



SHRP2 SOLUTIONS
TOOLS FOR THE ROAD AHEAD

Minnesota Update – Density Profiling System (DPS)

Kyle Hoegh, MnDOT

Eyoab Zegeye, MnDOT

Shongtao Dai, MnDOT

U.S. Department of Transportation
Federal Highway Administration

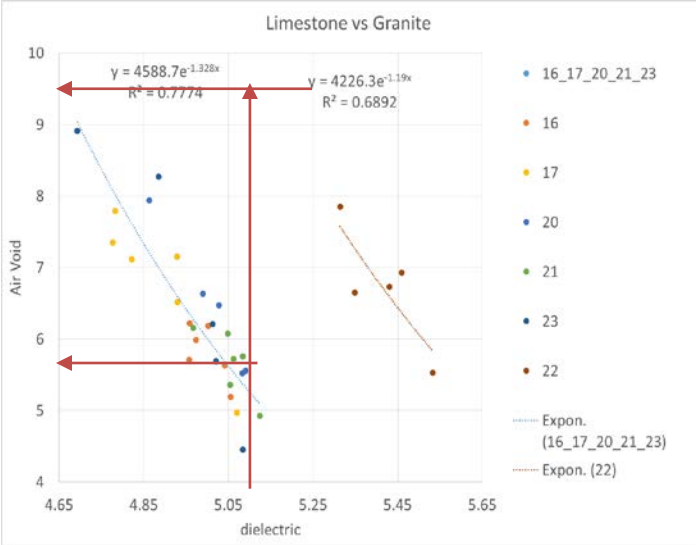
American Association of State Highway and Transportation Officials
AASHTO

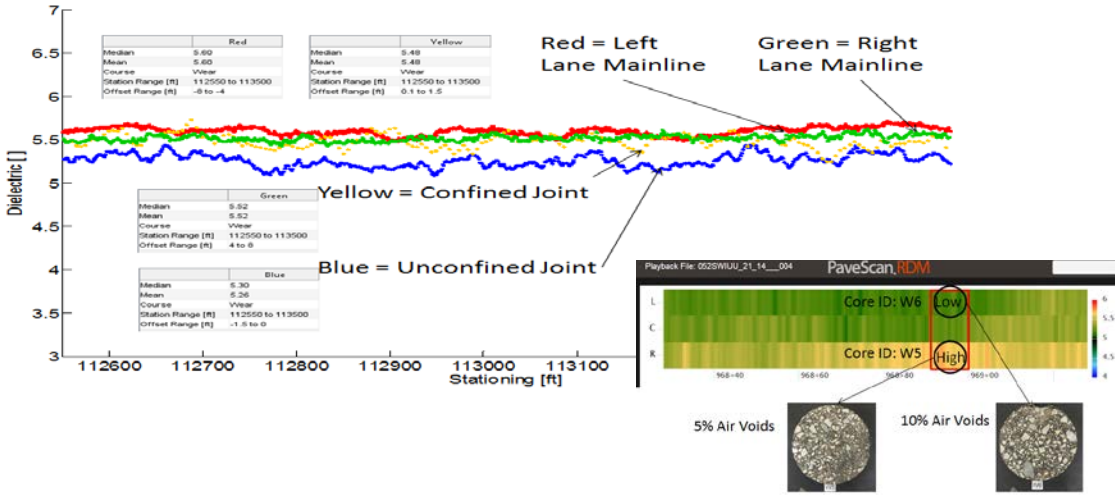
Outline

- Summary of current findings: success and improvements
- MnDOT history on research and evaluation
- MnDOT vision and roadmap
- Results of 2018 projects
  - TH371, TH14, TH109, TH10, TH60, TH.47(University Ave)
- Current Effort: Coreless calibration and preliminary sensitivity study
- A proposed pooled fund study

Summary of Current Findings

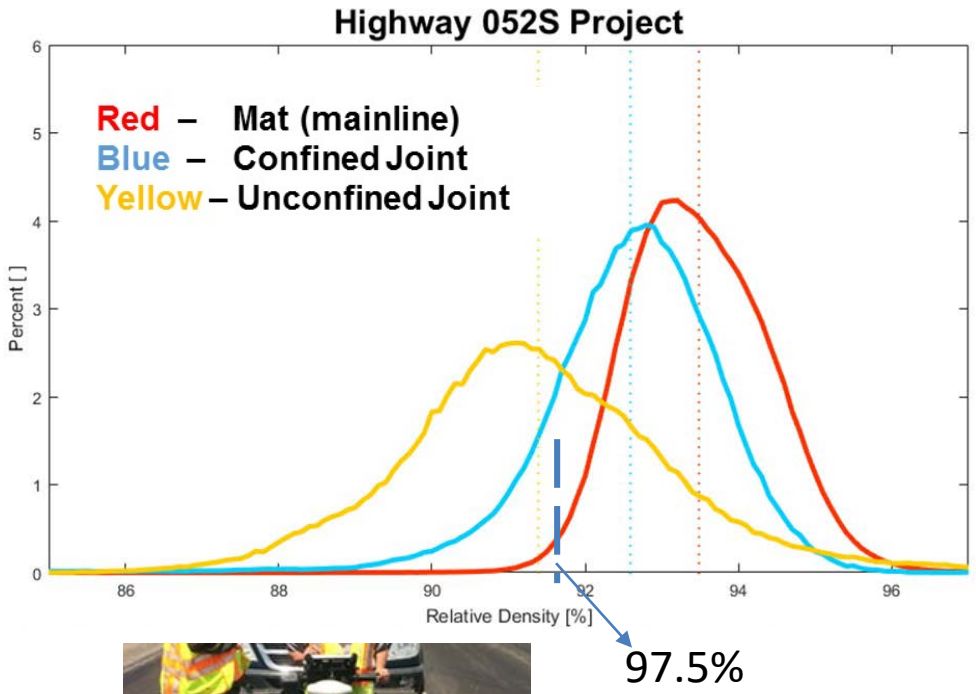
- The technology works.
  - Can be used to identify high and low compaction areas
  - Dielectric constant measured by the DPS relates to field density
    - Aggregate type has a great effects on dielectric constant





Summary of Current Findings

- Histogram is a good method for evaluating compaction quality and acceptance: uniformity and density



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)

Summary of Current Findings

- Improvements needed for the equipment:
  - GPS accuracy verification module: check static vs moving GPS.
  - Software improvement to eliminate effect of underlying layer.
  - Simplify user inputs: be able to read input project data from a different file
  - Cloud storage and compatibility with VETA.

- Antenna Stability
  - Currently requires max difference of dielectric constant < 0.08 among the three antennas during swerve calibration: some times works; some times needs to perform multiple calibrations.
  - Antenna reading jumped very high or sometimes zero on TH371 project.

