


SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

HMA COMPACTION ASSESSMENT USING GPR ROLLING DENSITY METER

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NEAUPG

Atlantic City, NJ
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MaineDOT
U.S. Department of Transportation
Federal Highway Administration
mn DEPARTMENT OF TRANSPORTATION
AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
AASHTO

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

SHRP2 Solution

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

Ground penetrating radar

- 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

Theory of operation for density

- 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

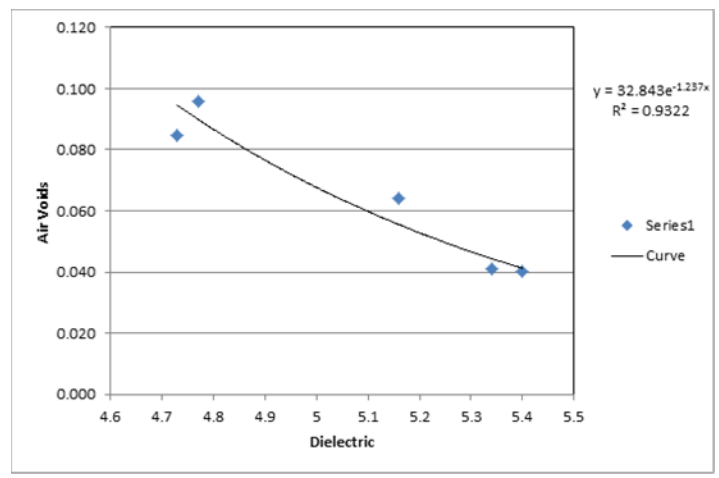
- Three – 2GHz antenna
- Portable push cart
- Capable of scanning 6’ width
- Onboard computer
  - Captures dielectric values
  - Can be correlated to core densities

Metal plate calibration

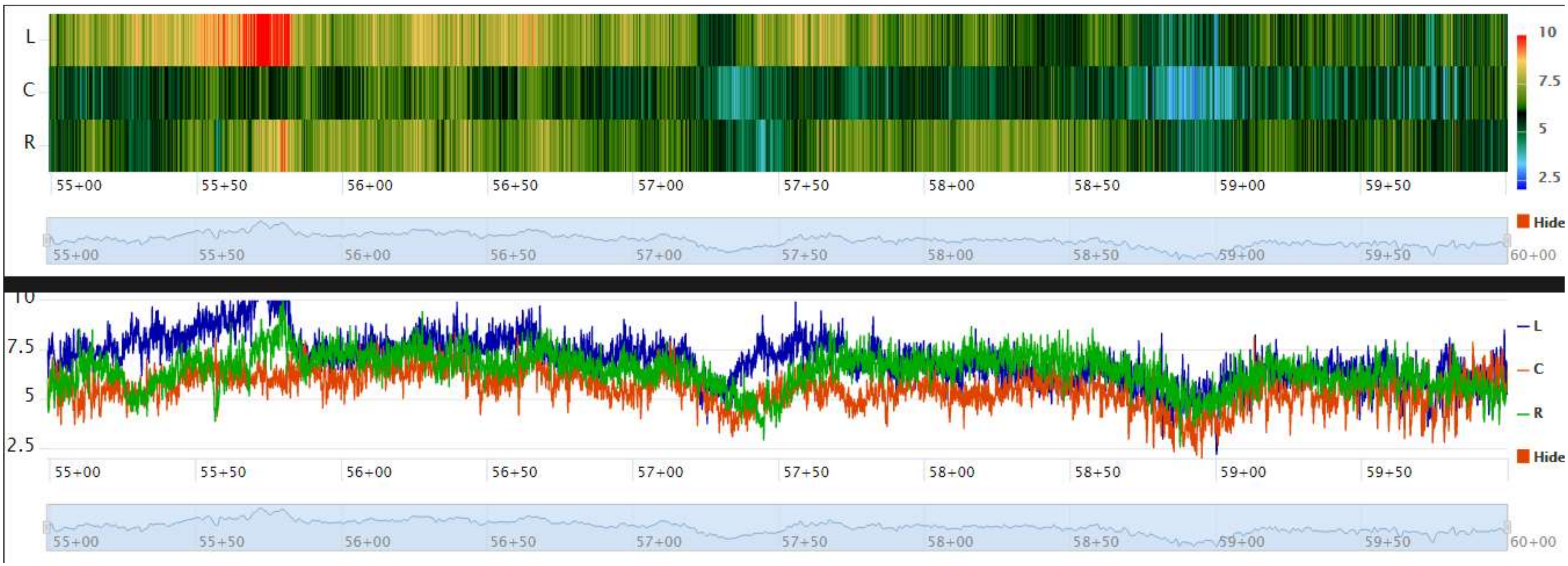
Correlation procedure

- 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



Density Profiles



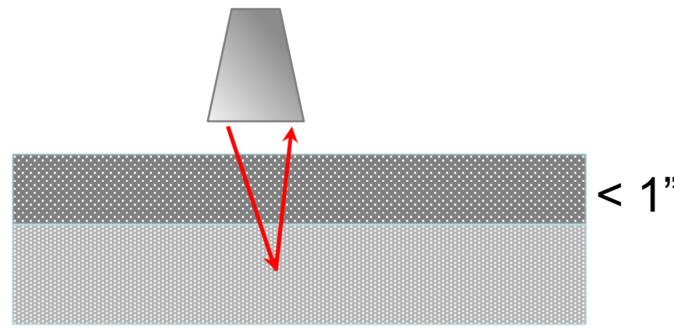
Typical density profile

Limitations

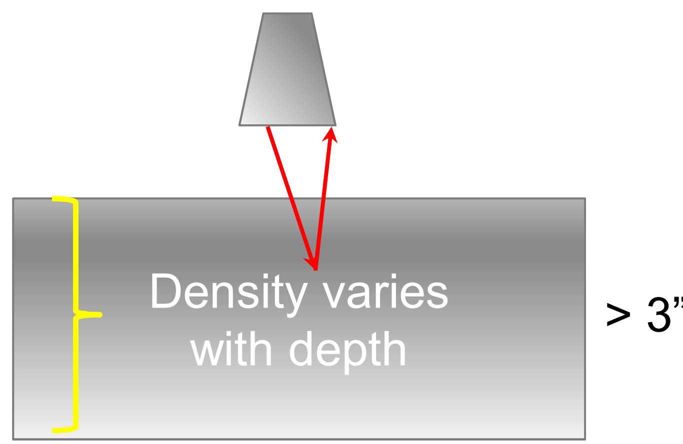
Affected by:

