Intelligent Compaction (IC) for Quality and Process Control of Cold in-Place Recycled (CIR) Pavements

Dr. Eyoab Zegeye Teshale
Pavement & Materials Engineer

David Rettner, P.E.
President/Principal Engineer

Presented to: 2018 Minnesota's Transportation Conference

MARCH 1, 2018

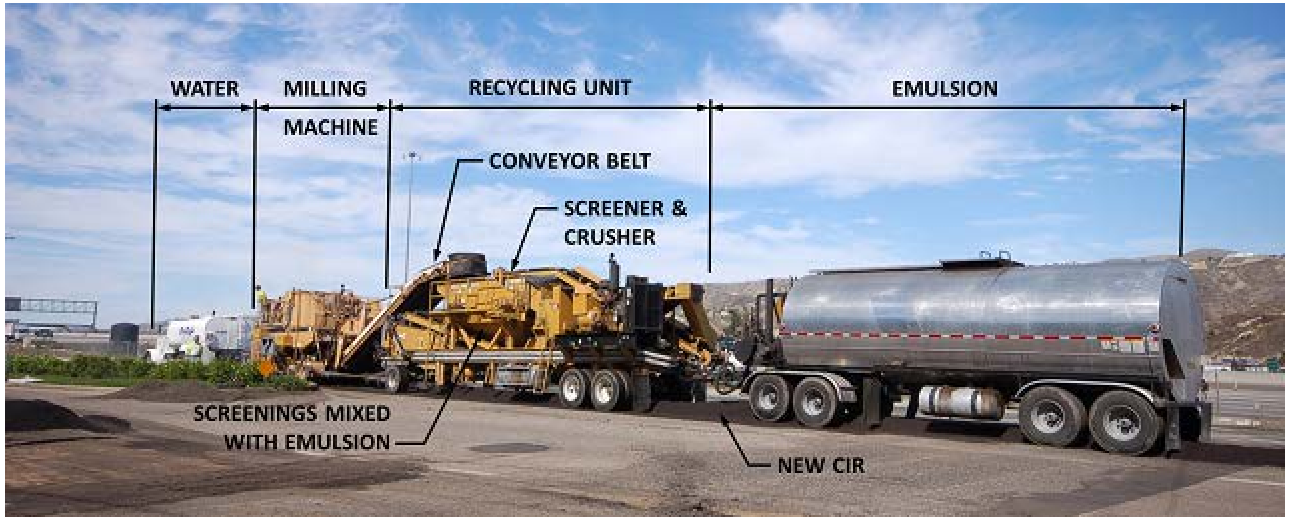
Trust Delivered.™

American Engineering Testing, Inc.

Cold In-Place Recycling (CIR)

Construction aspects

- Milling of the top 3-4 inches
- Crushing, screening and mixing
  - Engineered asphalt emulsion
  - Foamed asphalt binder
  - Other stabilizing additives
- Replacement and compaction



Los Angeles County Department of Public Work website

Cold In-Place Recycling (CIR)

What is missing?

- Rapid quality and process control tools
  - Uniformity & consistency of field produced RAP
  - That account for field adjustments & fine tuning of the mix design
  - As-constructed quality & performance of CIR pavements
  - Assessment of pavement readiness for traffic and heavy vehicles
    - Strength
    - Stability

Cold In-Place Recycling (CIR)

What is missing?

– Rapid quality and process control tools

- Uniformity & consistency of field produced RAP
- That account for field adjustments & fine tuning of the mix design
- As-constructed quality & performance of CIR pavements
- Assessment of pavement readiness for traffic and heavy vehicles
  - Strength
  - Stability