MnDOT History

- Obtained the equipment (RDM) in 2015

- Calibration of Equipment
  - HDPE used for calibration: e=2.3 - 2.35
  - Inter-antenna variation: 2nd generations
  - Verified footprint: longitudinal compaction

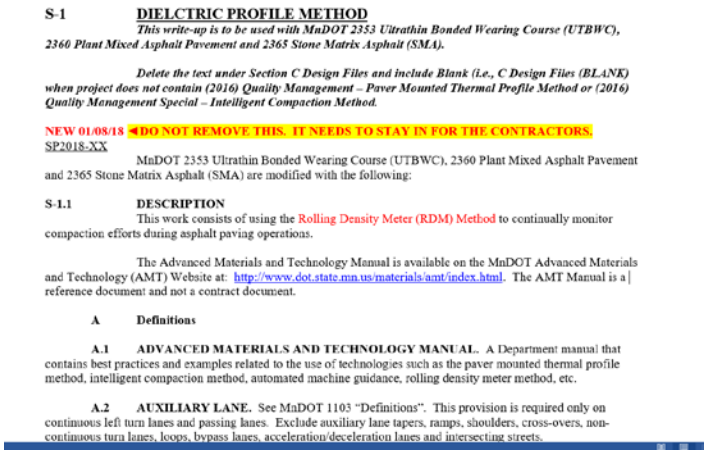
- Field Evaluation:
  - 2016: TH52 and TH14: Surveyed about 18miles.
  - 2017: I35; Th52; Th22; Th60; CR86; Th110; CSAH13 and MnROAD
    - Vehicle mounted system
    - Hired American Engineering Testing (AET) to collect data

MnDOT History

- 2018:
  - Pilot contractor data collection: “Ghost” specification TH371.
  - Developed core locator: automatically find core locations
  - Data collection: TH47, TH14, TH109,TH10, TH60.
  - Demonstration to local engineers: CSAH12

MnDOT History

- AASHTO Spec.
  - A draft was developed in 2017
  - A revised one is being reviewed
    - Name change: RDM to DPS (Density Profiling System).



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**

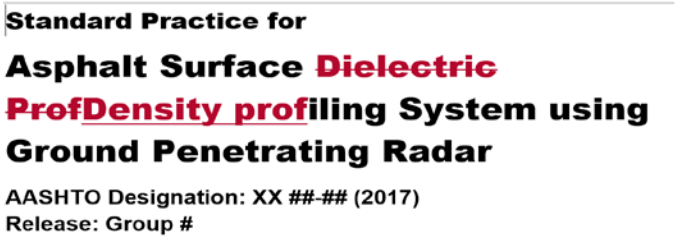
This work consists of using the Rolling Density Meter (RDM) Method to continually monitor compaction efforts during asphalt paving operations.

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.



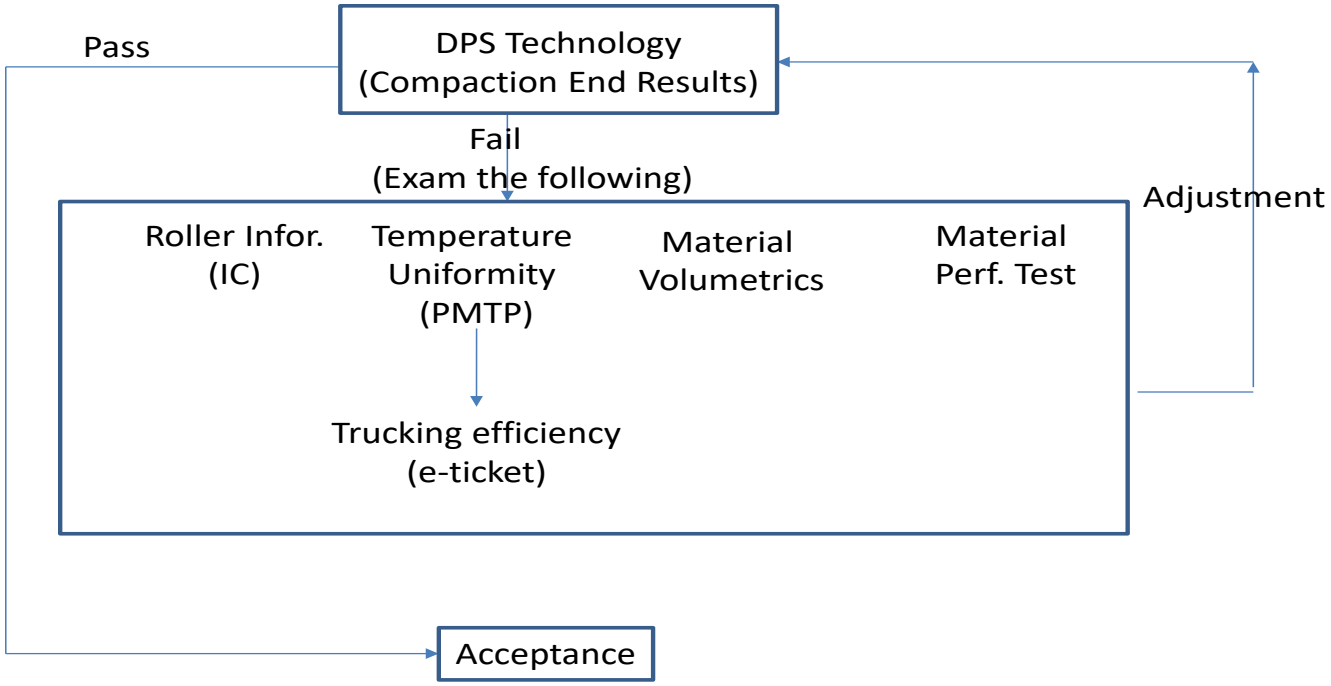
Standard Practice for

Asphalt Surface ~~Dielectric~~ ~~Prof~~Density profiling System using Ground Penetrating Radar

AASHTO Designation: XX ##-## (2017)
Release: Group #

MnDOT Vision and Roadmap

- Ultimate vision: Integrated Closed-loop Feedback System



MnDOT Vision and Roadmap

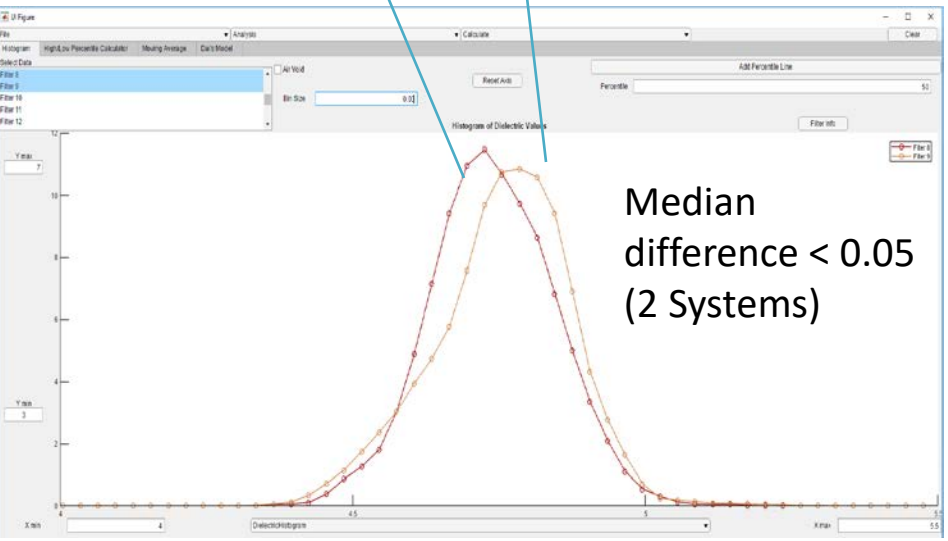
Draft Roadmap

Year	Description
CY2019	1. Publish AASHTO Specification for Equipment Acceptance 2. Evolve Technology toward Field Ready System through Pilot Field Evaluation: Safety, Reliability, Accuracy, Repeatability and Availability. 3. Develop MnDOT Specification for Data Collection. 4. Propose Specification for Dielectric to Density Conversion. 5. Establish a Pooled Fund Study.
CY 2020	1. Continue Pilot Field Evaluation. 2. Enhance VETA software so that DPS output and associated construction data can be analyzed by VETA. 3. Propose AASHTO Specification for DPS Data Collection. 4. Finalize and propose AASHTO Specification for Dielectric to Density Conversion. 5. Develop Trial DPS Acceptance Specification for Implementation.
CY 2021-CY2023	1. Establish precision and bias statement through pooled fund study 2. Pilot implementation of the above developed trial DPS specification on HMA layer of rehabilitation projects with FDR or CIR base for compaction quality assurance.
CY 2024	Deploy to AMT unit