- 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



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

Why MnDOT is interested in?

- MnDOT Uses Cores Density for Acceptance
  - Need a tool for continuous assessment: RDM
- Longitudinal Joint deterioration

Photo 1

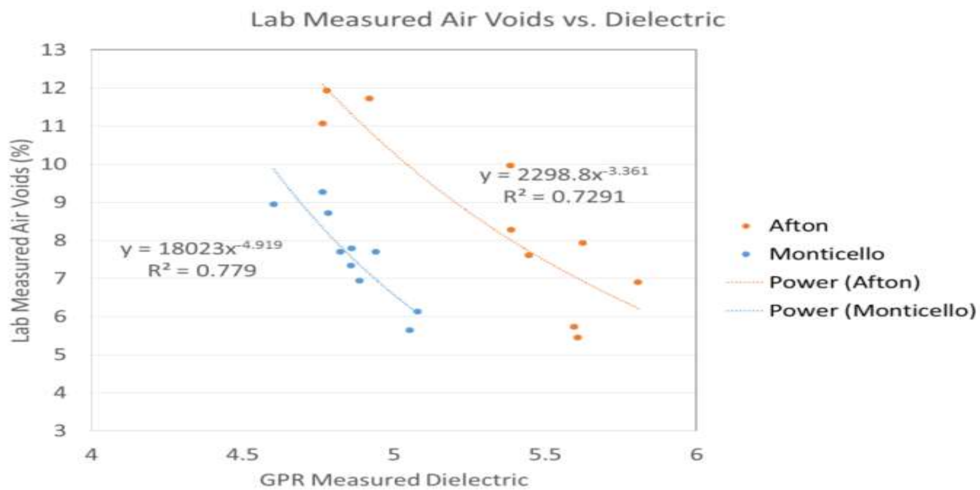
- IC and IR Implementation
  - IC&IR are QC tools
  - RDM (GPR) can be a QA tool
- RDM in 2015