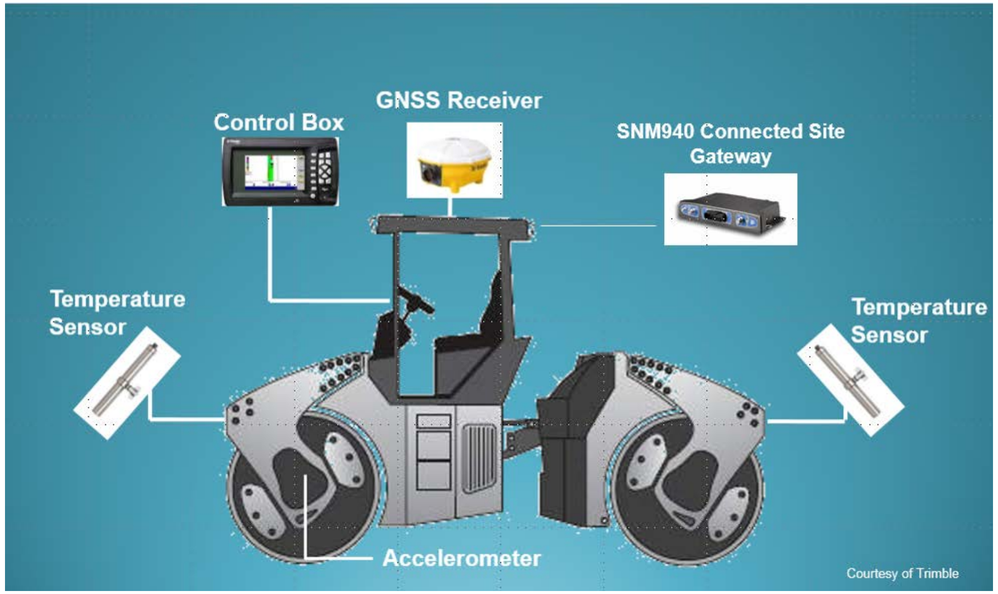
Critical to assess the readiness of CIR pavements to traffic or heavy construction vehicles

Intelligent Compaction

Intelligent Compaction (IC)

– Instrumented compaction rollers

- Global position monitoring systems
- On-board documentation and display
  - Real-time mapping & visualization of roller location, speed and number of passes
- Heat sensors
  - Surface temperatures
- Accelerometers
  - Vibration amplitude & frequency
- Stiffness index values
  - Intelligent Compaction Measurement Value (ICMV)



Intelligent Compaction

Intelligent Compaction (IC)

- Major difficulties
  - Different outputs depending on vendor
  - Managing large files
  - Analysis of large data

MnDOT

- VETA Standardized Intelligent Construction Data Management (ICDM) software
  - Data storage
  - Analysis of geospatial data
  - Statistical summary
  - Map visualization
  - Project Report & submittal forms
- Special provisions
  - Starting from 2018 IC will required on all CIR projects

Intelligent Compaction

For more information on IC, VETA, Special provisions
Rebecca Embacher
Advanced Materials and Technology Engineer
MnDOT | rebecca.embacher@state.mn.us | 651-366-5525

Objective

Explore practicability of using of IC data for rapid evaluation CIR pavements

- What type of information can be retrieved from IC data collected during the construction of CIR pavements
- How can these parameters be used to assess readiness to traffic

Project

Hwy 110 – Twin City Metro Area

- Milling-off the top 3-in.
- Reclaiming and recycling the next 4-in. with CIR
- Finishing with 3-in. of HMA overlay

Construction of CIR

- Midstate Reclamation & Trucking, Inc.
- Multi Unit Train (milling, screening, crushing, water and emulsion tanker)
- Compaction using two IC instrumented rollers

Photos by Jessica Lombardo, Construction News Feb 2018

Project

Project Challenges

- Rainy season
  - Led to wet and soft grade
  - Few rutting/depression instances during the paving of the HMA overlay
  - Solved by adjusting emulsion rates, compaction efforts and due to a more favorable weather
- Cross-slopes and elevation in turn lanes
  - Variable depth milling
  - Limiting CIR to only mainline pavement
- Traffic staging
  - Full directional closure

