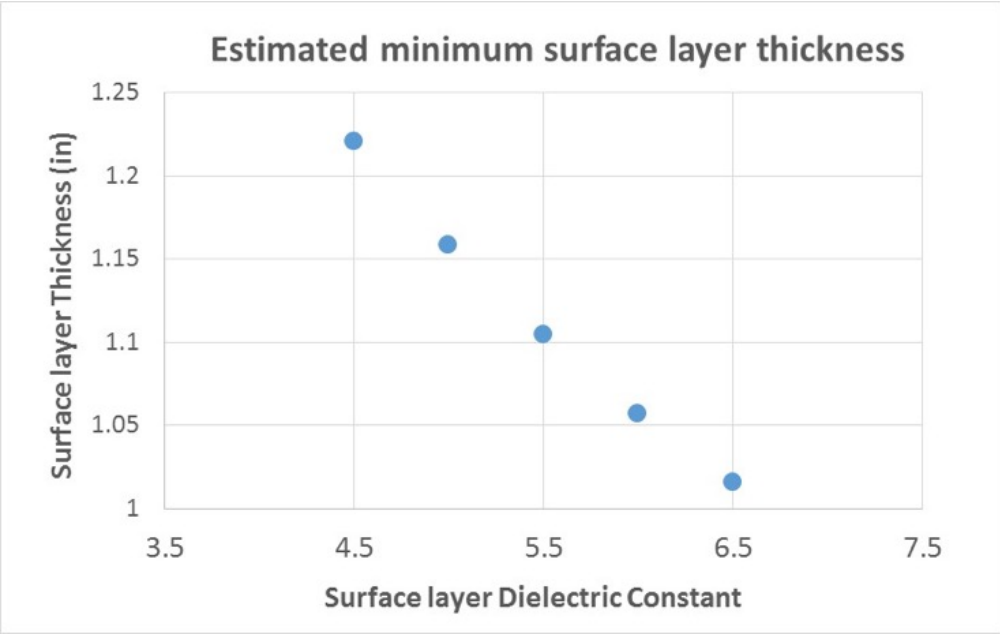
- High Density Polyethylene (HDPE)
  - Reported dielectric: 2.3-2.35

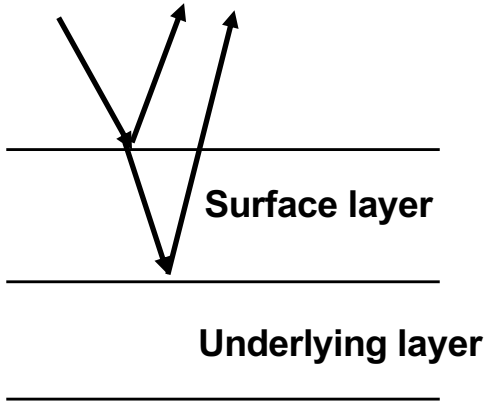
$$\varepsilon_{HMA} = \left(\frac{1 + \frac{A_0}{A_P}}{1 - \frac{A_0}{A_P}} \right)^2$$

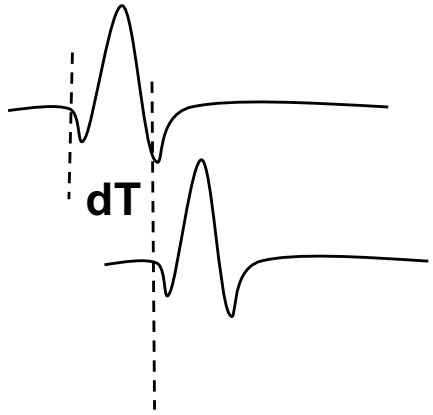




- Underlying layer effect on surface measurement?
  - How thick does the HMA layer need to be so that the underlying layer (agg. base) has no effects?