Results of 2018 Projects

- TH371
  - First pilot project.
  - Hired a contractor to collect data: 100hr @$70/h budgeted.
  - 8miles, 4 days data collection (contractor); 3 days (MnDOT)
  - MnDOT collected data with the contractor: repeatability

2018 Projects (TH371)

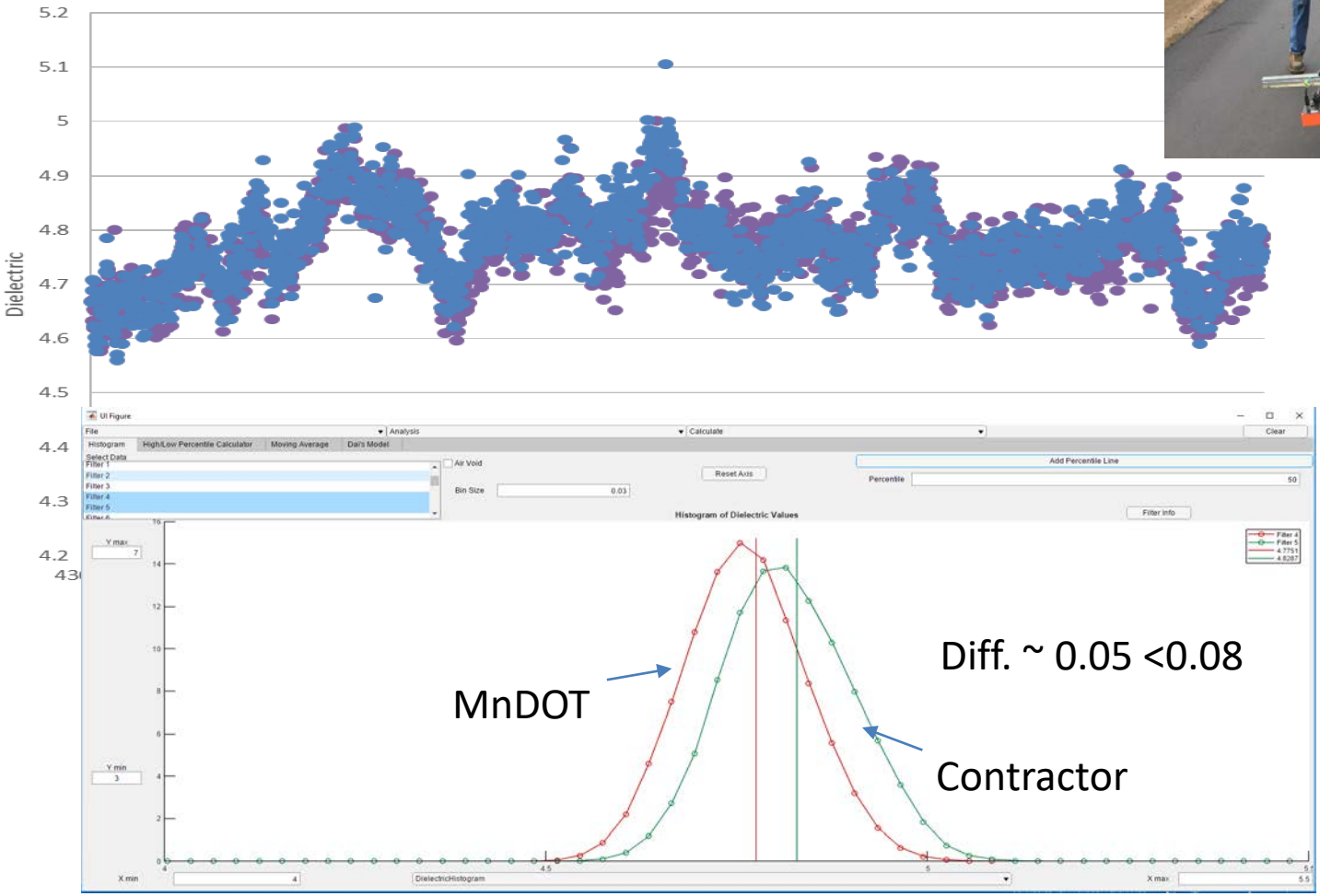


- What is Swerving Test?
  - A way to verify inter-antenna variation in the field.
  - Select approximately 500ft: Histogram of each antenna should be similar – Max difference <0.08

Swerving Test:

* Good agreement between Contractor and MnDOT data: Median dielectric difference < 0.05

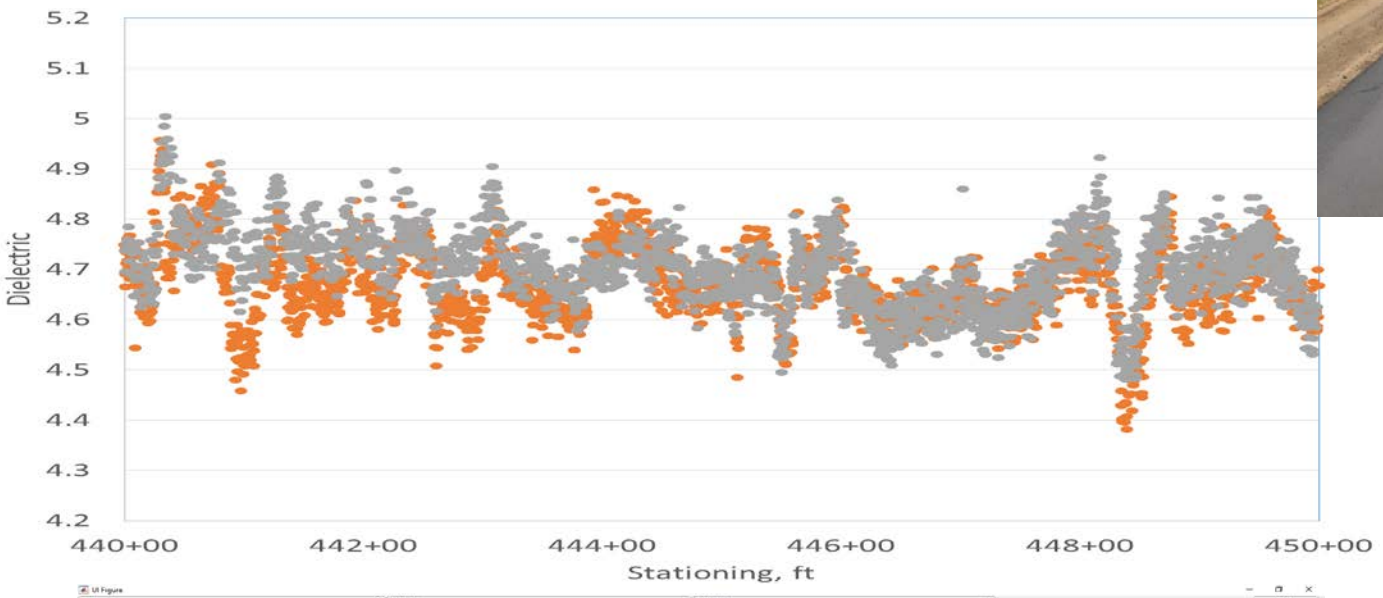
2018 TH371 contractor experience – equipment validation: Mainline



