Coreless Asphalt Pavement Compaction Assessment: Density Profiling System

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TRB 99th Annual Meeting
Asphalt Pavement Construction and Rehabilitation Committee
DPS: Deficiency Detection
Need for Improved QA

**Goals:**
- 100% joint coverage
- Improve random mat sampling (random cores on steroids)
- Improve dielectric to density conversion process.
- Reduce field cores!

Elephant = 6 tons
Hedgehog < 1 pound

For every 100 elephants of mix, we sample and test two hedgehogs (cores)

THAT’S IT?
Analysis: 100% Joint Coverage

Geospatial Representation
Analysis: Mat Compaction

“Random Cores on Steroids”
• Nondestructive
• Many Samples

Swerve Survey
Method Overview: Field Calibration

Daily Check

Sensor Corrections of 2019_08_08 Agency

- Sensor 113 CF = 0.041085
- Sensor 114 CF = -0.03887
- Sensor 115 CF = 0.00322

Time of Day

10:00 10:30 11:00 11:30 12:00
Convert “Moving Nuke Gage” to Moving “Core Machine”

- Create daily dielectric to density conversion
  - Fabricate coreless calibration pucks every day of production
    - Design voids (4%), -250 grams (8-10%), -500 grams (12-15 AV%)
    - Contractor vs Agency: Good agreement 2019 on TH 61
    - Day to day variation of same mix showed very little variation
    - Coreless calibration effective at picking up changes in the mix

Proactive contractor lab QC
Coreless Calibration Case Study: October 1\textsuperscript{st} - 10\textsuperscript{th} 2018 TH371

Dielectric - Air Void Model for TH371

AV = \frac{0.20}{1 + (\exp(5.1)^{10.74})^{8.35 + 0.008/(-1)}}

Contractor RDM1 real time display

Core measured relative density
94.2%  87.8%

RDM measured dielectric
4.6  4.1
371 Results: Example PAL Variability

Percent Joint Above 91%RD and Mat Above 93%RD for TH371

<table>
<thead>
<tr>
<th>Stationing</th>
<th>+joint</th>
<th>+mat</th>
</tr>
</thead>
<tbody>
<tr>
<td>220+00</td>
<td>50.0%</td>
<td>70.0%</td>
</tr>
<tr>
<td>221+00</td>
<td>40.0%</td>
<td>60.0%</td>
</tr>
<tr>
<td>222+00</td>
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<tr>
<td>224+00</td>
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</tr>
<tr>
<td>226+00</td>
<td>0.0%</td>
<td>10.0%</td>
</tr>
</tbody>
</table>
Coreless Dielectric to Air Voids

Gyratory Compacted “Puck” Coreless Calibration

TH 371

TH 60

TH 55

ND 18

TH 15

TH 61
Coreless Calibration Case Study: TH 55 Daily Report

Swerve Correction over Time

- Time, Minutes
- Correction Factor

- AASHTO Tolerance

- Colors Represent:
  - 72
  - 74
  - 75
Coreless Calibration Case Study: TH 55 Daily Report

Dielectric - Air Void Model for TH55

\[ AV = \frac{0.20}{(1+\left(e/9.12\right)^{11.25})^{1001.4}+0.008/(e-1)} \]
Coreless Calibration Case Study: TH 55 100 ft. Lot Analysis

TH55 05-20 AV vs Stationing

AV

Stationing

0.0% 1.0% 2.0% 3.0% 4.0% 5.0% 6.0% 7.0% 8.0% 9.0%

94+00 96+00 98+00 100+00 102+00 104+00

+mat
+Joint
Coreless Calibration Case Study:
TH 55 100 ft. Lot Analysis

TH55 05-20 AV vs Stationing

Stationing

AV

+mat
+Joint
Coreless Calibration Case Study: TH 55 100 ft. Lot Analysis

Percent Joint Above 91%RD and Mat Above 93%RD for TH15

- **joint**
- **+mat**

Stationing: 274+00, 275+00, 276+00, 277+00, 278+00, 279+00, 280+00, 281+00, 282+00, 283+00
FHWA Visit TH15:
July 17th 2019 Demo
FHWA Visit TH15: 
July 17th 2019 Demo

- Morning
  - Production Mix Collected
  - Field Testing
  - Demonstration
  - Run Gyratory Pucks

- Afternoon
  - Test Pucks for Dielectric
  - Run Analysis on Morning Data
  - Run Auto Report
  - Add results to afternoon presentation for FHWA