Project

Project Challenges

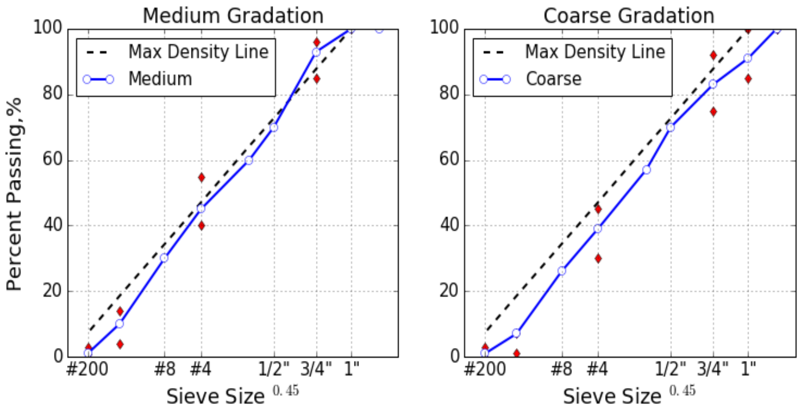
- Rainy season
  - Led to wet and soft grade
  - Few rutting/depression instances during the paving of the HMA overlay
  - Solved by adjusting emulsion rates, compaction efforts and due to a more favorable weather
- Cross-slopes and elevation in turn lanes
  - Variable depth milling
  - Limiting CIR to only mainline pavement
- Traffic staging
  - Full directional closure

MnDOT estimated over $800,000 in saving due the use of CIR
- Tim Clyne

Project

AET's involvement

- Forensic investigation & sampling
- CIR Mix design testing
  - 100% RAP
  - PG XX-28 supplied by FHR
- Analysis of IC data collected by Midstate
  - Hwy 110 East Bound
  - Retrieving data from vendor's cloud storage web
  - Analysis of IC data using VETA
  - MnDOT submittals (VETA projects & forms)



Mix Parameter	Laboratory Test results				Specification Requirement
Mix Type	**Optimal**	Trial	Trial	Trial	
Gradation	**Medium**	Medium	Medium	Coarse	
Emulsion (%)	**2.0**	2.5	3.0	2.0	
Prewet Water (%)	**1.5**	1.5	1.5	1.5	
Lime Cement (%)	**0.0**	0.0	0.0	0.0	
Bulk Specific Gravity (Gmb)	**2.102**	2.112	2.118	2.112	
Density, lb./ft³	**131.2**	131.8	132.2	131.9	
Max. Specific Gravity (G_{mm})	**2.448**	2.430	2.412	2.455	
Dry Stability at 40°C, lb.	**1342**	1260	1121	1319	1250 lb. min
Vacuum Saturation (%)	**56.2**	55.9	59.9	55.5	55-75
Retained Stability at 40°C, lb.	**1226**	1180	1051	1051	
% Retained Stability	**91%**	94%	94%	80%	70% Min
Air Voids (%)	**14.1**	13.1	12.2	14.0	
Raveling Test (%)	**1.1**	N/A	N/A	1.1	2% Max
Critical Low Temp., °C	**-33**	N/A	N/A	1.1	Report Only

Project

AET's involvements

– Forensic

– CIR Mix

• 100% RA

• PG XX-2

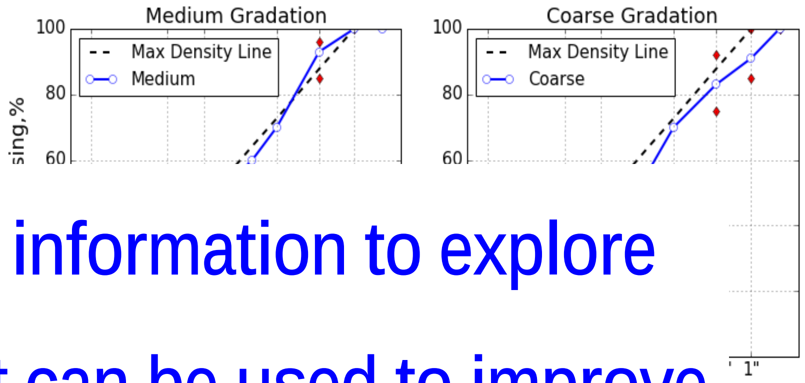
– Analysis

• Hwy 110

• Retrievin

• Analysis of IC data using VETA

• MnDOT submittals (VETA projects & forms)