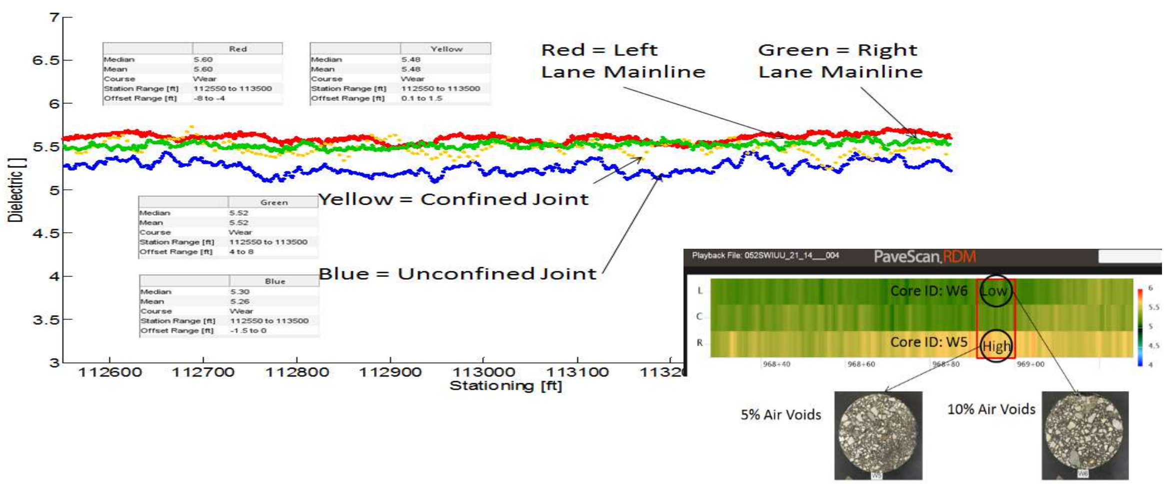
MnDOT Equipment

- Push Cart Type RDM

- Vehicle Mounted RDM

RDM Principal





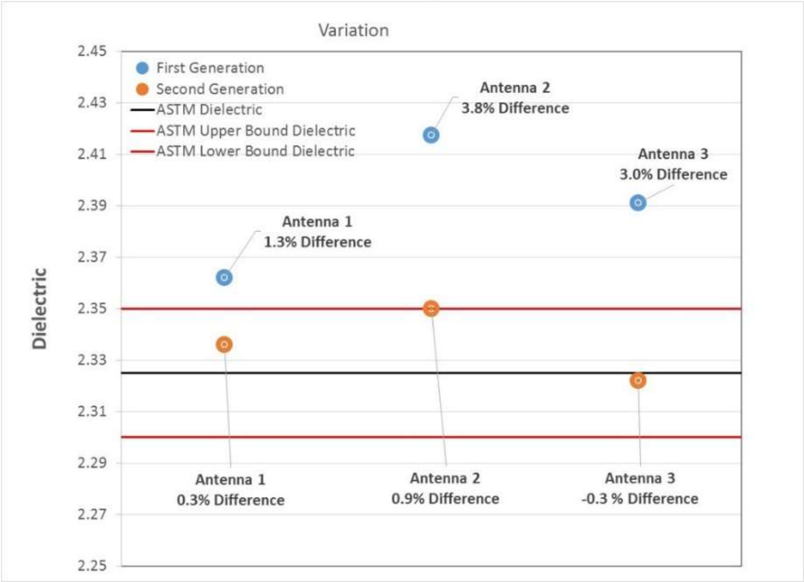
- **Mainline Survey: multiple passes**

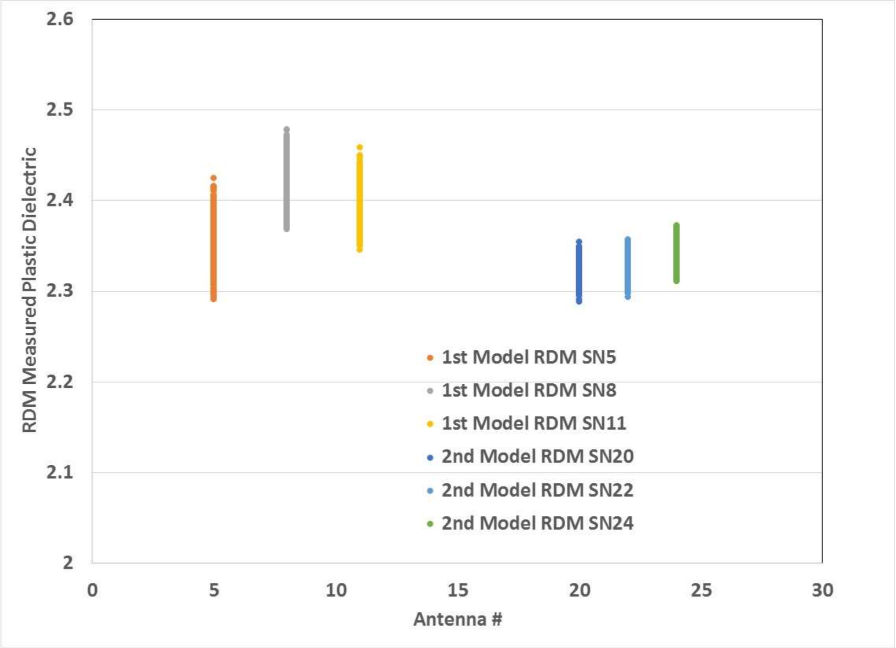
- **Joint Survey: one antenna close to joint**

Equipment Calibration

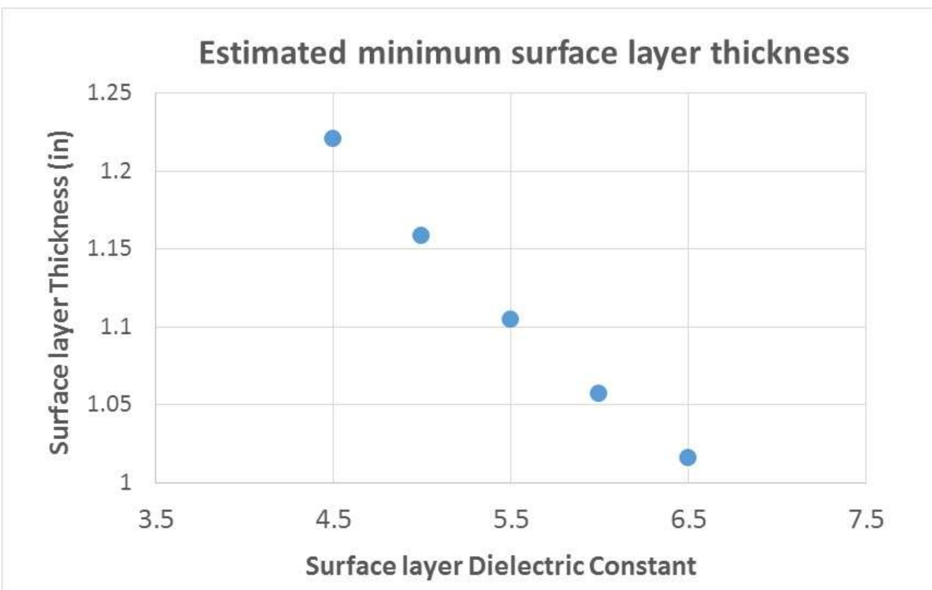
- High Density Polyethylene (HDPE)
  - Reported dielectric: 2.3-2.35

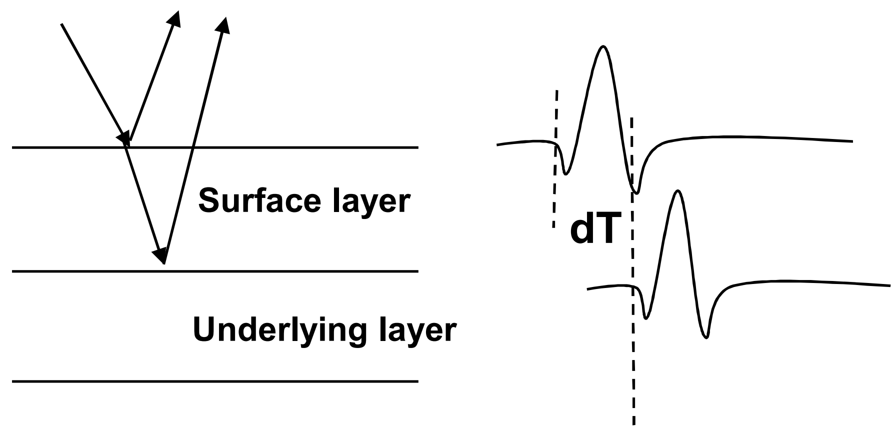
$$\varepsilon_{HMA} = \left(\frac{1 + \frac{A_0}{A_P}}{1 - \frac{A_0}{A_P}} \right)^2$$





- 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?





