Minnesota Update – Density Profiling System (DPS)

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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
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 effect on dielectric constant
Histogram is a good method for evaluating compaction quality and acceptance: uniformity and density

Summary of Current Findings

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)
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.
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 18 miles.
- 2017: I35; Th52; Th22; Th60; CR86; Th110; CSAH13 and MnROAD
  - Vehicle mounted system
  - Hired American Engineering Testing (AET) to collect data
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
AASHTO Spec.
- A draft was developed in 2017
- A revised one is being reviewed
- Name change: RDM to DPS (Density Profiling System).
MnDOT Vision and Roadmap

- Ultimate vision: Integrated Closed-loop Feedback System

DPS Technology (Compaction End Results)

- Fail (Examine the following)
  - Roller Infor. (IC)
  - Temperature Uniformity (PMTP)
  - Trucking efficiency (e-ticket)

- Acceptance

- Material Volumetrics
- Material Perf. Test

Adjustment
## MnDOT Vision and Roadmap

### Draft Roadmap

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
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</table>
| 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.  
              5. Establish a Pooled Fund Study. |
              2. Enhance VETA software so that DPS output and associated construction data can be analyzed by VETA.  
| 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
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
Summary Field Use: 2018 TH371 contractor experience – equipment validation: Joint

MnDOT Joint

Contractor Joint

Diff. ~ 0.05
Summary Field Use: 2018 TH371 Overall (Mainline vs Joint; Combined MnDOT and Contractor)

- Unconf. Joint Median: 4.64
- Conf. Jt Median: 4.73
- Mainline Median: 4.82

- UCJ/ML = 96.3%
- CJ/ML = 98.1%
Summary Field Use – Equipment Use

On-Site Feedback

- 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)
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
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
  - Core R01
    - 3.83 dielectric
    - 90.6% Relative Density
  - Core R02
    - 4.07 dielectric
    - 93.8% Relative Density
Coreless Calibration and Sensitivity Study

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

\[ d = 6 \text{cm (2.36")} \]

\[ t_0 \]

\[ t_2 \]
Coreless calibration and sensitivity study (GSSI: Roger Roberts method)

<table>
<thead>
<tr>
<th>Aggregate Source</th>
<th>Agg. SpG.</th>
<th>% of mix</th>
<th>Agg. SpG.</th>
<th>% of mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powers BA Sand</td>
<td>2.632</td>
<td>32</td>
<td>2.632</td>
<td>30</td>
</tr>
<tr>
<td>Powers 1/2 Rock</td>
<td>2.712</td>
<td>26</td>
<td>2.712</td>
<td>26</td>
</tr>
<tr>
<td>Powers Dust</td>
<td>2.685</td>
<td>12</td>
<td>2.685</td>
<td>12</td>
</tr>
<tr>
<td>Powers 5/8 Rock</td>
<td>2.716</td>
<td>0</td>
<td>2.716</td>
<td>0</td>
</tr>
<tr>
<td>Swenson 3/4 Rock</td>
<td>2.702</td>
<td>0</td>
<td>2.702</td>
<td>0</td>
</tr>
<tr>
<td>Rap</td>
<td>2.642</td>
<td>30</td>
<td>2.642</td>
<td>32</td>
</tr>
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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
Core Locator Application

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

<table>
<thead>
<tr>
<th>Mixture</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>Approved Mix (Control)</td>
</tr>
<tr>
<td>M1</td>
<td>Modified Mix 1: Replace 10% granite sand with extra 10% lime sand</td>
</tr>
<tr>
<td>M2</td>
<td>Modified Mix 2: Replace 20% granite sand with extra 20% lime sand</td>
</tr>
<tr>
<td>M3</td>
<td>Modified Mix 3: Remove RAP and increase by 5% both granite lime sands</td>
</tr>
</tbody>
</table>
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?

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