MnDOT Mainline

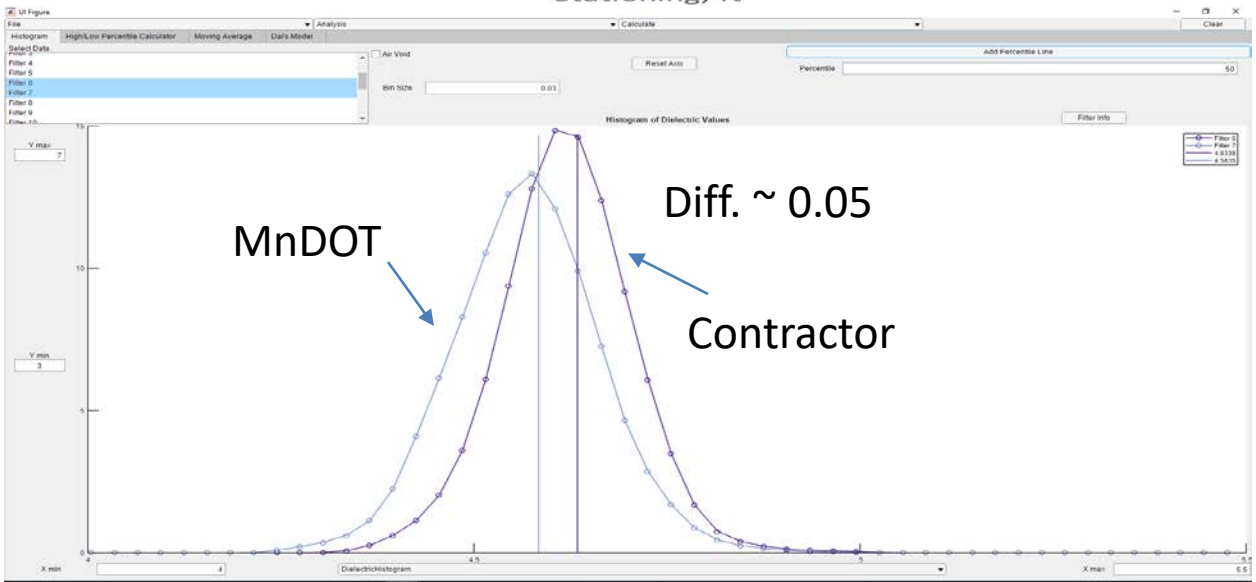
Contractor Mainline

Summary Field Use: 2018 TH371 contractor experience – equipment validation: Joint

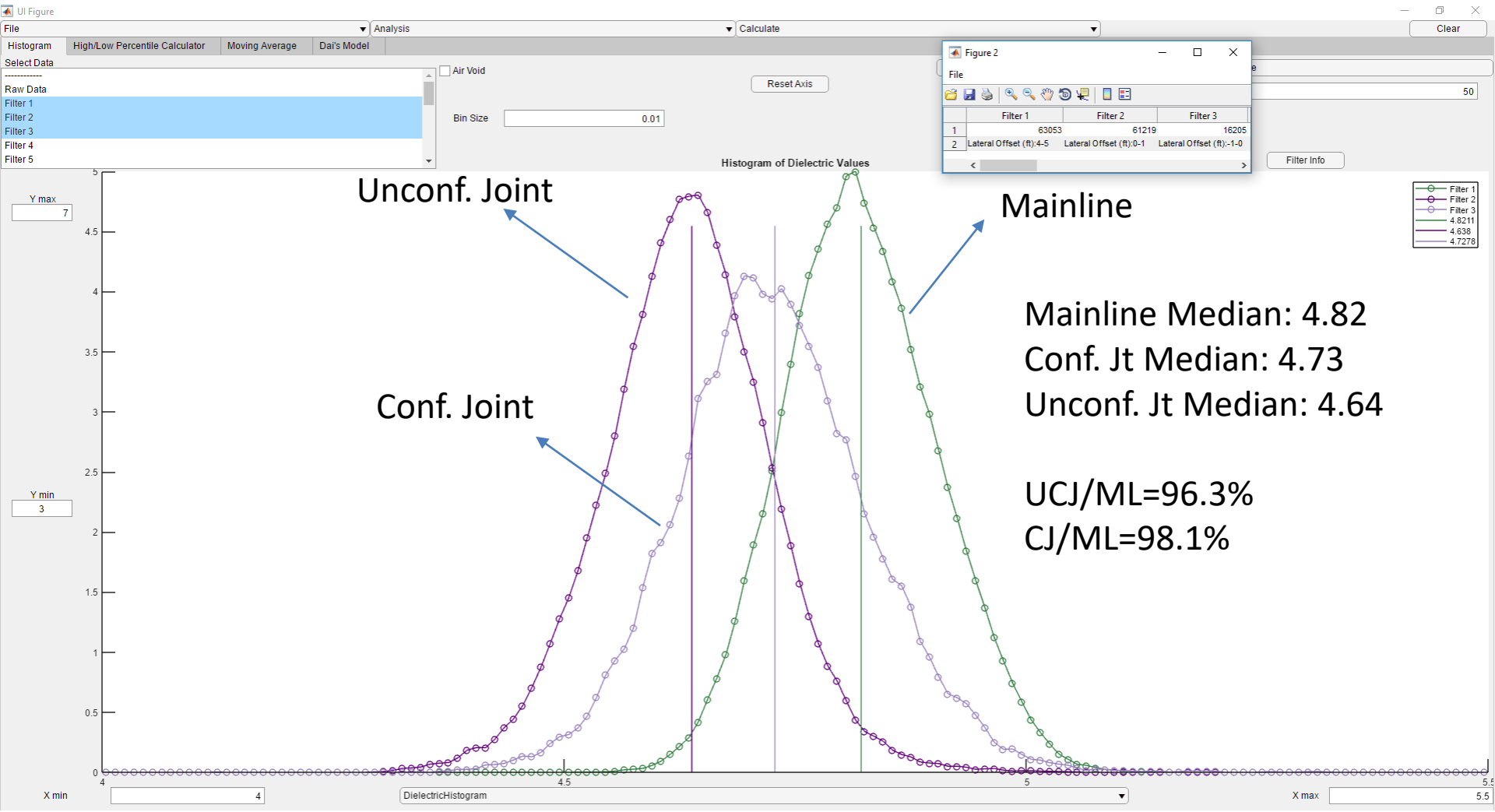


MnDOT Joint

Contractor Joint

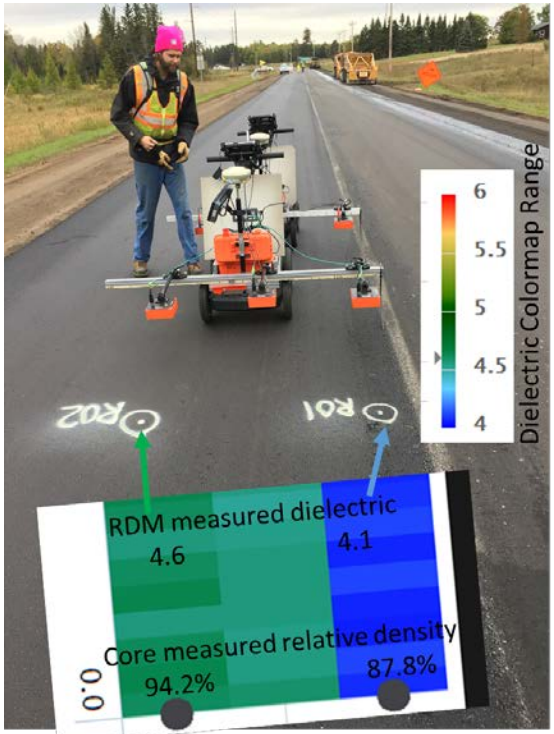


Summary Field Use: 2018 TH371 Overall (Mainline vs Joint; Combined MnDOT and Contractor)