$$h_1 = v^* \Delta t_1 / 2$$

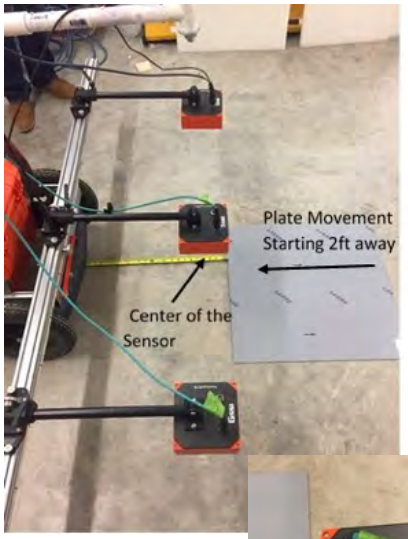
$$v = c/\sqrt{\varepsilon_1}$$

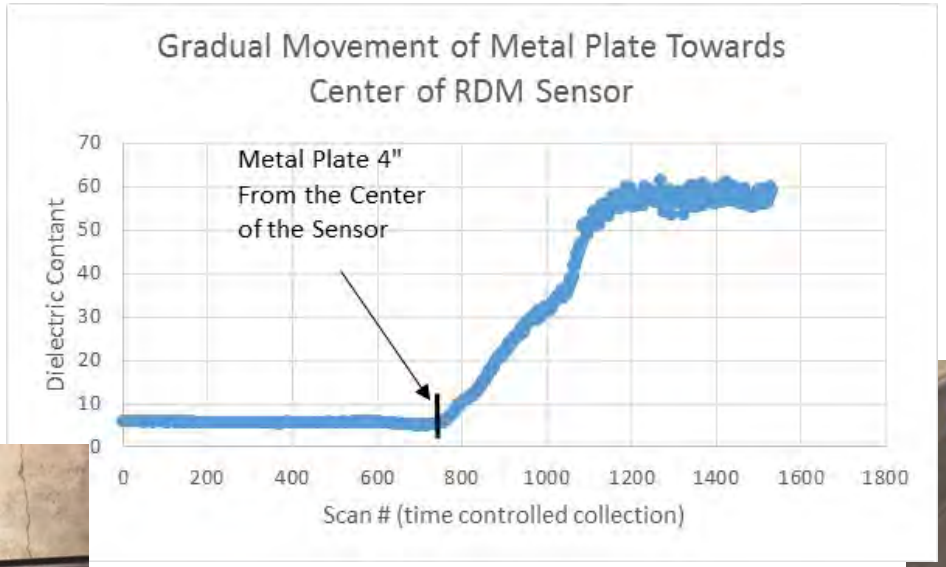
dT ~ 0.439us

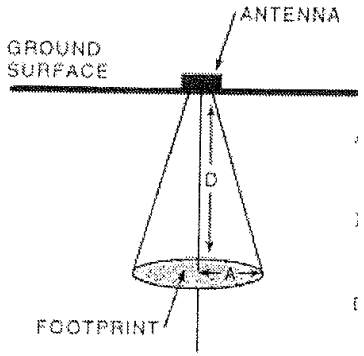
Footprint area of an antenna (Fresnel Zone)?

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

D=12”, Fr (Radius) ~ 3.6” (for 2.7Ghz-RDM)