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

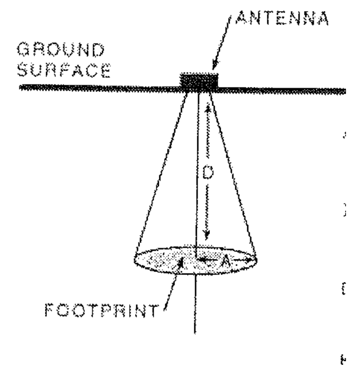
$$v = c/\sqrt{\varepsilon_1}$$

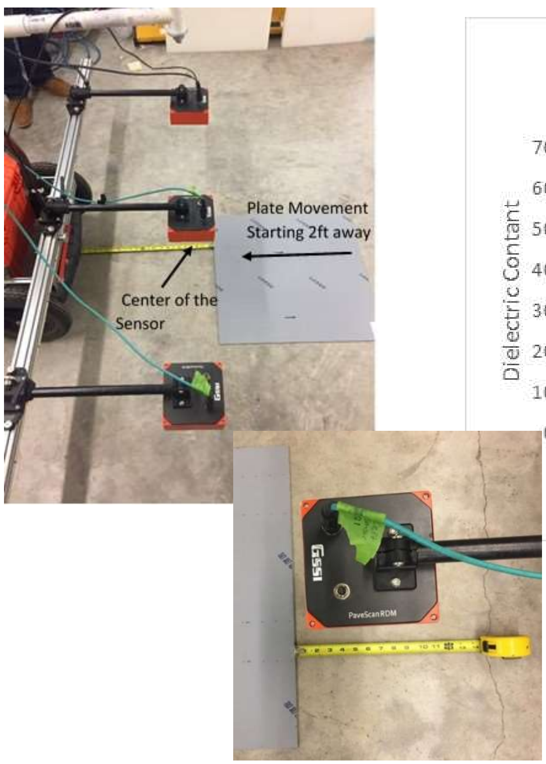
dT ~ 0.439us

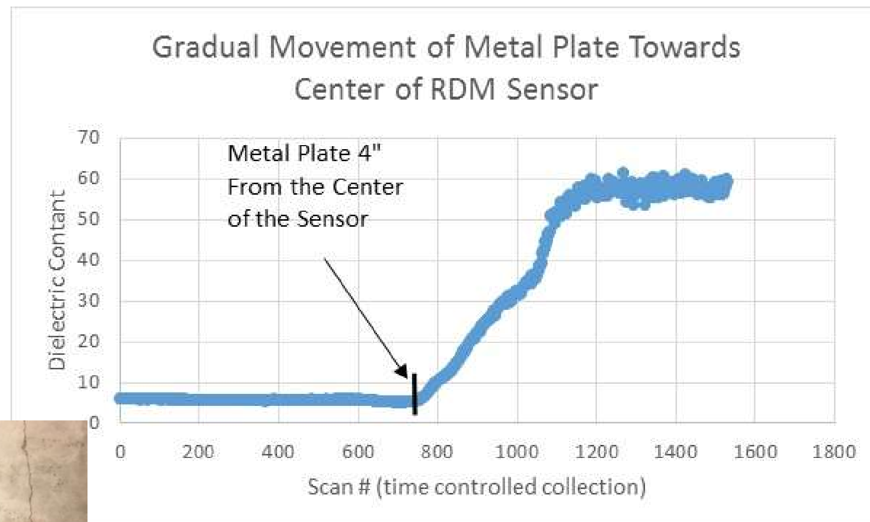
- Footprint area of an antenna (Fresnel Zone)?

