Determining Asphalt Pavement Milling Best Practices Through Enhanced Understanding of Milling Operations

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October 16, 2024

Northeast User Producer Group Meeting

University of New Hampshire

DEPARTMENT OF TRANSPORTATION

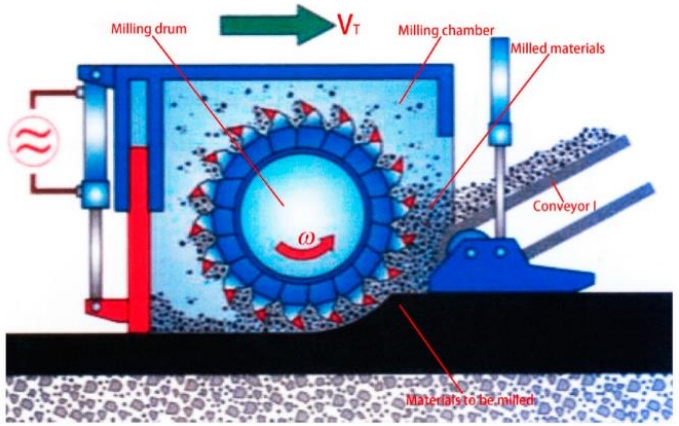
NRRA National Road Research Alliance

Presentation Outline

- Motivation and Objectives
- Methods
- Select Results
- Conclusions and Future Work

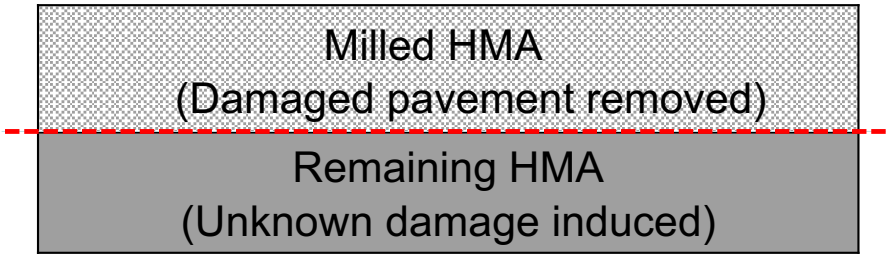
Motivation

- Milling is commonly used in maintenance and rehabilitation to correct functional distresses
- Milling is a high-stress activity
- Milling parameters are selected based on cost, routine, and state of existing pavement
- The extent of potential damage induced in the layer below the milling line is unknown



Project Objective

To better understand the influence that milling operations and specific milling parameters have on the pavement layer that remains directly below the mill line.



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Sampling Methods

- Sampling was performed at the MnROAD Research Facility
- Pre- and post-milling cores were collected adjacent to each other and then trimmed to represent the equivalent layer, directly below the mill line