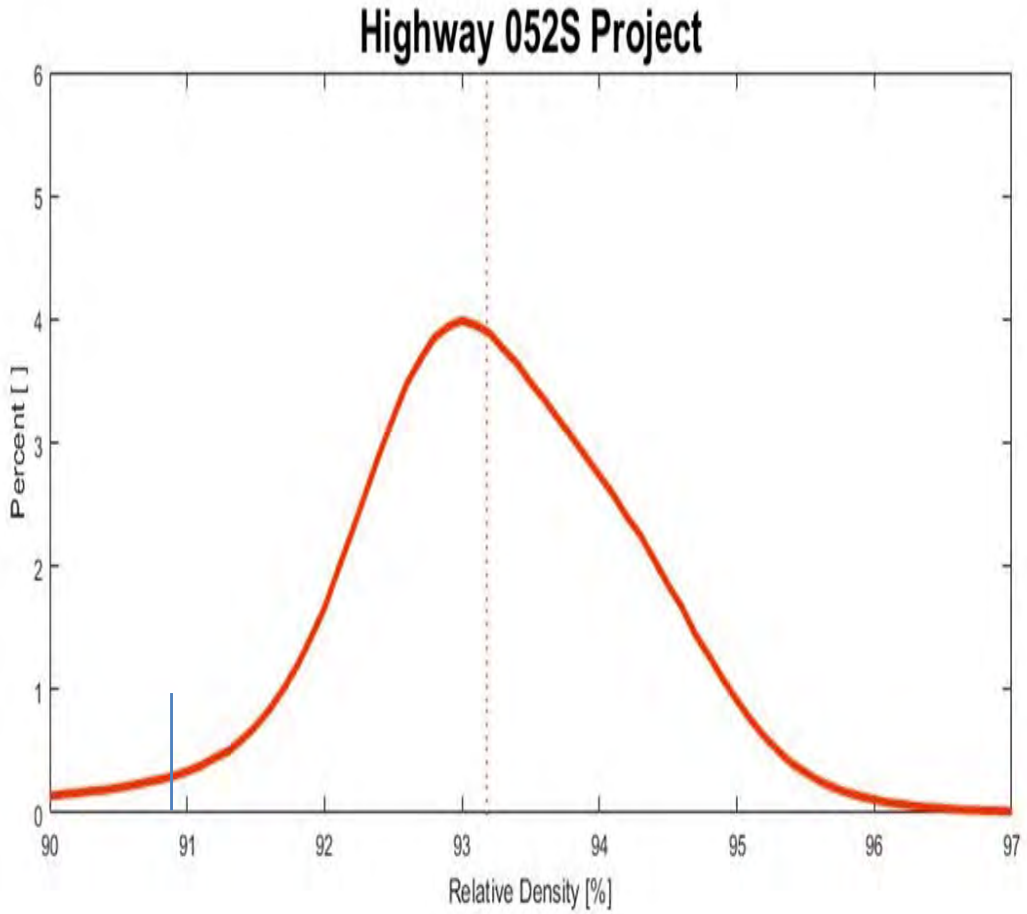






Histogram

- **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

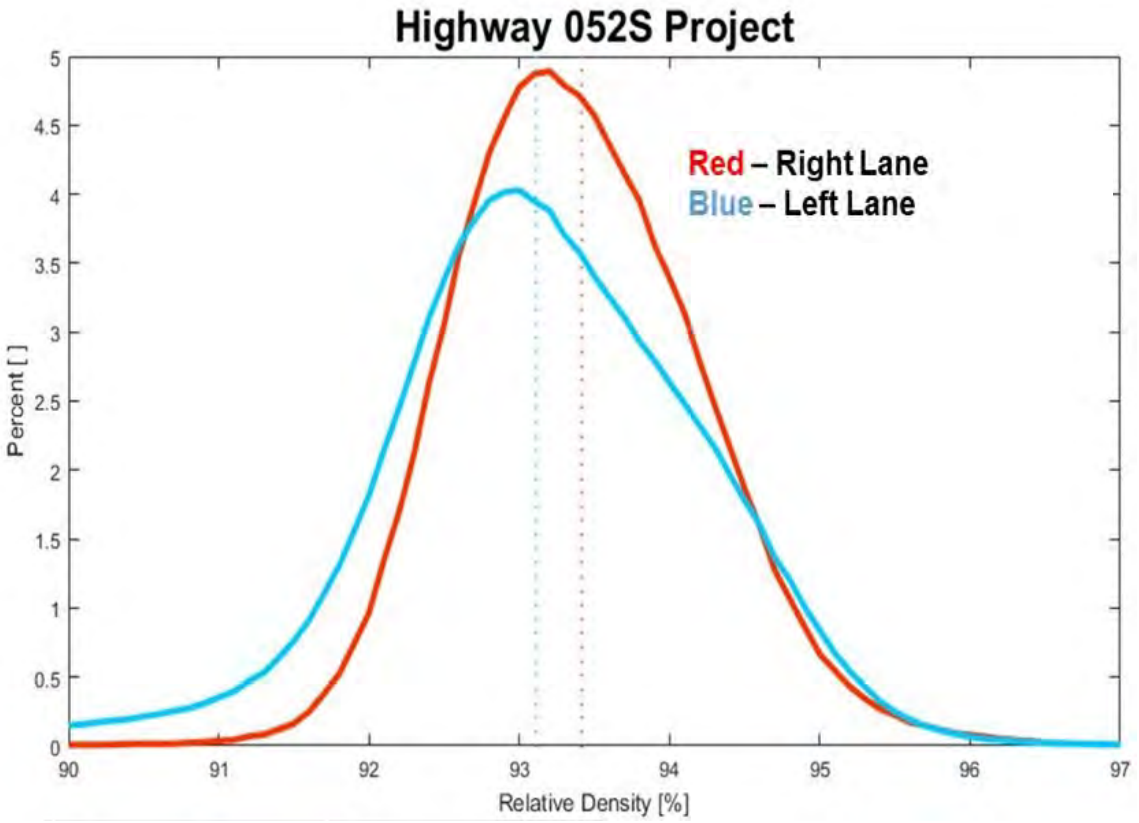
- Summary Stats

▪93.2% median density

▪STD: 1.18

▪97.5% locations density>90.8%