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

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

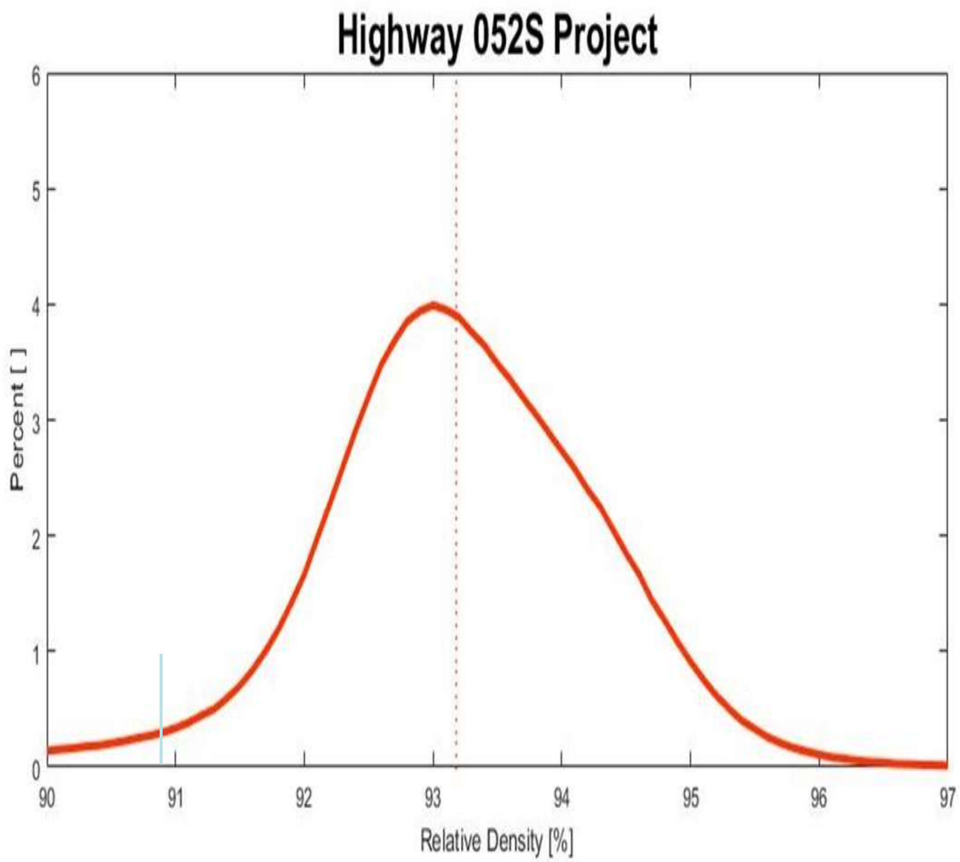






Histogram

- **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%

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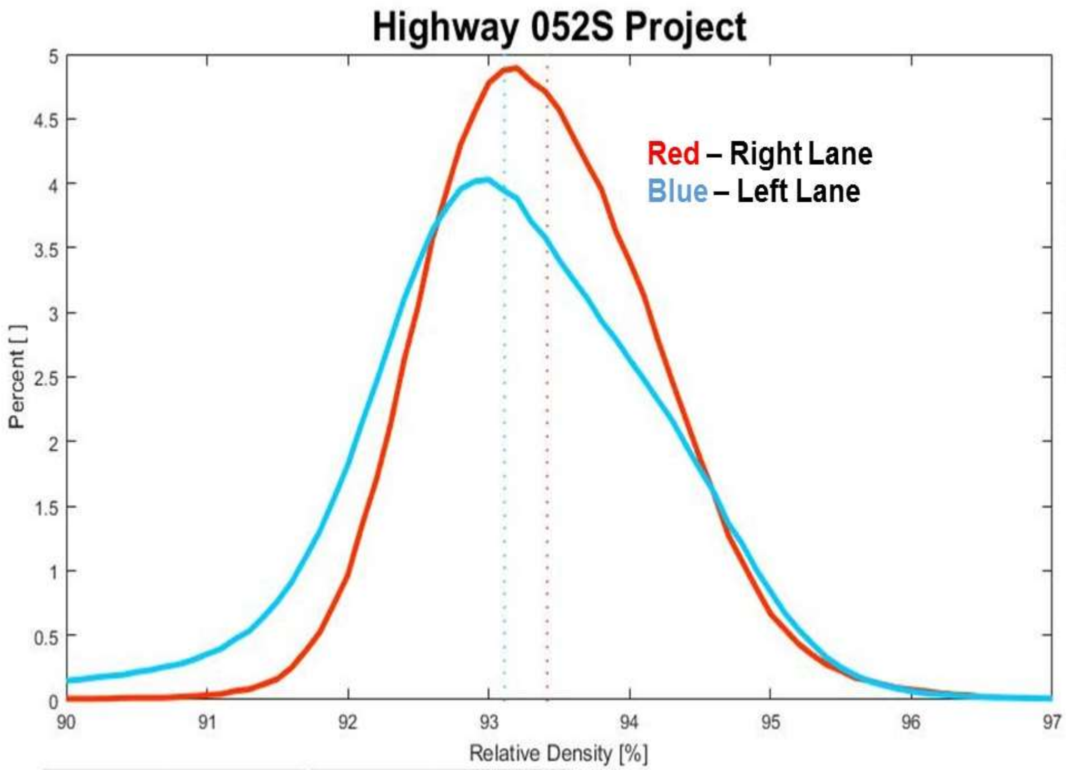
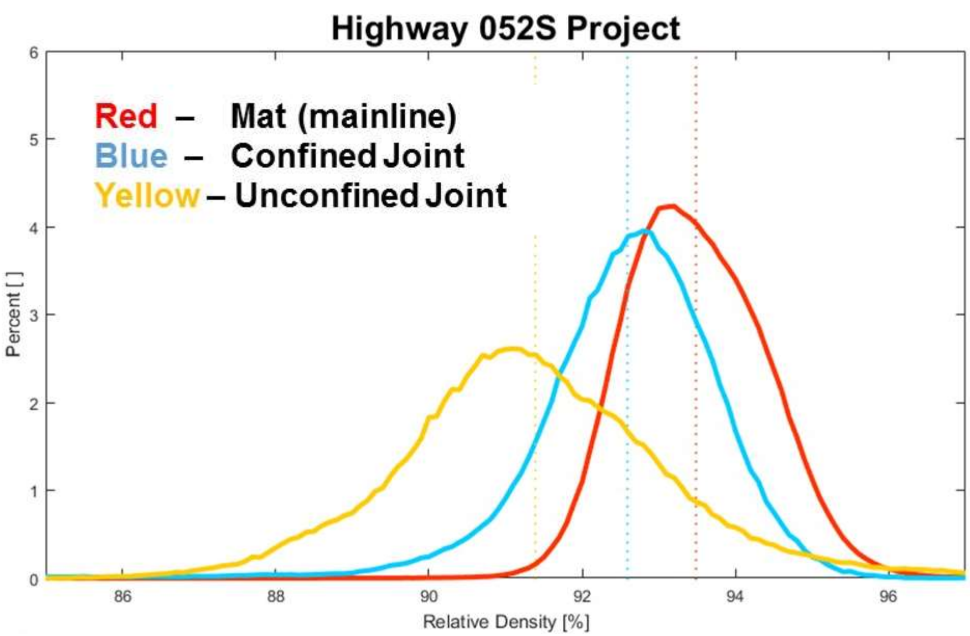
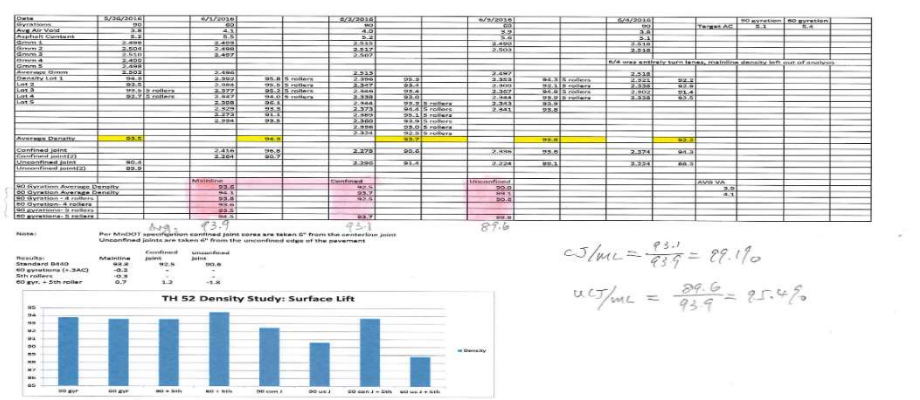
Examples: TH 52 – Left and Right Mainline