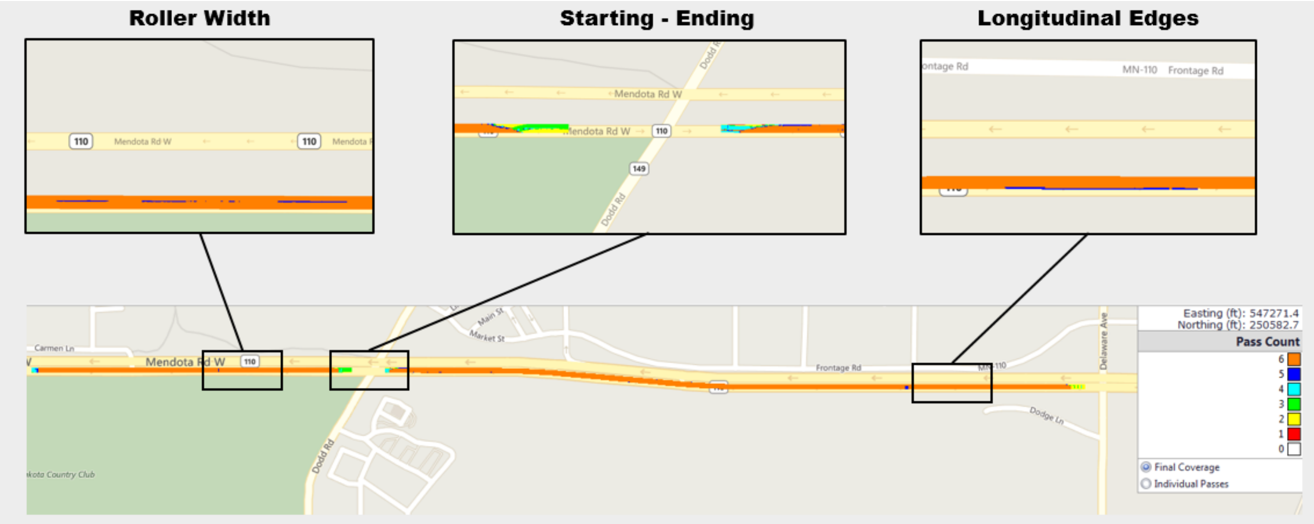
Can we use this wealth of information to explore potential IC parameters that can be used to improve the quality of CIR pavements and to rapidly assess their readiness to traffic ?

					ification irement
					lb. min
Vacuum Saturation (%)	**56.2**	55.9	59.9	55.5	55-75
Retained Stability at 40°C, lb.	**1226**	1180	1051	1051	
% Retained Stability	**91%**	94%	94%	80%	70% Min
Air Voids (%)	**14.1**	13.1	12.2	14.0	
Raveling Test (%)	**1.1**	N/A	N/A	1.1	2% Max
Critical Low Temp., °C	**-33**	N/A	N/A	1.1	Report Only

Project

Potential IC parameters for QC of CIR

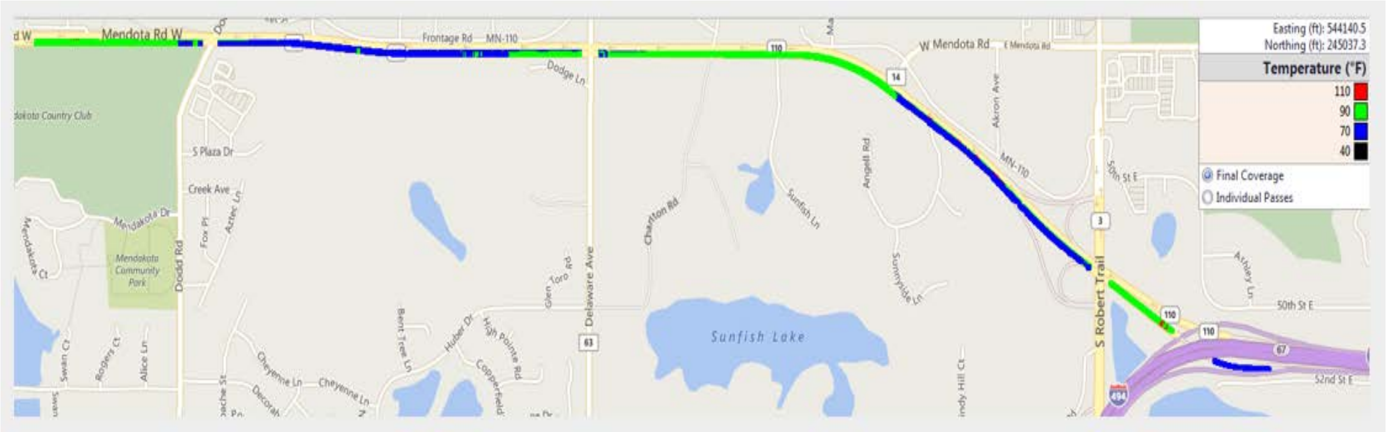
- Number of Roller Passes
  - Closer look at IC data can help identify locations that are hard to reach and thus likely to receive fewer roller passes than the mat