Examples: TH 52 – Left and Right Mainline

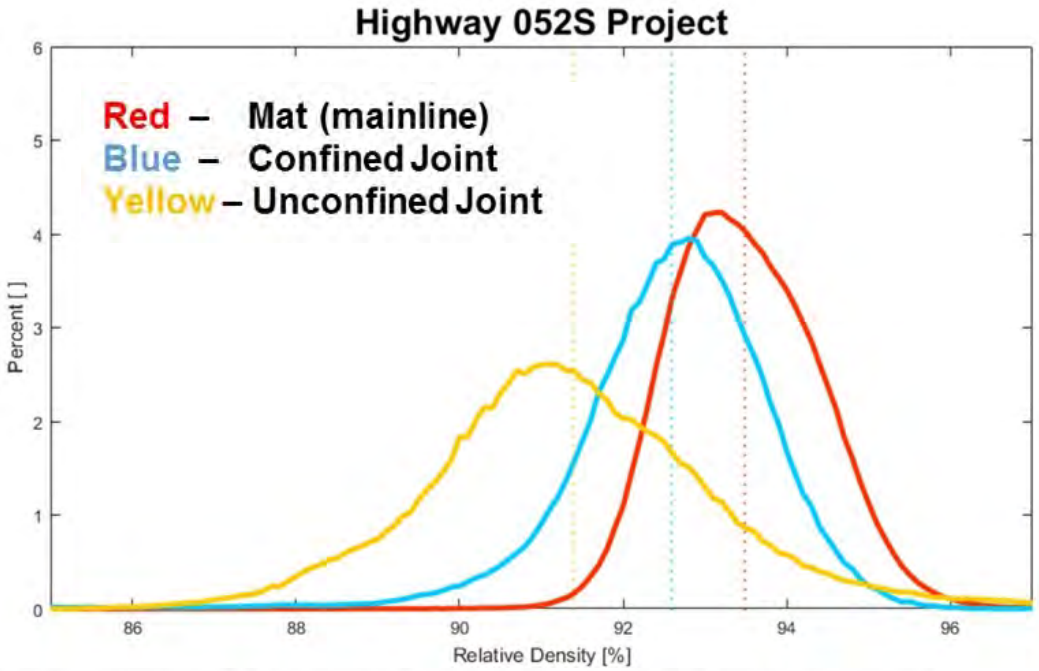


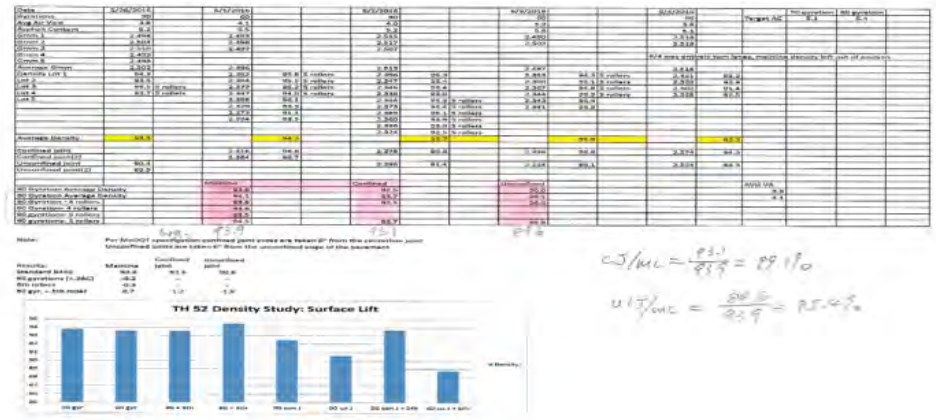
- Median Density
  - Right: 93.4%
  - Left: 93.1%
- STD: 0.92(R) and 0.96(L)
- 97.5% locations:

  > 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)