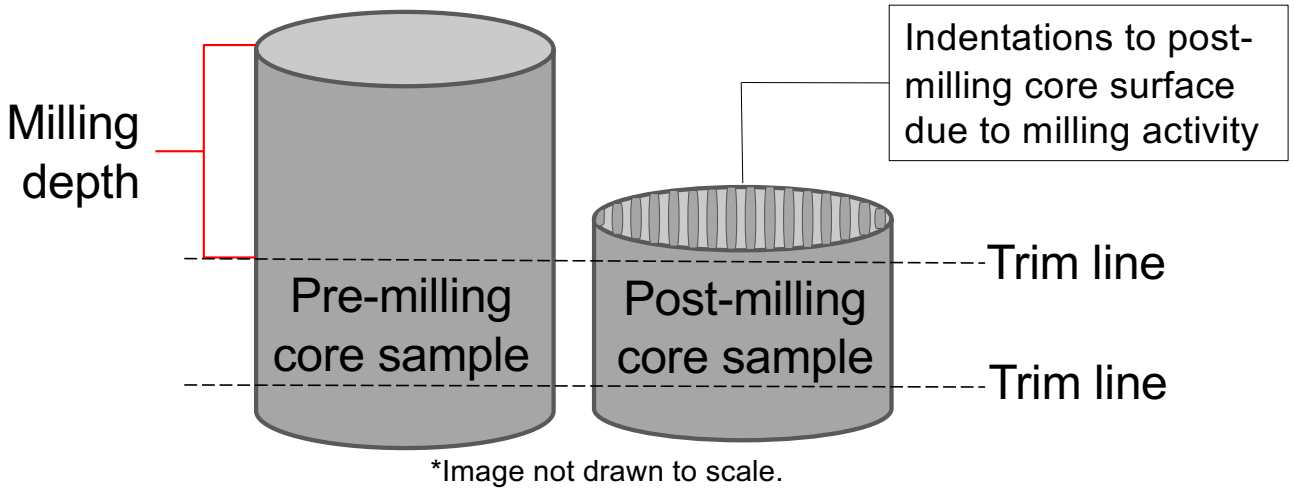


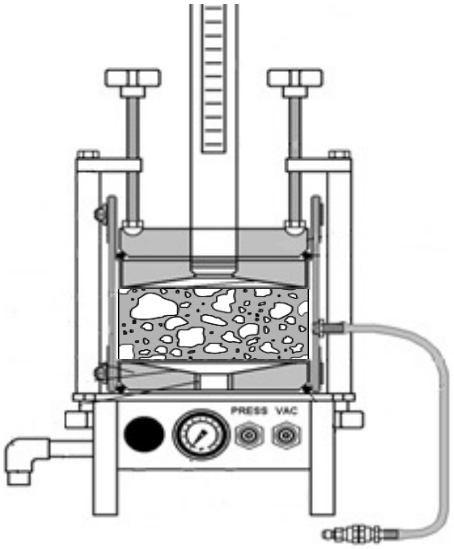
*Image not drawn to scale.

Milling Parameters Evaluated

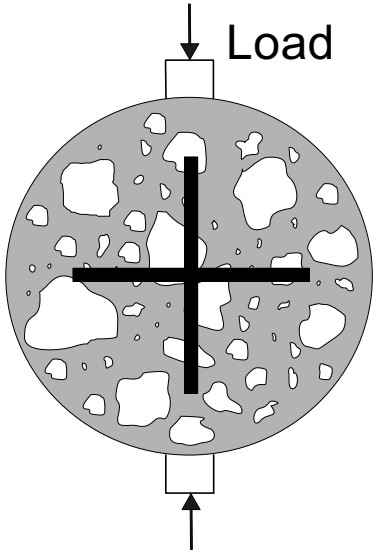
- Time between milling and overlay construction
  - Immediate, 1 week, 2 weeks after milling
- Proximity of mill line to asphalt layer interface
  - Full lift, ½ lift, ¾ lift
- Pavement temperature at time of milling
  - Cooler vs. warmer temperature
- Operational and equipment parameters
  - Rotor speed, teeth spacing, rotor type
- Structure of existing pavement
  - 3 pavement structures

Laboratory Testing Methods

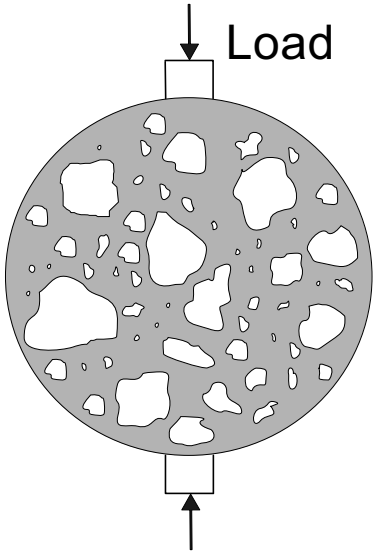
- Physical Properties: Bulk Specific Gravity & Permeability
- Mechanical Properties: Resilient Modulus & Indirect Tensile Strength