Next Day: Core Validation Results

Project and Testing Information

Density Profiling System (DPS) testing was conducted on 07-17-2019 at Trunk Highway 15 (TH 15) in Kimball, Minnesota on State Project 7303-50 with Knife River paving bituminous spanning Saint Augusta miles. The testing was conducted on the 2nd lift with Mix Design SPWQA440F. The lift tested with the DPS is highlighted in yellow in Figure 1. The testing was conducted following the paving operation moving South to North on the mainline Northbound lane with the increasing stationing direction with DPS testing ranging from 274+00 to 338+00 with paving moving South to North (see Figure 2). The centerline joint edge of the mainline was confined throughout the testing, while the shoulder was unconfined throughout testing. Project Manager Rob Abalter (320-291-7284) and Project Inspector Jim Blackmore (320-309-4944) from MnDOT District 3 office accommodated the testing efforts. Nate Greaves from District 3 coordinated field coring and reporting with James Carlson at Knife River (James.Carlson@kniferiver.com). Mike Daniels (320-293-9421) coordinated asphalt puck fabrication and testing in the District 3 St. Cloud laboratory. The mix used for puck testing was test 001, corresponding to the first approximately 200 tons of paving, corresponding to MDR: 3A-2019-120. Kyle Hoegh (651-366-5526) from MnDOT Materials and Road Research (MRR) coordinated the DPS testing. Figure 3 gives the typical sections for SP 7303-50.
FHWA Visit TH15: July 17th 2019 Demo

- Sensor 72
  - In specification 100% of the time (7/7)
  - Median Correction Factor: -0.04 +/- 0.02
- Sensor 22
  - In specification 100% of the time (7/7)
  - Median Correction Factor: -0.05 +/- 0.03
- Sensor 74
  - In specification 100% of the time (7/7)
  - Median Correction Factor: -0.01 +/- 0.03

The AASHTO 0.08 dielectric tolerance was monitored throughout the day, validating the quality of the data for use in assessing compaction. The Median correction factors given in the bullets above were applied to ensure the different sensors are measuring uniformly, and used for results presented herein.

Figure 2. Google Earth image of DPS tested areas (link to.kml file for viewing).

Figure 6. Swerve correction factor results versus time of day.
Figure 11. PWL throughout project (91 for joint, 93 for mat). First plot has data on joint and in mat.
Goals Required for Use as QA Tool

- Create daily dielectric to density conversion
- Fabricate coreless calibration pucks every day of production
  - Design voids (4%), -250 grams (8-10%), -500 grams (12-15 AV%)
  - Contractor vs Agency: Good agreement 2019 on TH 61
  - Day to day variation of same mix showed very little variation
  - Coreless calibration effective at picking up changes in the mix

### All Pucks and Models for TH61 Project

- 440 mix Surface 5.3 binder
  - 5.5 e_Surface = 4.7% AV
  - Normal Surface Model
- SP Surface Pucks 6.1 binder
  - 5.5 e_SP Surface = 3.8% AV
  - SP Surface Model
- Normal Base Pucks binder 4.9
  - 5.5 e_Base = 6.9% AV
  - Normal Base Model
- SP Base Pucks binder 5.2
  - 5.5 e_SP Base = 6.8% AV
  - SP Base Model
TH 61 Case Study: Puck Vs Cores
Coreless Calibration Case Study: Puck Vs Cores

Core Correction Factor

Dielectric - Air Void Model for 2019_08_19 Agency

AV = 0.20/(1+(e/5.87)^10.64)^4.07 + 0.008/(e-1) \Delta e = -0.09
Goals Required for Use as QA Tool

- Conduct Daily Validation of Coreless Calibration Prediction

Last Season: Marked one high and one low dielectric location each day

2020: No additional cores, just use QA randomly selected locations
- Selected/marked after final roller but within traffic control
- **Proactive on-site inspector**
- Test with DPS during routine data collection throughout the day
Goals Required for Use as QA Tool

- Routine collection that is accurate and not too labor intensive

**Proactive contractor field collection**

Manual Collection

**Robot Collection**

Single Pass: Programmable moving bracket collection (Gator)
2020 NRRA PAVEMENT WORKSHOP

May 19-21, 2020 | Shoreview, Minnesota

Visit our booth #548 or online: mndot.gov/mnroad/nrra/pavement-workshop

Meeting @ TRB: Jan. 15 | 6:30-8pm | Chinatown (M3) Marriot Marquis