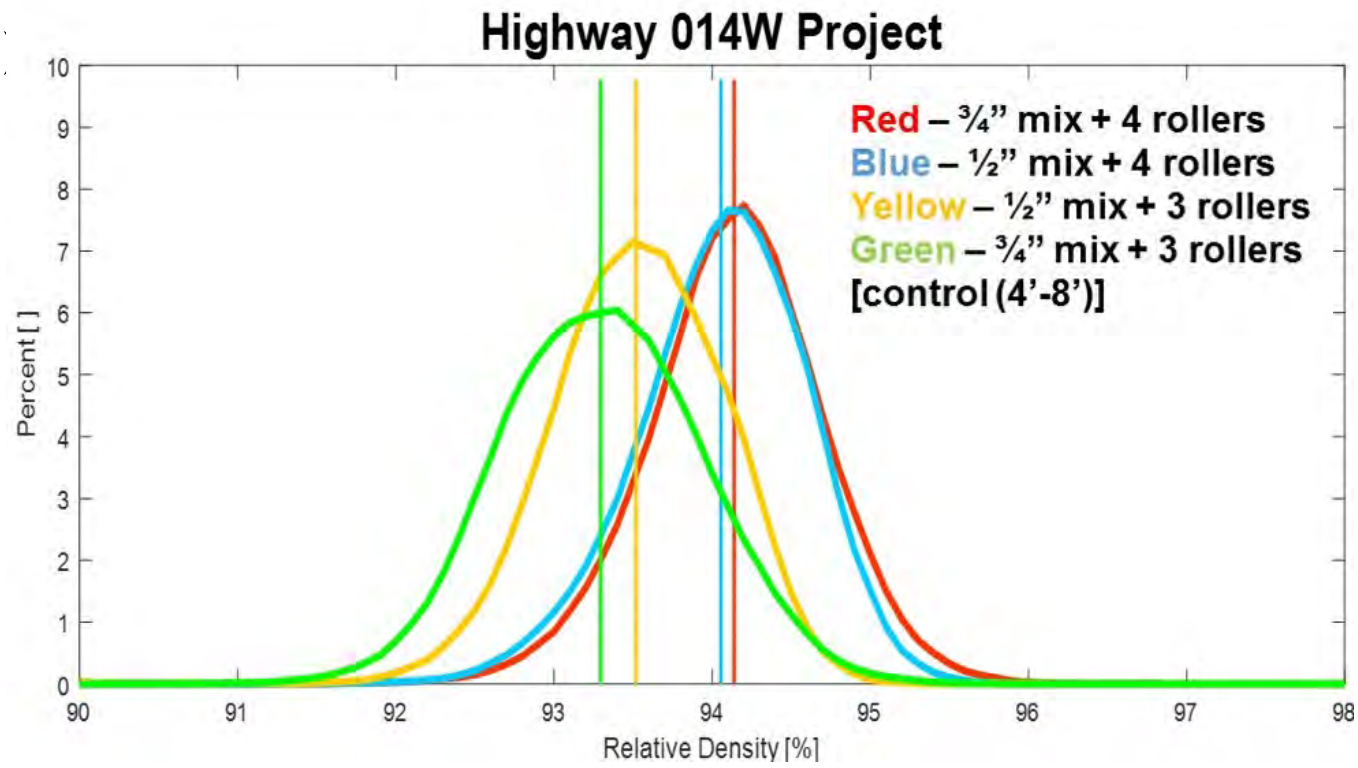
- SD: 0.94(ML); 1.22(CJ); 1.8(UCJ)

