Importance of Intelligent Compaction – Agency Perspective

July 9, 2020

Australian Asphalt Pavement Association | Interactive Forum with Intelligent Compaction Masters
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Deployment of Intelligent Compaction Technology
MnDOT’s Roadmap for Asphalt Pavements

2010-2012
Stage 1
For Information Only - Data

2013
Stage 2
Refined Specification
Established Roadmap
Increased Training

2014
10%

2014-2017
Stage 3 – Phased Deployment
Continued Refinement of Specification

2015
15%

2016
50%

2017
75%

2018
100%
Stage 4 – Full Deployment

2020
100%
Added IC requirements per 600-ft sublot

Future
Continue to increase requirements.

2018

Future

~ 15 Million Tons Paved / Year

Total Number of IC Projects: 427
Total Number of PMTP Projects: 382

- IC Granular - Non-Granular
- IC: Redamtion
- IC: Ultrathin Bonded Wear Course
- IC: Asphalt Pavement
- Paver Mounted Thermal Profiling

2004-2010
Focused on Earthwork
Tabled - Further Research

2010 - Present
Focused on Asphalt Applications
Retrofit Systems Available
NO ONE SHOULD BE ASKED TO BID ON SOMETHING THEY DO NOT UNDERSTAND!

• Ensure Agency-Contractor-Vendor Collaboration

• Agency flexibility is needed during early implementation stages
HOLD DISCUSSIONS WITH CONTRACTORS:

‘Buy-In’

Increase Knowledge

Realities of Field

DECREASE RISK
MnDOT’s Fiscal Responsibility
Remaining Service Life
Enhancing Financial Effectiveness

• Advancement of Technologies is increasing accountability of both the Agency and Contractor

• Implementation of New Technologies
  
  • ↑ Life of Pavements
  
  • ↓ Annual Maintenance Costs
Expense of $6 Million over 4 year period (both IC & PMTP)

Over $540 Million on Asphalt Paving Pay Items

Only an additional 1.1% over a 4-year period!

Typical Asphalt Overlay lasts ~ 17 years (204 months)

An average life increase for a project using the technologies would have to be a mere 2.2 months to be considered cost effective!!!
Continuing hire of a strong workforce is getting difficult ...

Quoted in Asphalt Pavement Magazine, pg. 51

“Technology is going to be a huge part of our industry going forward,” said Jay. “Fleet tracking and optimization of equipment utilization has advanced and will continue to advance. Everything will continue to move toward real time. We need to provide our young people with technology – they want the latest and the greatest. And as fast as technology is moving, we need to ramp up our efforts regarding continuing education.”
Why MnDOT is Using Intelligent Compaction

Increase Long-Term Pavement Life
How do you know when density is achieved?

- Maximum density is measured by taking cores.
- Ordinary compaction involves setting up a standard rolling pattern (control or test strip).
Elephant = 6 tons

Hedgehog < 1 pound

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

THAT’S IT?
It is unrealistic to collect the number of samples and tests required to statistically represent material properties.
Some Stuff Happens . . .

• .... with feeding paver,
• .... paver placing mat,
• .... rollers rolling,
• .... mat cooling
• ....

• ....then 24 hours later we take some cores

All we know is what we have seen in the mat.

... If we have someone available.
“You should stop worrying about taking the right number of tests. Once this stuff leaves the plant, you have no controls over quality until it’s too late. Fix your process, not your testing.”

Asphalt Pavements

University of Minnesota Industrial Engineer Professor upon completion of a study to determine proper testing rate for HMA density.
Material Failure: 21%
Workmanship: 79%

Figure Courtesy of Mark Woolaver, VAOT
From the past studies, 1% increase in air voids would decrease the service life by an conservative estimate of 10%

This means . . .

An asphalt overlay constructed to 93% density might be expected to last 20 years while the exact same asphalt overlay constructed to 92% density would on be expected to last 18 years.
Improved Compaction = Improved Performance

A **Bad Mix** with **Good Density** out-performed a **Good Mix** with **Poor Density** for ride and rutting.

WesTrack Experiment
Effect of In-Place Air Voids on Life
Washington State DOT Study

![Graph showing the effect of in-place air voids on percent service life.]
In-Place Air Voids vs. Fatigue Life

UK-AI Study

1.5% ↑ Density leads to 10% ↑ in fatigue life
Average Increase in Fatigue Life for 1% Decrease in Air Voids

NCAT Report 16-02 (2016)
Average Decrease in Rut Depth for 1% Decrease in Air Voids

NCAT Report 16-02 (2016)
Average No. Years Until Maintenance / Rehabilitation
Research from New Jersey
Intelligent Compaction - Rolling Patterns

Kandiyohi County

On-Board Display Covered

On-Board Display Uncovered
Identification of Soft Spots

Reflection of hard spots on the HMA layer

Reflected hard spots on the HMA layer

Reflection of soft spots on the HMA layer

HMA L1 Base

CCV
- 0 - 3
- 3 - 6
- 5 - 9
- 9 - 12
- 12 - 15
- 15 - 18
- 18 - 21
> 21

Images: ©2014 Dibiliscape, USDA Farm Se
Portland Cement Concrete (PCC) Joints

Reflective Cracking

15 ft concrete panel spacing

Lift 1
Rollers Not Keeping up with Paver

- Breakdown Roller
- Intermediate Roller
Less Compaction by Breakdown Roller & Cooler Compaction Temp.