Project

Potential IC parameters for QC of CIR

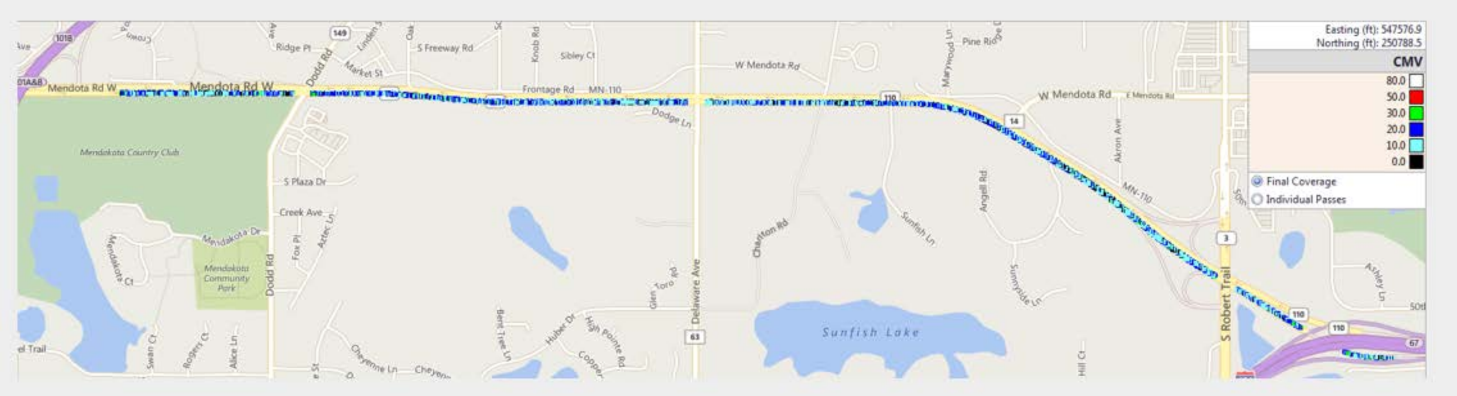
- Surface temperature
  - Infrared temperature sensors installed at the front and back of the rollers
  - Thermal uniformity or segregation
    - Cold-milling and mixing at ambient temperature
    - Small variabilities associate to weather



Project

Potential IC parameters for QC of CIR

– Compaction Meter Value (CMV)
  - Based on vibration amplitude and frequency readings
  - Processing via vendor proprietary algorithm (Trimble)
  - Measures the response of the compacted material to the roller’s compaction effort
  - Indicator of stiffness of the compacted material