Summary Field Use – Equipment Use

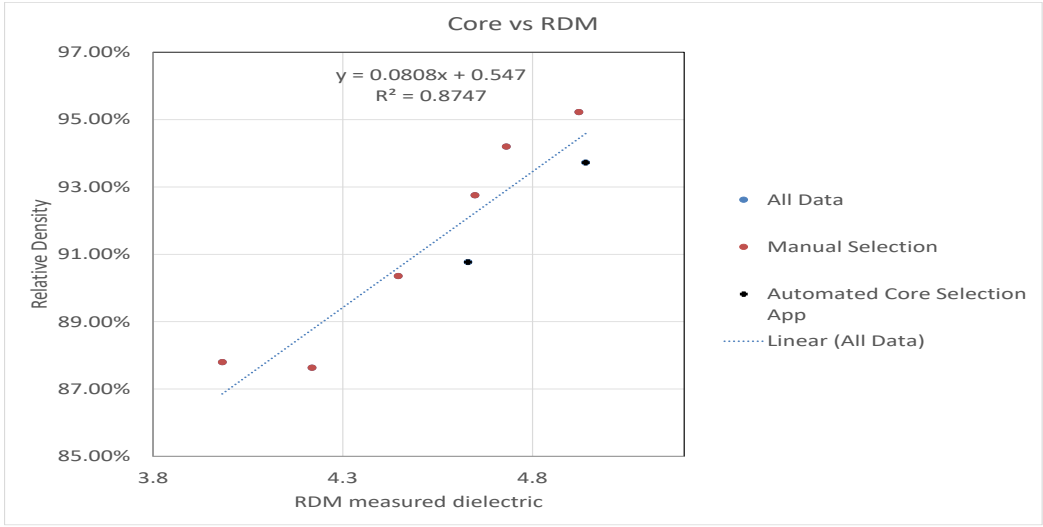
On-Site Feedback



Contractor RDM1 real time display

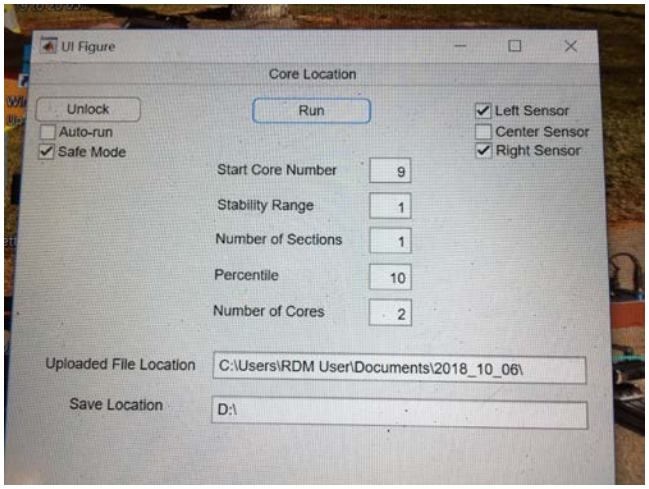
- Contractor could identify low and high density locations
- R01 – dielectric 4.1
- R02 – dielectric 4.6
- Corresponded to 87.8% and 94.2% relative density respectively

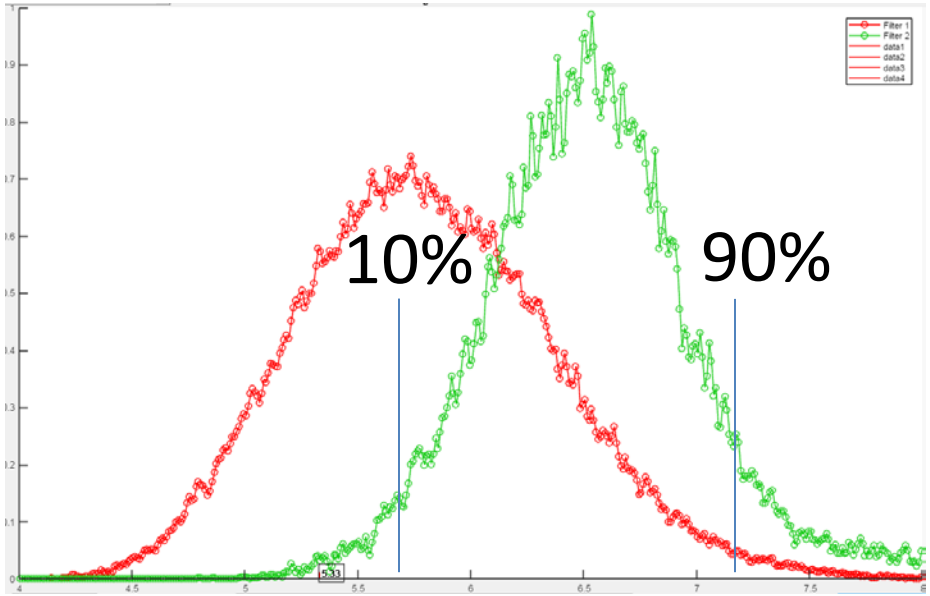
Automatically guide field person to the core location for coring (Blue points)



Automatic Core Locator for Implementation

- Currently still use field cores to establish E– density calibration curve.
  - Ideally select high and low dielectric areas
- Trial of 10% and 90% core location