- 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%

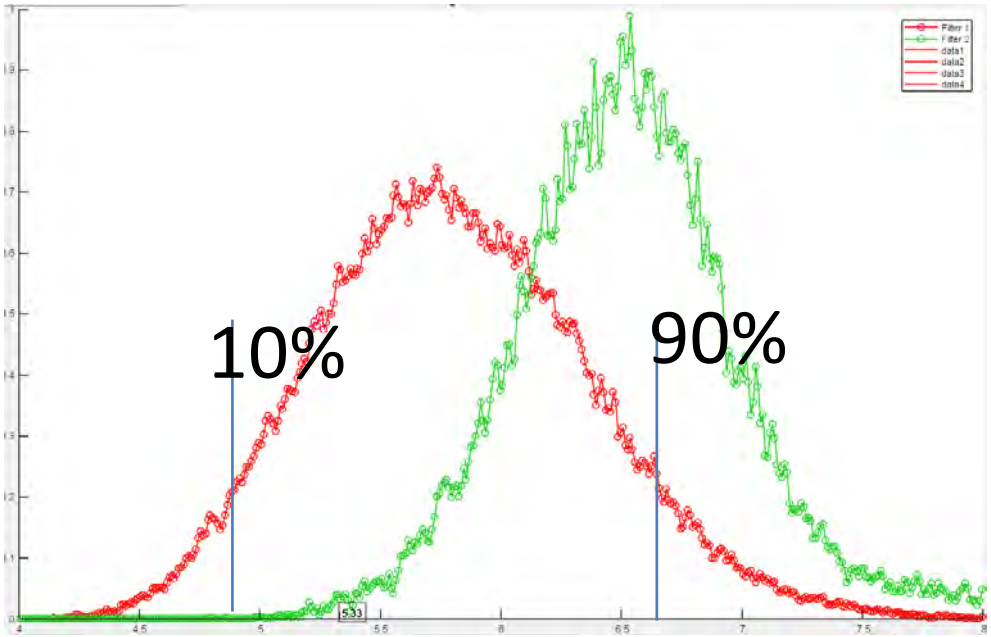
  Red: 94.2%

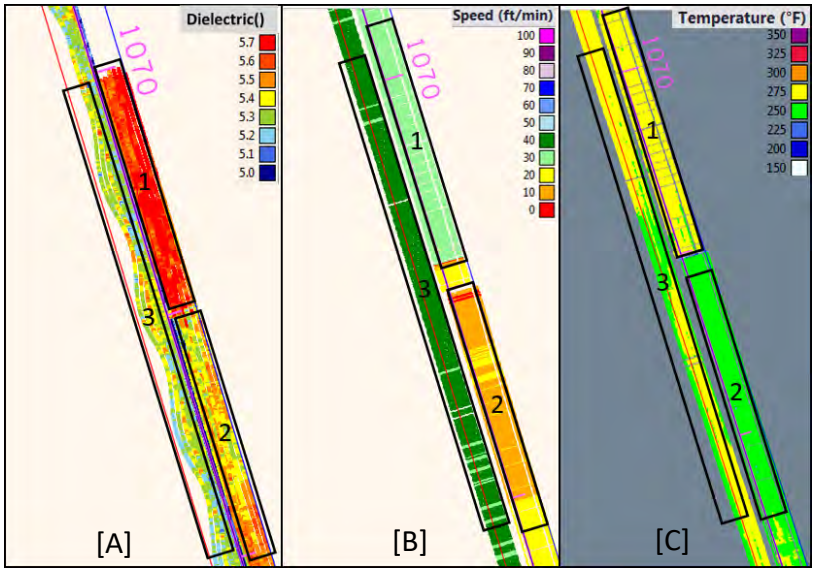
  Yellow: 93.5%

  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%



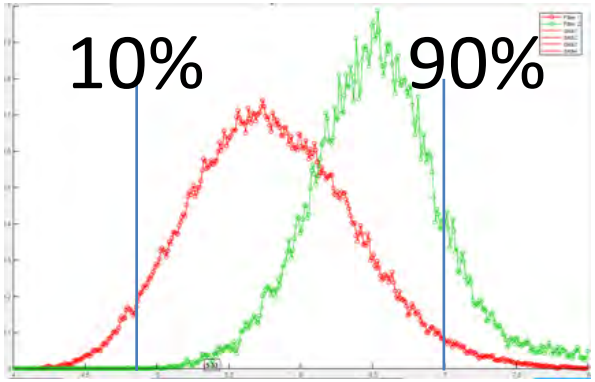


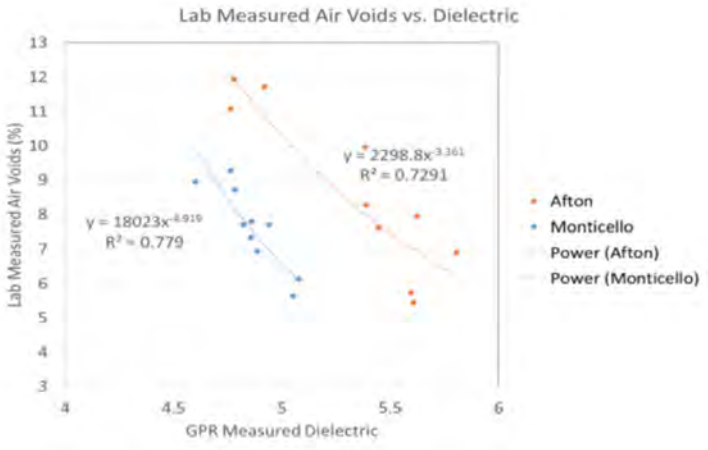
- Generate core location text file and load to a GPS device to automatically guide field person to the core location for obtaining the core.