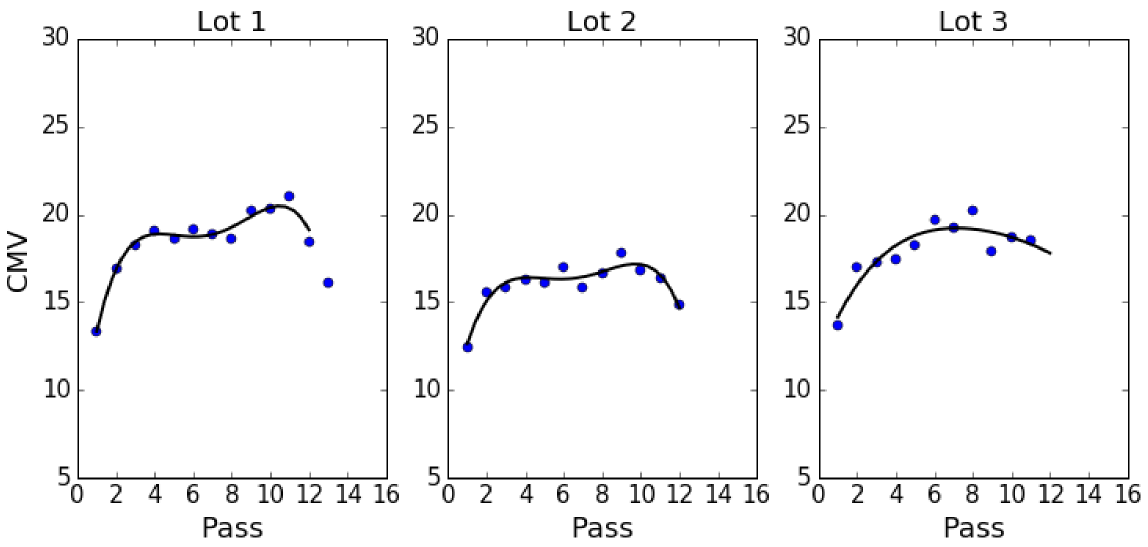


Project

Potential IC parameters for QC of CIR

– Compaction Meter Value (CMV)

- Can be used to produce compaction curves
- Average CMV for each roller pass vs. number of roller pass

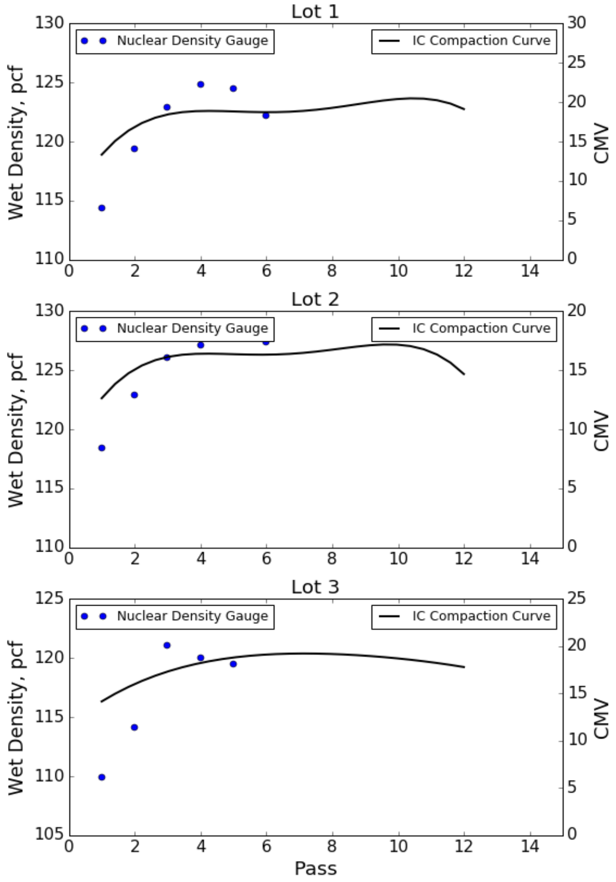


Project

Potential IC parameters for QC of CIR

– Compaction Meter Value (CMV)

- Can be compared to roller passes curves obtained in the control strip testing
    - Both approaches appear to agree on the number of roller passes required to achieve maximum compaction (roughly 4)
    - Nuclear density → target density represented by a single peak point
    - CMV → target CMV represented by a plateau region
- Advantages of CMV compaction curves
    - Dynamic and real-time compaction targets
    - More realistic range of optimal compaction (between under and over compaction)