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

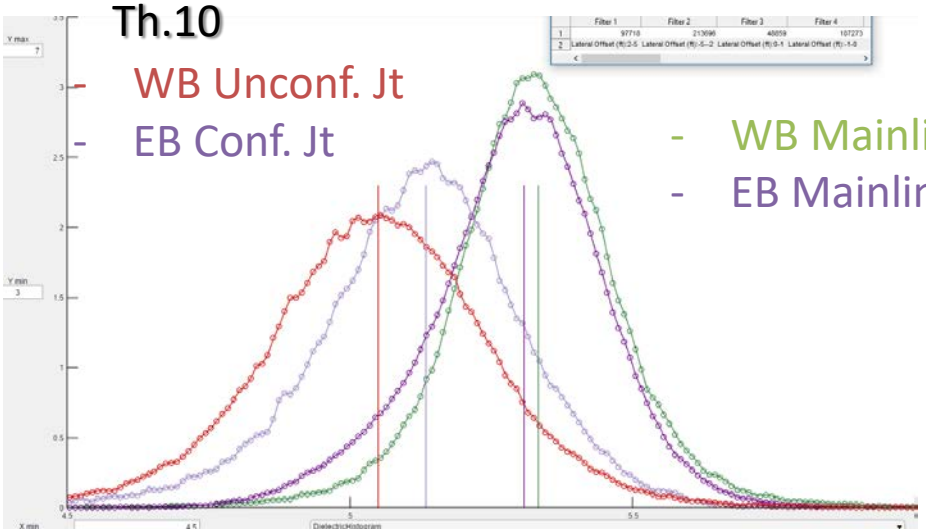
Summary Field Use – Core Locator

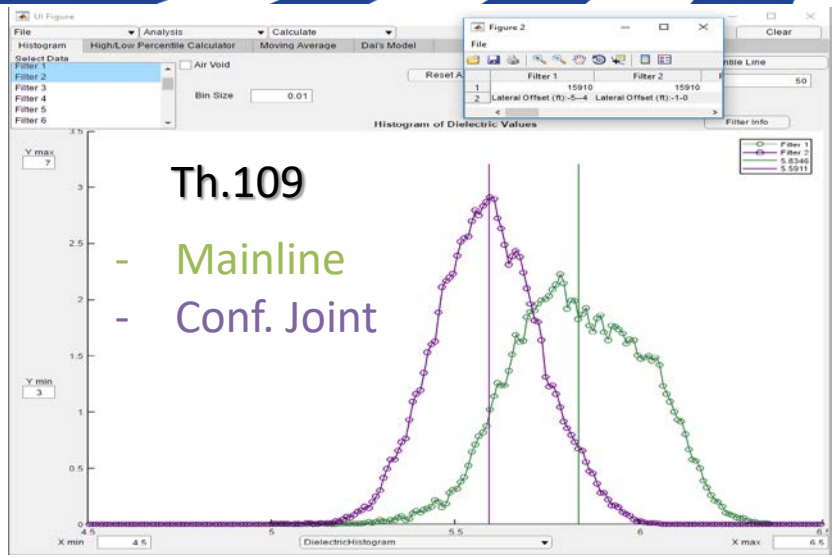
- automatically guide field person to the core location for coring

Other project data

Th.10

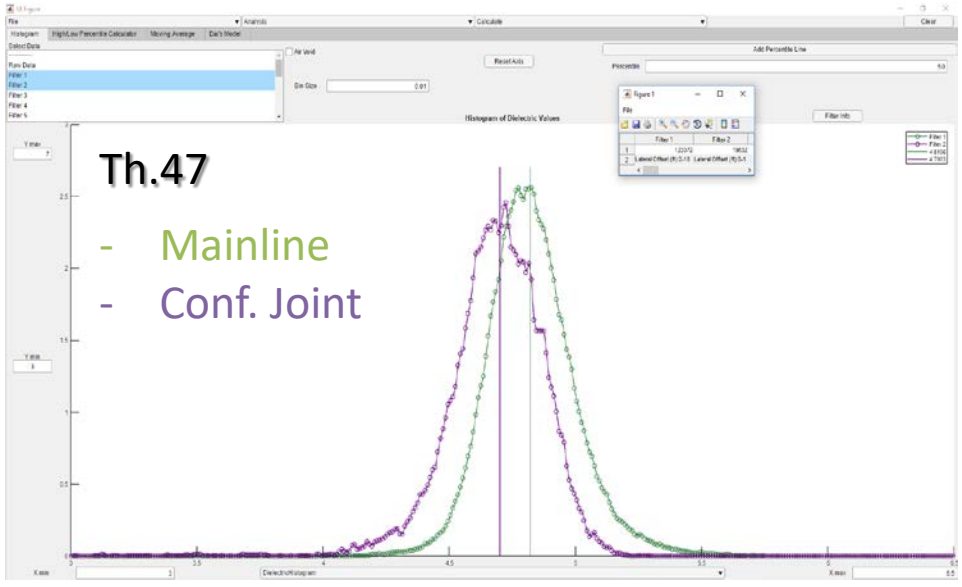
- WB Unconf. Jt
- EB Conf. Jt
- WB Mainline
- EB Mainline