- 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



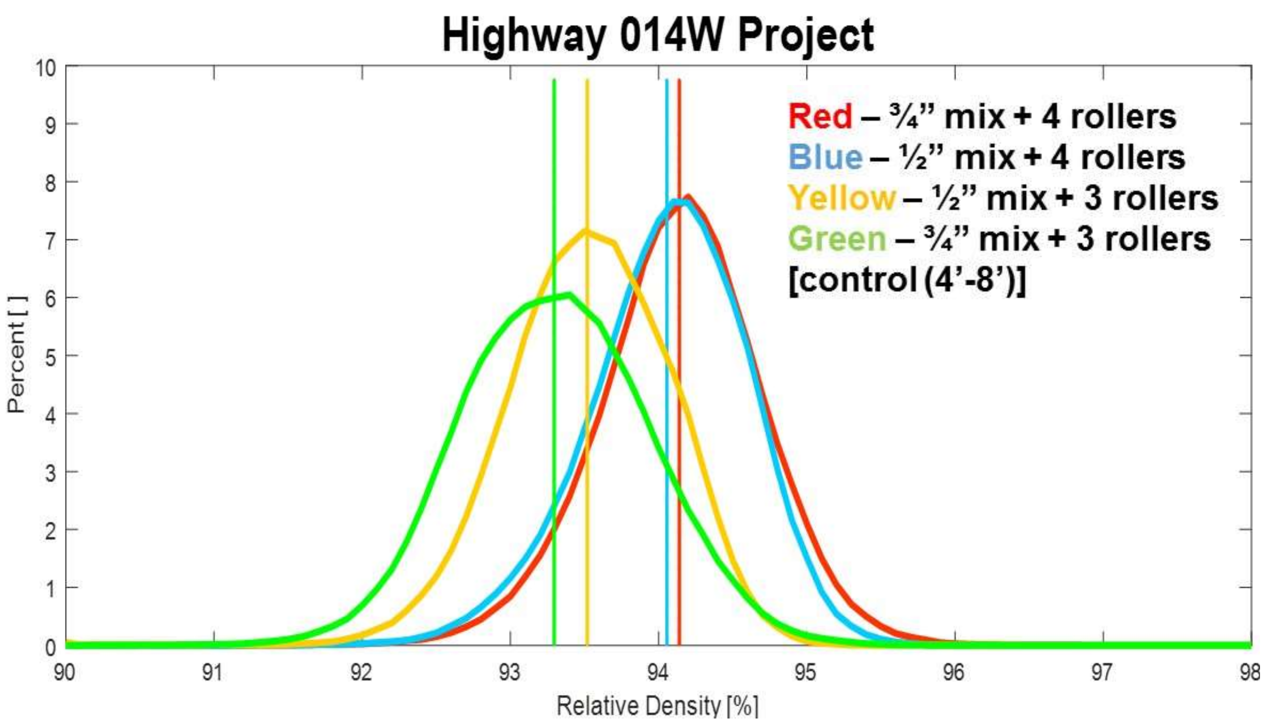


- Top lift Mainline vs Confined and Unconfined Joints Summary:
  - 93.5% (ML), 92.6%(CJ) and 91.4%(UCJ)
  - SD: 0.94(ML); 1.22(CJ); 1.8(UCJ)
  - Density:
    - UCJ/ML=97.7%; CJ/ML=99%
    - Core data: UCJ/ML=95.1%

      CJ/ML = 99.1%
  - 97.5% locations:
    - > 91.6%(ML),
    - > 90.2% (CJ)
    - > 87.8% (UCJ)