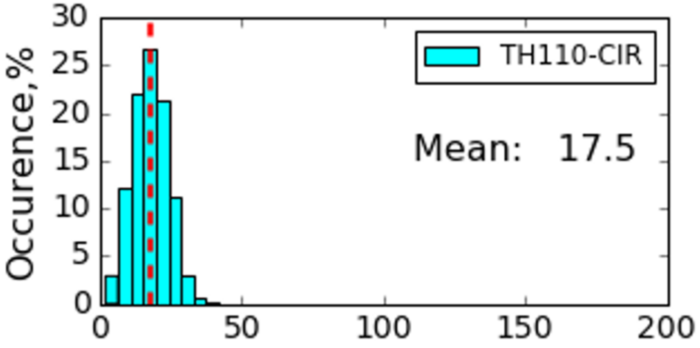


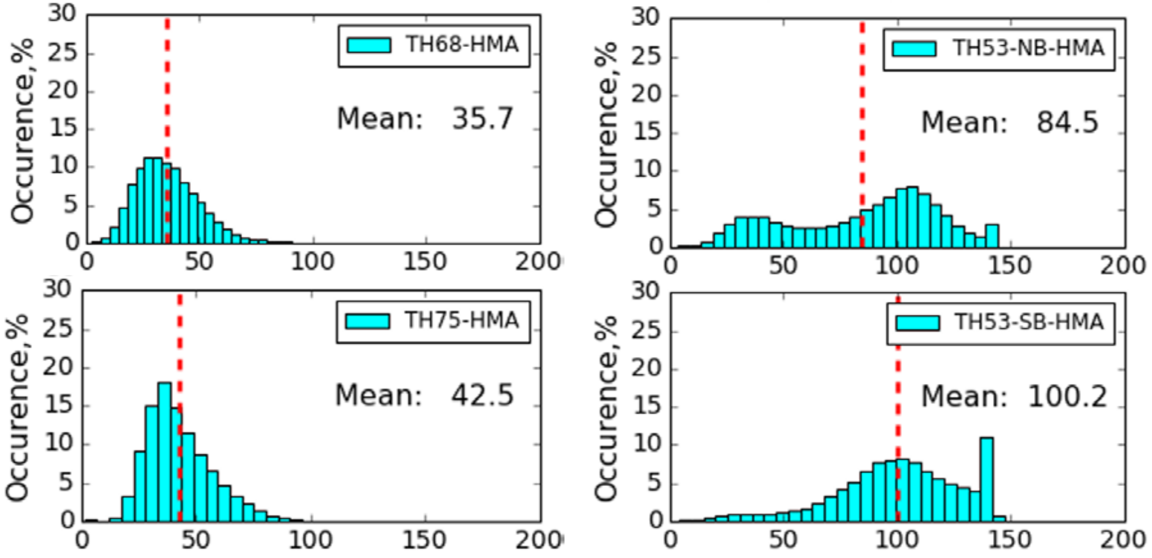
Project

Potential IC parameters for QC of CIR

– Compaction Meter Value (CMV)

- How does CIR compare to HMA
- CIR softer but less variability



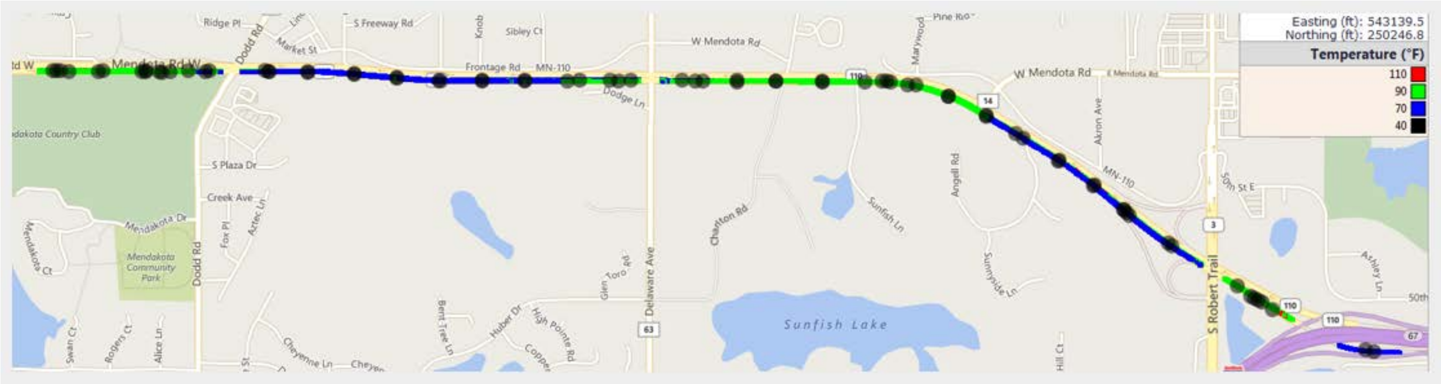


Project

Potential IC parameters for QC of CIR

– Compaction Meter Value (CMV)

- Correlation to wet density measurements
  - Nuclear density readings (1 test every 500 ft.)
  - GPS coordinates measured using a hand-held rover
  - Checked for correlations checked with IC data