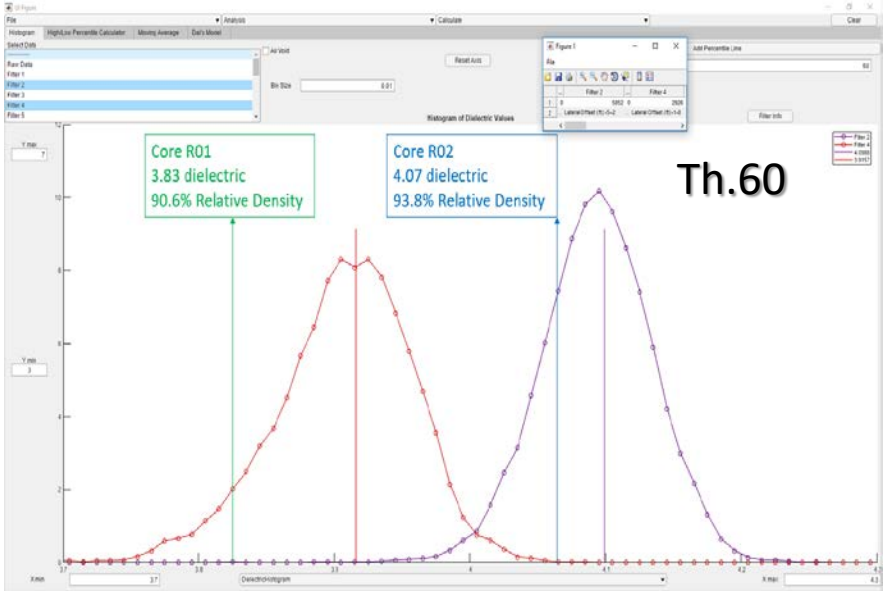
Th.109

- Mainline
- Conf. Joint



Th.47

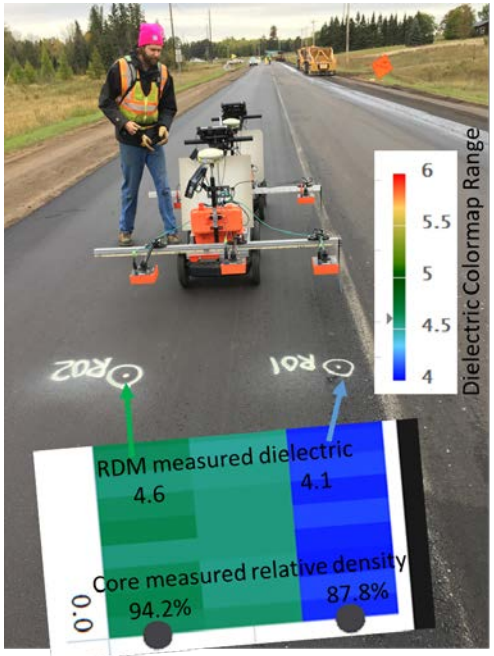
- Mainline
- Conf. Joint



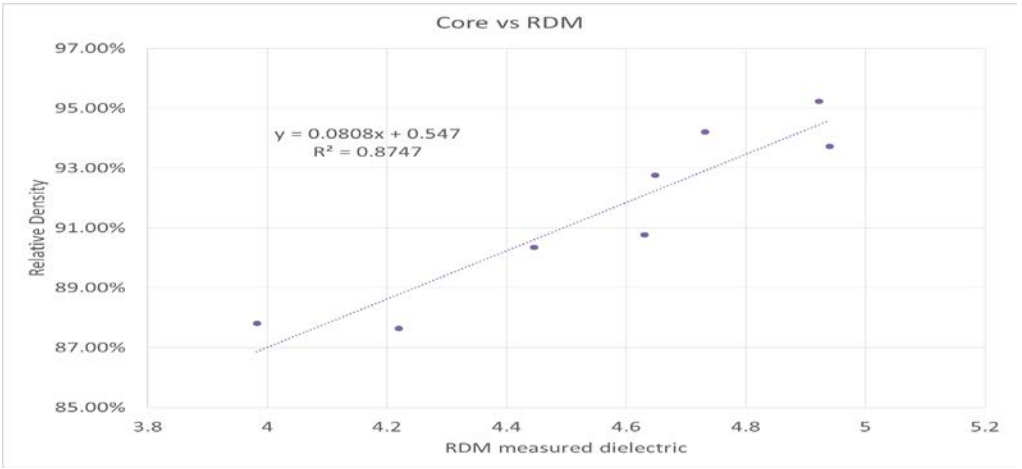
Th.60

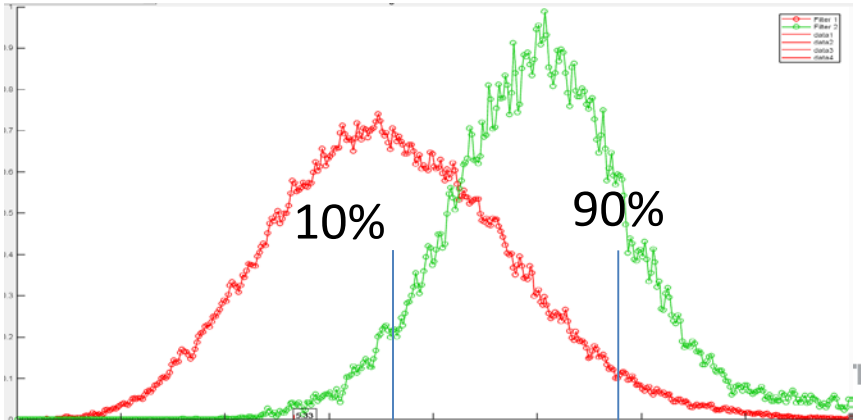
Coreless Calibration and Sensitivity Study

- Currently Field Cores Needed to Obtain E-Density
  - Destructive & safety concern
  - Need to wait for core density results