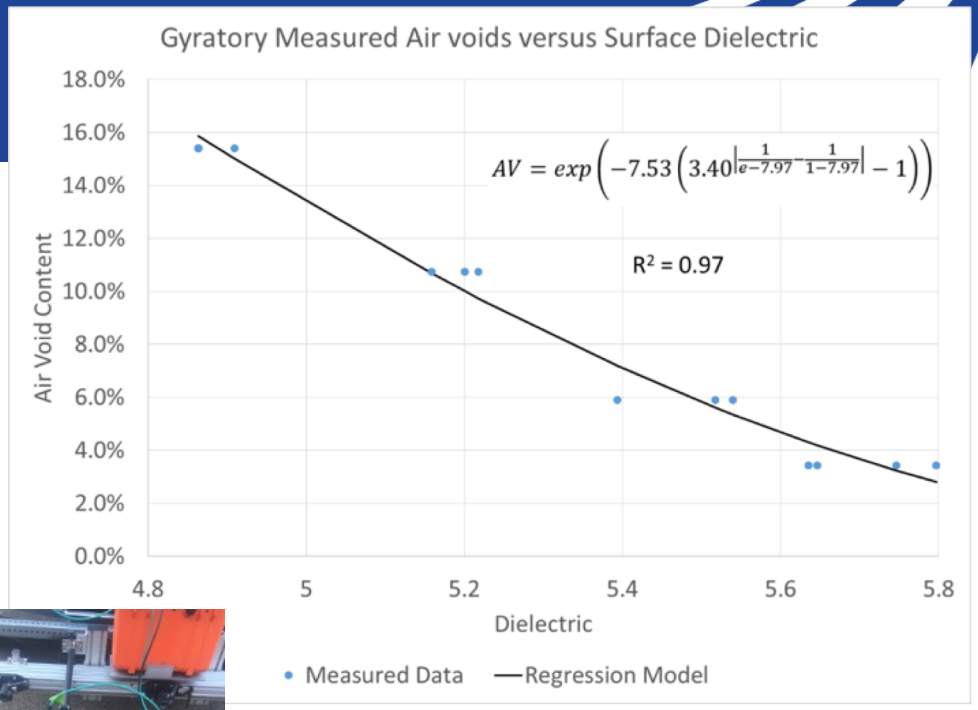
R293.1	298478.7227	519108.2862
R294.1	302565.1707	520114.0246
R295.1	299279.1239	519298.2314
R296.1	299599.5422	519377.6685
R297.1	300540.5022	519610.8459
R298.1	300331.6291	519559.0812
R299.1	301378.5352	519818.6575
R300.1	301907.3905	519951.4897
R301.1	303106.5117	520228.2346
R302.1	302670.5928	520139.8712
R303.1	304480.9524	520289.7976
R304.1	304360.0461	520297.9872