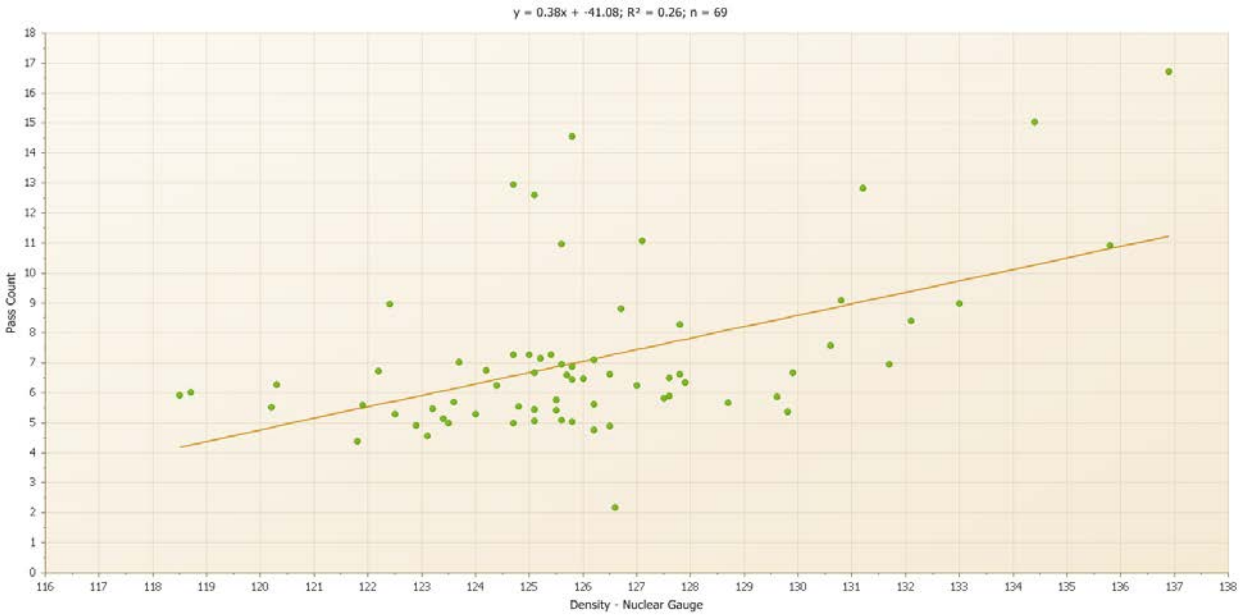


Project

Potential IC parameters for QC of CIR

– Compaction Meter Value (CMV)

- Correlation to wet density measurements
  - Very weak correlations between CMV and wet density.
  - Number of roller passes to wet density a slightly better correlation



Project

Conclusion

- The results shown in this presentation, suggest it is worth exploring in more detail the use of IC method to efficiently monitor and improve the uniformity of CIR layers in real-time
- The IC method's CMV stiffness index lend itself well for rapid assessment of CIR pavement's readiness to traffic. A target CMV can be established through a focused research investigation
- The CMV values shown herein confirmed that CIR is significantly softer than HMA pavements. On the other hand, given the cold milling and mixing, the tested CIR exhibited superior thermal and stiffness uniformity than the HMA pavements considered here

Project

Conclusion

– The target roller passes established using the CMV data were identical to those derived from test strip data.

– In general, correlations between wet density and the various IC data were weak. But they captured the trend of increasing density as the number of roller passes increases

Rolling Density Meter (RDM)

Thank you

Trust Delivered.™

AMERICAN ENGINEERING TESTING, INC.

Intelligent Compaction

Recent technology innovations

- Geographic Information System (GIS)
  - Linking measured properties to the tested location
  - Real-time map visualization and monitoring of collected data
- Intelligent Compaction (IC) methods
  - Real-time continuous feedback to the operator
  - Real-time continuous measurements of pavement properties
  - Automatic adjustment and optimization of paving operations
- Superior computing & processing powers
- Big Data analytics

Toward
REAL-TIME
FULL COVERAGE
testing

Project

Potential IC parameters for QC of CIR

- Number of Roller Passes
  - Based on GPS and time series data collected during compaction
  - Computes and maps mat coverages & number of roller passes
- Hwy 110 East Bound
  - 100% coverage was achieved
  - The min required number of roller passes of two was achieved in the entire CIR mat