TH 14 – Mainline

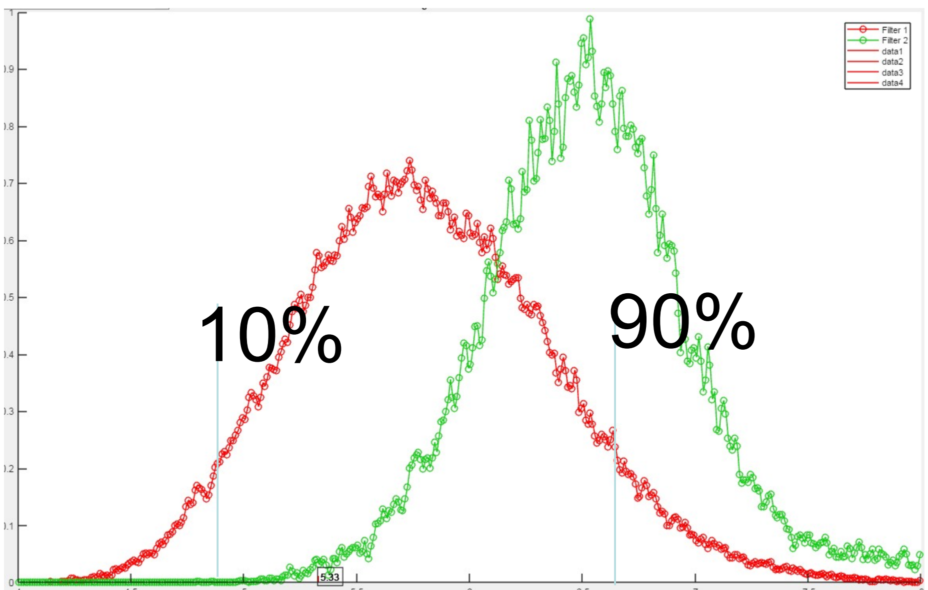
- Comparison of Test Sections
  - Mix B (3/4-) to A(1/2-): not much difference on compaction.
  - Adding a roller: density slightly increased on this project.
  - .

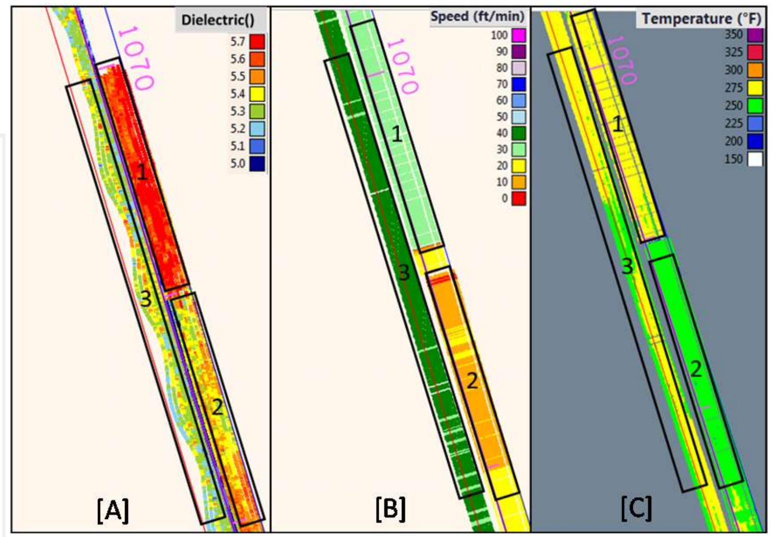


- Median Density:
  Blue: 94.1%
  Red: 94.2%
  Yellow: 93.5%
  Green: 93.3%

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%



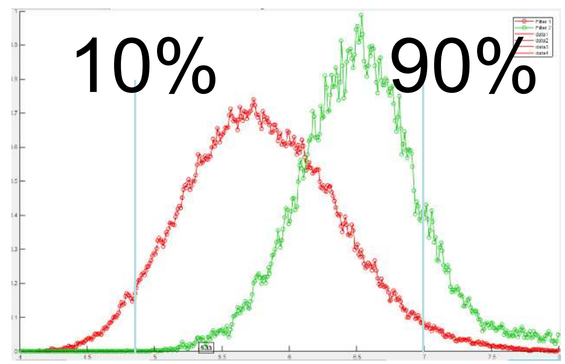


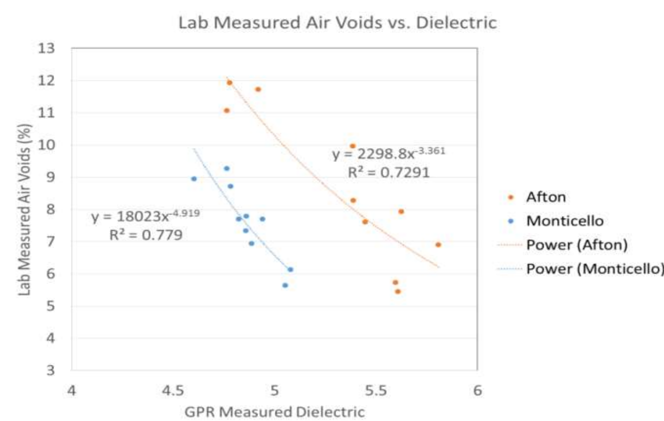
➢Generate core location text file and load to a GPS device to automatically guide field person to the core location for obtaining the core.

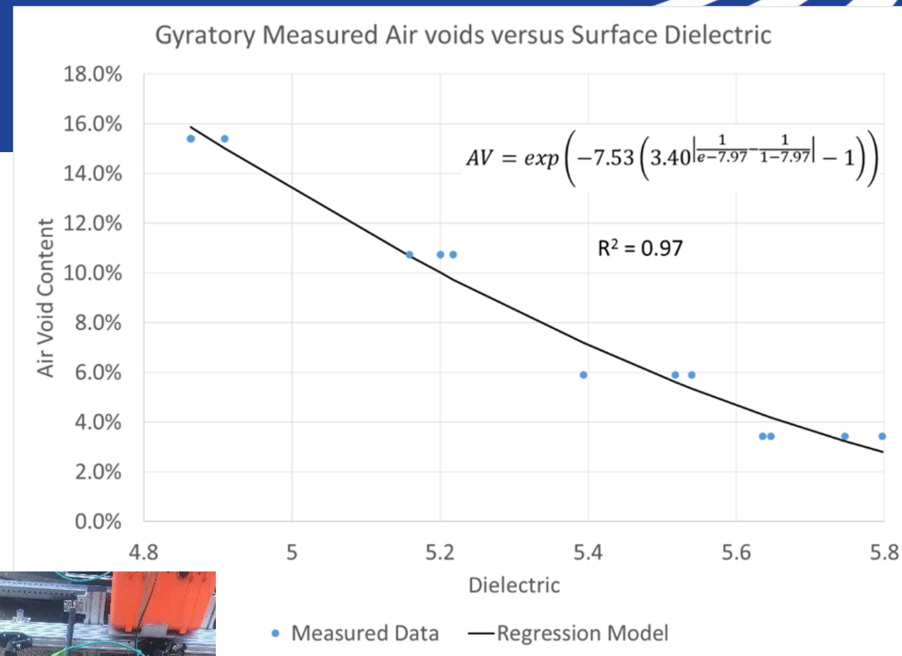
R293.1	298478.7227	519108.2862
R294.1	302565.1707	520114.0246
R295.1	299279.1239	519298.2314
R296.1	299599.5422	519377.6685
R297.1	300540.5022	519610.8459
R298.1	300331.6291	519559.0812
R299.1	301378.5352	519818.6575
R300.1	301907.3905	519951.4897
R301.1	303106.5117	520228.2346
R302.1	302670.5928	520139.8712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