Density Deduction = (9,405.25)

Breakdown Roller (Tmean = 235°F)

Intermediate Roller (Tmean = 185°F)

Finishing Roller (Tmean = 125°F)
Densities after IC Data Utilized

• Average Lot Density:
  • Lot 1 – 92.6%
  • Lot 2 – 93.2%
  • Lot 3 – 93.2%
  • Lot 4 – 93.2%
  • Lot 5 – 93.7%
Observe Rolling Operations

Failing Core Densities

Added 4th Roller

Final Breakdown Roller Coverage
(3 Rollers in rolling train)
Repeated 50 to 100 ft sections with No Vibration
Yielding Base
Removed Yielding Material – Geotextile

Failure Area
Base / Subbase Repairs

Check for soft spots and repair before any paving is allowed.
First Time Users of Intelligent Compaction System

Lift 1 Compaction Efforts

Coef. of Variability = 71%

Lift 2 Compaction Efforts

Coef. of Variability = 55%

30% Increase in Compaction Efforts

69% 31%

90% 10%
Effects of Permeability on Performance

Permeability can cause severe failures!
Effects of Air Voids on Permeability

- **Air Voids, percent**
  - 0
  - 2
  - 4
  - 6
  - 8
  - 10
  - 12

- **Permeability, $k \times 0.00001$ cm/sec**
  - 0.00
  - 200.00
  - 400.00
  - 600.00
  - 800.00
  - 1000.00

- **Impermeable**
- **Permeable**
## Research on Critical Air Void Level for Impermeability

### 9.5 mm Mixes

<table>
<thead>
<tr>
<th>Researcher</th>
<th>Institution</th>
<th>Year</th>
<th>Critical Voids where Permeable</th>
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<tbody>
<tr>
<td>E. Zube – California Dept. of Highways – 1962</td>
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<td>8.0</td>
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### 12.5 mm Mixes

<table>
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<tr>
<th>Researcher</th>
<th>Institution</th>
<th>Year</th>
<th>Critical Voids where Permeable</th>
</tr>
</thead>
<tbody>
<tr>
<td>J. Westerman – Arkansas HTD – 1998</td>
<td></td>
<td>6.0</td>
<td></td>
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</table>

NCHRP 531 (Dr. Brown) “...to ensure permeability is not a problem, the in-place air voids should be between **6 and 7 percent or lower**. This appears to be true for a wide range of mixtures regardless of NMAS and grading.”
Permeability: Top Lift Locations

Maryland Joint
No Vibration Along Longitudinal Joint

Failing Core Densities
Effects of Compaction Temperature vs. Density

- Charles F. Parker (1959)
  - 275°F – standard temperature – reference air voids
  - 200°F – doubled the air voids
  - 150°F – quadrupled the air voids

- Kim A. Willoughby, et. al. (2001)
  - Mix temperature differentials
    - \(\leq 25^\circ\text{F}\) – generally consistent air voids
    - \(\geq 25^\circ\text{F}\) – greater air void spread
      - Pneumatic rollers reduced spread
      - End dumps showed a greater spread.


Temperature is the most important factor in achieving density.
Effects of Temperature on Pavement Life

Figure 2. HMA samples tested in the APA to failure. (Collins (1998))
Cold Weather Compaction

IC and PMTP data used to support cooler mat temperatures during compaction efforts at location.
Less Compaction by Breakdown Roller & Cooler Compaction Temp.

Density Deduction = ($9,405.25)

Breakdown Roller (Tmean = 235°F)

Intermediate Roller (Tmean = 185°F)

Finishing Roller (Tmean = 125°F)
Roller Speed is Critical

Slower = More Compaction per Pass
Density Issues
Roller Speeds in Excess of 10 MPH!
IC and PMTP Technology on Asphalt Paving Projects

- Reduced Paver Speeds
- Additional Rollers
- Modification to Rolling Patterns
- Equipment Considerations
- Increased Fleet Management
- Tarping Trucks
- Piloting e-ticketing
- Crew Competitions
- Comparing Projects & Yearly Results
- Creating Paving Crew Summaries
- Winter Training
- Equipment Supplier Site Visits
- Guiding Belly Dumps
- Monitoring Stockpiles

What are others doing?
Summary

- Thermal segregation and poor compaction affect density and long-term pavement performance.

- Intelligent Compaction & Paver Mounted Thermal Profiling:
  - 100% Coverage
  - Uniformity Information
  - Real-time feedback
    - Identify
    - Fix
    - Prevent
Thank you again!

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AMT Website  |  http://www.dot.state.mn.us/materials/amt/index.html