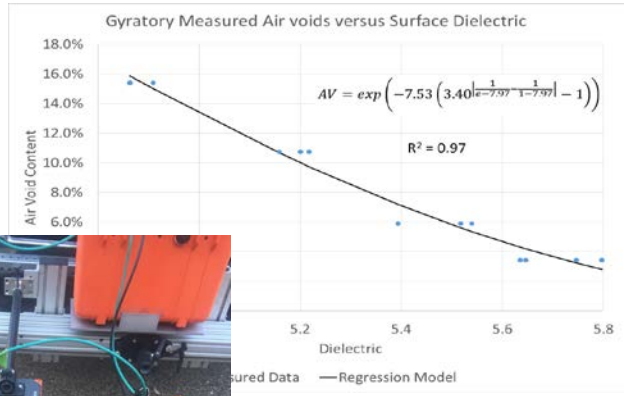
Contractor RDM1 real time display

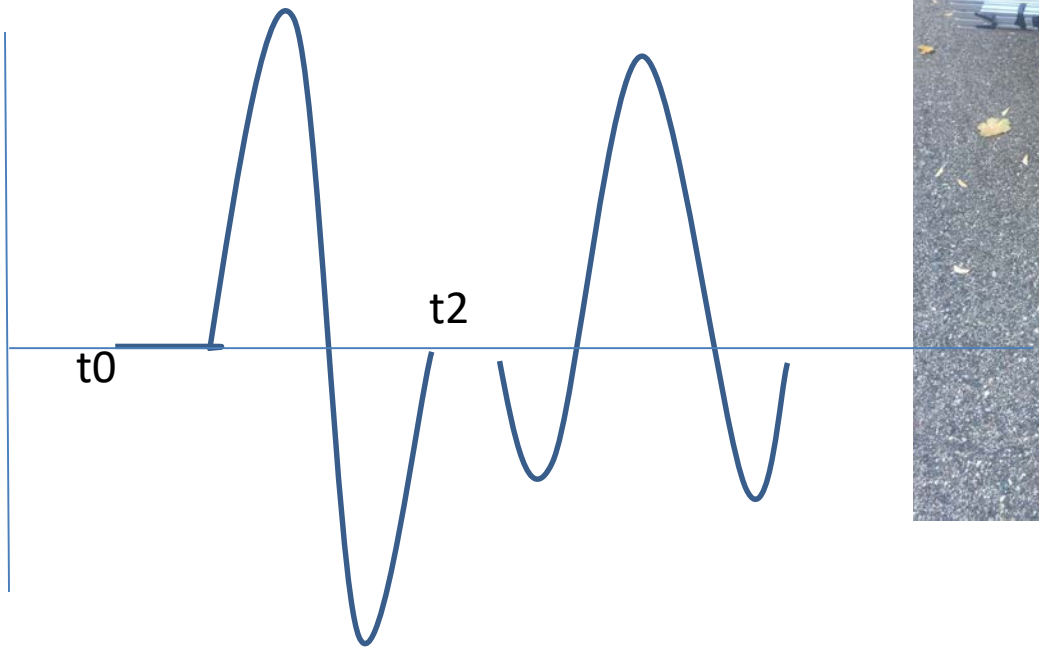


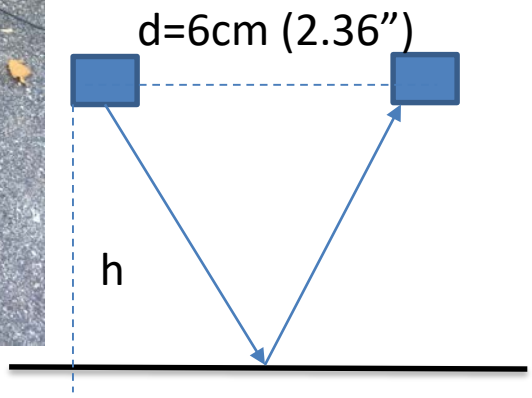


Coreless Calibration and Sensitivity Study

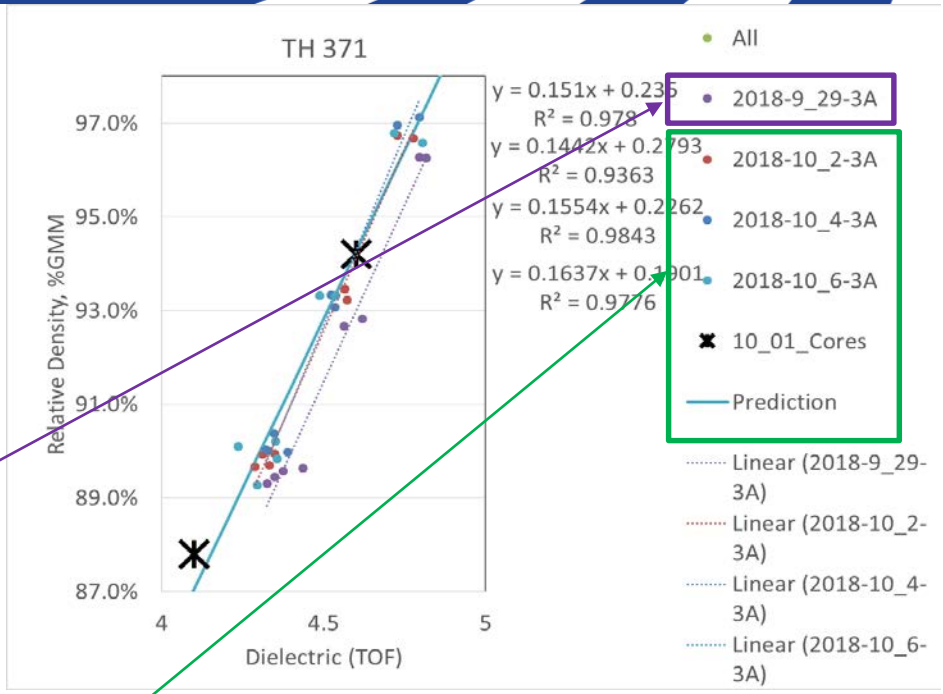
- Can Gyratory Specimen be Used for Calibration?
  - If yes, manufacture specimens with different densities at laboratory to obtain calibration curve.
  - Challenge
    - Footprint size > Specimen Dia.
    - Direct wave interference







Coreless calibration and sensitivity study (GSSI: Roger Roberts method)



Delrin

Aggregate Source	9/29 Agg. SpG.	9/29 % of mix	10/1 to 10/6 Agg. SpG.	10/1 to 10/6 % of mix
Powers BA Sand	2.632	32	2.632	30
Powers 1/2 Rock	2.712	26	2.712	26
Powers Dust	2.685	12	2.685	12
Powers 5/8 Rock	2.716	0	2.716	0
Swenson 3/4 Rock	2.702	0	2.702	0
Rap	2.642	30	2.642	32

Contractor Comments

Here are a few of my thoughts after working with Kyle and using the RDM cart on our TH371 (SP1118-21) project:

*Didn't feel it was hard to learn how to run.

*Took me about an hour to setup:

* Seeing results live would be helpful if one is able to communicate with the rollers to improve density.

* Would love to see a power source instead of carrying all the batteries.

* 2000ft back from finish roller is better than 500ft

* Show design/alignment map on computer as IC: easy to follow the center line.

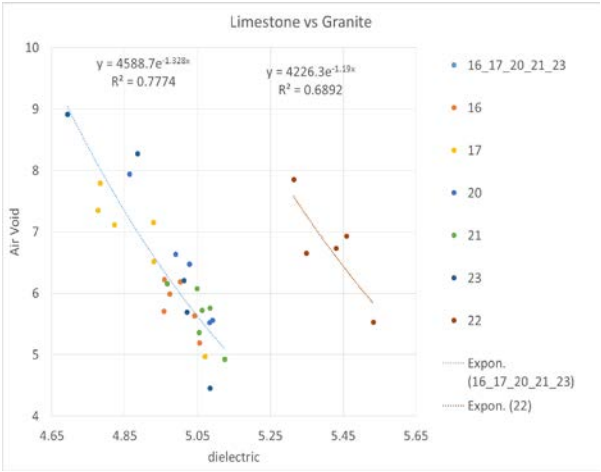
* Lifting the cart solo was a little rough on the back. Was very awkward

* Didn't feel completely safe in traffic control

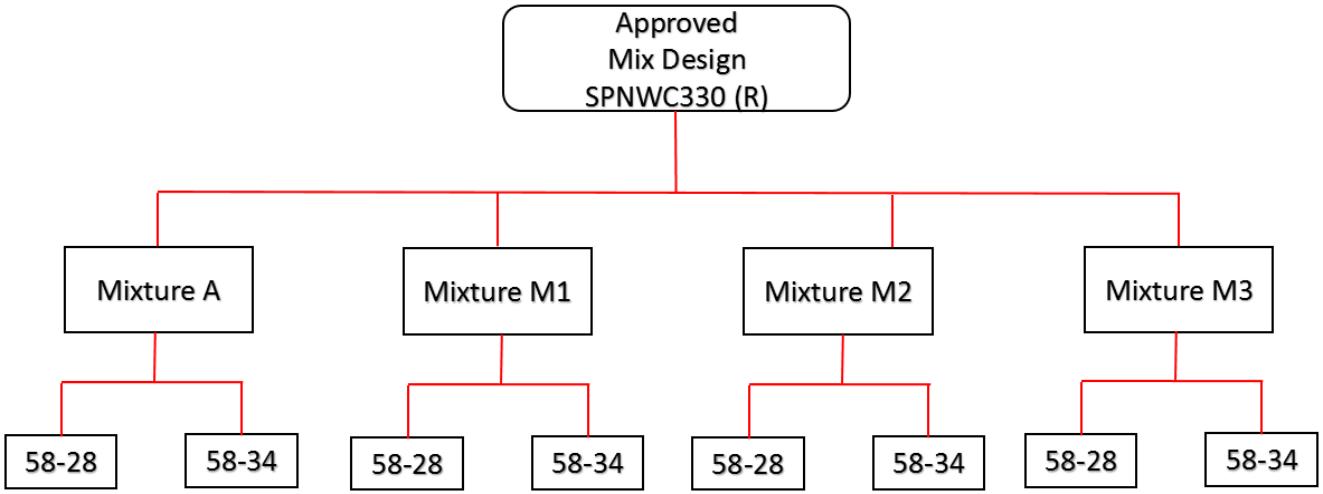
Preliminary Sensitivity Study

- Aggregate type has a pronounced effect on dielectric
- Effects of other components in a mixture?
- Purpose:
  - Need to establish criteria when a new calibration curve is needed

Mixture		Description
A	Approved Mix	As per mix design (Control)
M1	Modified Mix 1	Replace 10% granite sand with extra 10% lime sand
M2	Modified Mix 2	Replace 20% granite sand with extra 20% lime sand
M3	Modified Mix 3	Remove RAP and increase by 5% both granite lime sands



Preliminary Sensitivity Study



- Variables
  - Aggregate type; RAP; air void; specimen thickness; binder grade; temperature; moisture; aging.

A Proposed Pooled Fund Study

- Identified a need to establish a pooled fund study at the last peer exchange (July 30 – Aug. 1 2018)
  - This is a very promising and breakthrough technology for HMA compaction quality control/assurance.
  - More and more states are interested in the technology
    - AK, NE; ME; TX; FL; OH; MD; ID,NY(?)
  - SHRP 2 fund is running out and need a method to keep the momentum going.

- The objective of the proposed pooled-fund project is to establish a research consortium focused on

  - A) further advance and improve the system based on experience and needs from participants so that the system can effectively and efficiently support their Quality Assurance Program;
  - B) support communication;
  - C) provide participating agencies guidelines on data collection and analysis protocols, support AASHTO specification development and refinement;
  - D) provide training and technical assistance that include to provide support for specification development and strategies for agency full implementation;
  - E) conduct technology promotion and marketing for the system.

Tentative Timeline:

Solicitation: Spring this year

Project starts: Oct. or Nov. this year

Questions?

Contact: Shongtao Dai

Shongtao.dai@state.mn.us

Kyle Hoegh

Kyle.hoegh@state.mn.us