Research on Laboratory Calibration

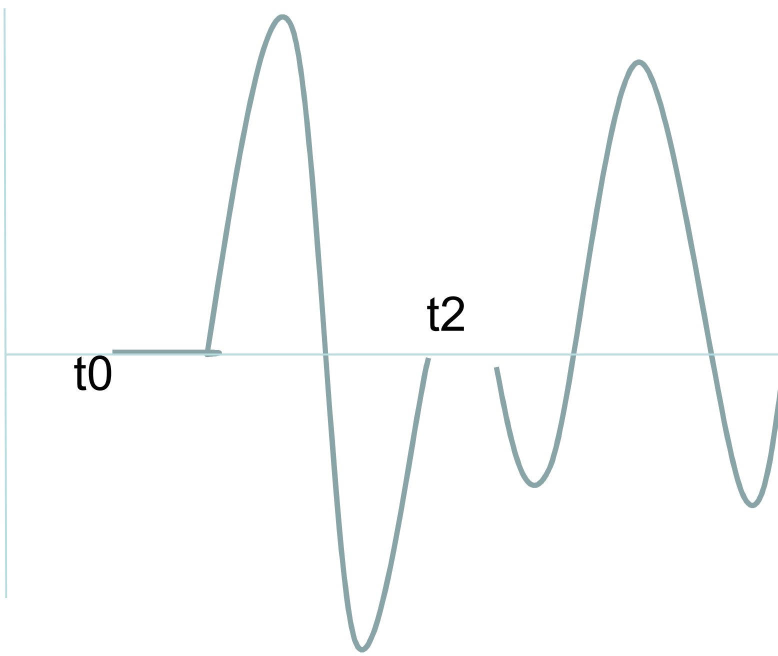
- Measure dielectric constant on a gyratory specimen?
  - Establish Calibration Curve in Lab & Sensitivity Study
    - Currently use field cores for calibration: ex: 10% and 90%
    - Hope to establish calibration curve at lab in future
    - How does each component in a mixture affect dielectric constant,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



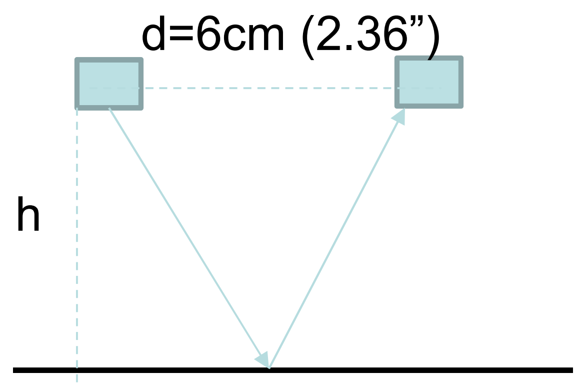




Gyratory Measured Air voids versus Surface Dielectric
$AV = exp\left(-7.53\left(3.40^{\left|\frac{1}{e-7.97}-\frac{1}{1-7.97}\right|}-1\right)\right)$
$R^2 = 0.97$
Air Void Content
18.0%
16.0%
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
4.8
5
5.2
5.4
5.6
5.8
Dielectric
Measured Data
Regression Model



t0
t2



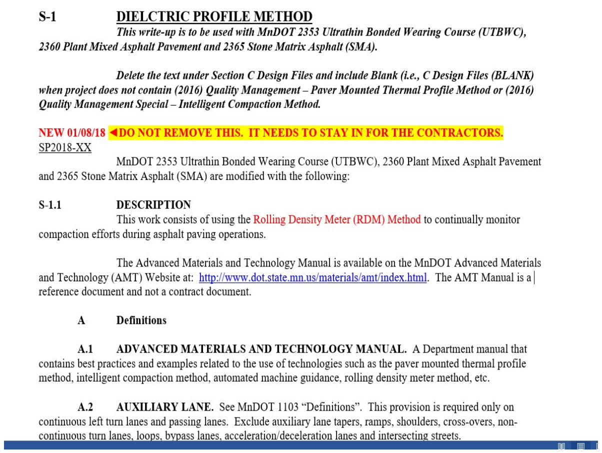
d=6cm (2.36”)
h

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

For more information

For more information on improving the quality of asphalt pavements through SHRP2 products:

- Steve Cooper (FHWA) stephen.j.cooper@dot.gov
- Kate Kurgan (AASHTO) kkurgan@aashto.org

For more information on Maine's experience:

- Rick Bradbury (Maine DOT) richard.bradbury@maine.gov

For more information on Minnesota's experience:

- Shongtao Dai (Minnesota DOT) shongtao.dai@state.mn.us

MaineDOT

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