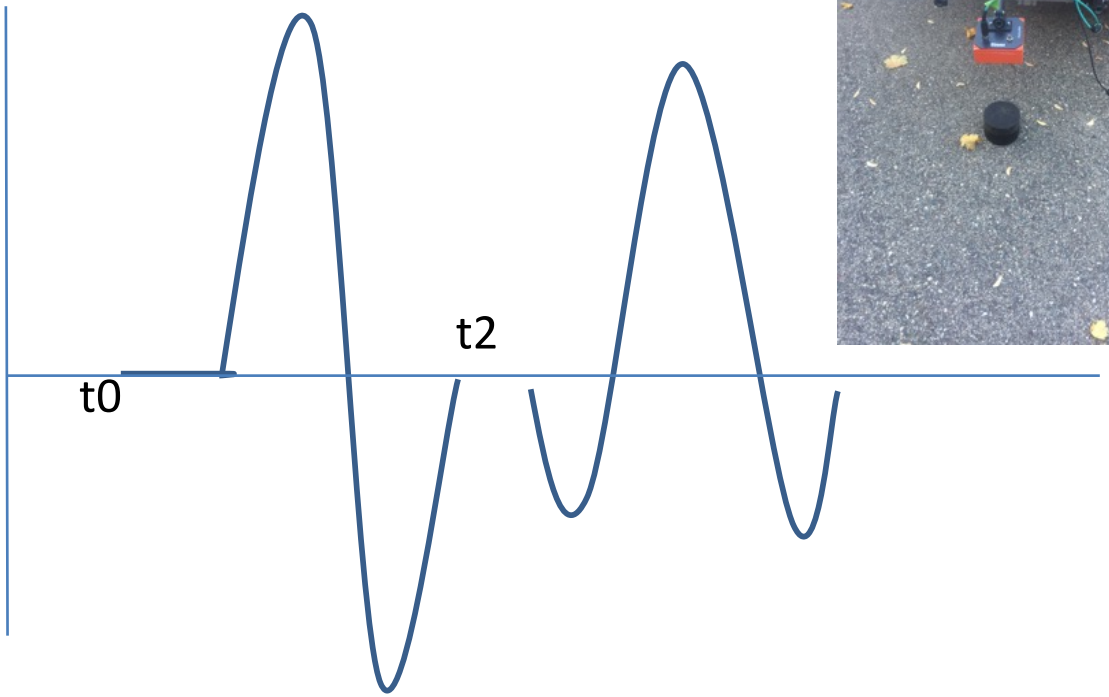
Research on Laboratory Calibration

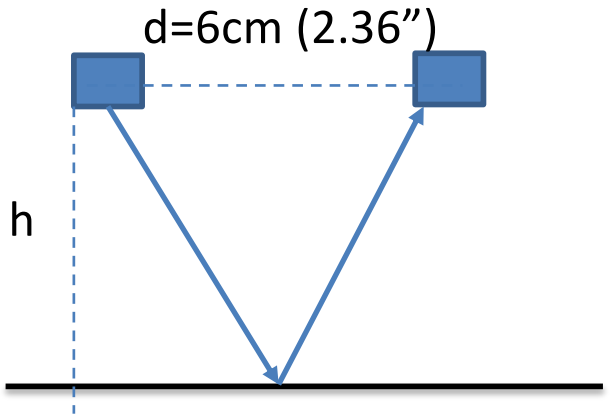
- Measure dielectric constant on a gyratory specimen?
  - Establish Calibration Curve in Lab & Sensitivity Study
    - Currently use field cores for calibration: ex: 10% and 90%
    - Hope to establish calibration curve at lab in future
    - How does each component in a mixture affect dielectric constant,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






Gyratory Measured Air voids versus Surface Dielectric
18.0%
16.0%
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
Air Void Content
4.8
5
5.2
5.4
5.6
5.8
Dielectric
$AV = exp\left(-7.53\left(3.40\left|\frac{1}{e-7.97}-\frac{1}{1-7.97}\right|-1\right)\right)$
$R^2 = 0.97$
Measured Data
Regression Model


t0
t2

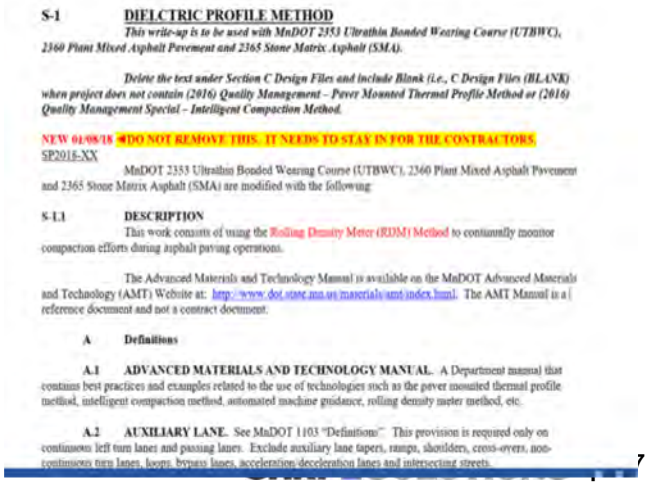

d=6cm (2.36”)
h

Activities

- Calibration of Equipment
- Field Testing:
  - 2016: TH52 and TH14: Surveyed about 18miles.
  - 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



S-1 DIELCTRIC PROFILE METHOD

This write-up is to be used with MnDOT 2353 Ultrathin Bonded Wearing Course (UTBWC), 2360 Plant Mixed Asphalt Pavement and 2365 Stone Matrix Asphalt (SMA).

Delete the text under Section C Design Files and include Blank (i.e., C Design Files (BLANK) when project does not contain (2016) Quality Management – Paver Mounted Thermal Profile Method or (2016) Quality Management Special – Intelligent Compaction Method.

NEW 01/08/18 **DO NOT REMOVE THIS. IT NEEDS TO STAY IN FOR THE CONTRACTORS.**
SP2018-XX

MnDOT 2353 Ultrathin Bonded Wearing Course (UTBWC), 2360 Plant Mixed Asphalt Pavement and 2365 Stone Matrix Asphalt (SMA) are modified with the following:

S-1.1 DESCRIPTION

This work consists of using the Rolling Density Meter (RDM) Method to continually monitor compaction efforts during asphalt paving operations.

The Advanced Materials and Technology Manual is available on the MnDOT Advanced Materials and Technology (AMT) Website at: http://www.dot.state.mn.us/materials/amt/index.html. The AMT Manual is a reference document and not a contract document.

A Definitions

A.1 ADVANCED MATERIALS AND TECHNOLOGY MANUAL. A Department manual that contains best practices and examples related to the use of technologies such as the paver mounted thermal profile method, intelligent compaction method, automated machine guidance, rolling density meter method, etc.

A.2 AUXILIARY LANE. See MnDOT 1103 "Definitions". This provision is required only on continuous left turn lanes and passing lanes. Exclude auxiliary lane tapers, ramps, shoulders, cross-overs, non-continuous turn lanes, loops, bypass lanes, acceleration/deceleration lanes and intersecting streets.

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