Permeability



Resilient Modulus



Indirect Tensile Strength

Analysis of Laboratory Measured Data

- The average values laboratory measurements
- Percent difference calculations using average values

$$\%\, diff = 100 * \left(\frac{post\ milling\ core\ avg. - pre\ milling\ core\ avg.}{pre\ milling\ core\ avg.}\right)$$

- Statistical significance testing

Pavement Life Analysis

- Difference in expected pavement life using pre- and post- milling M_R values with MnPAVE software

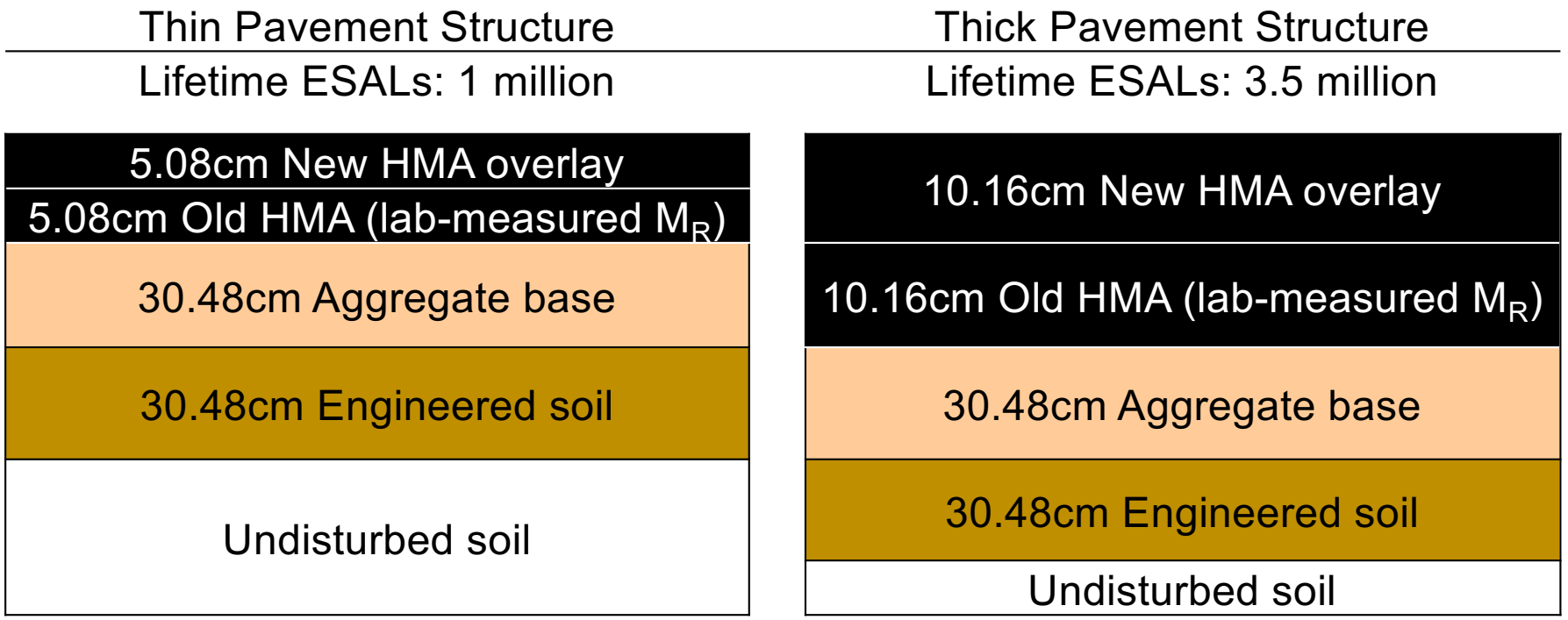


*Figure not drawn to scale.

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Time between Milling and Overlay Construction

2.54 cm (1”) mill depth

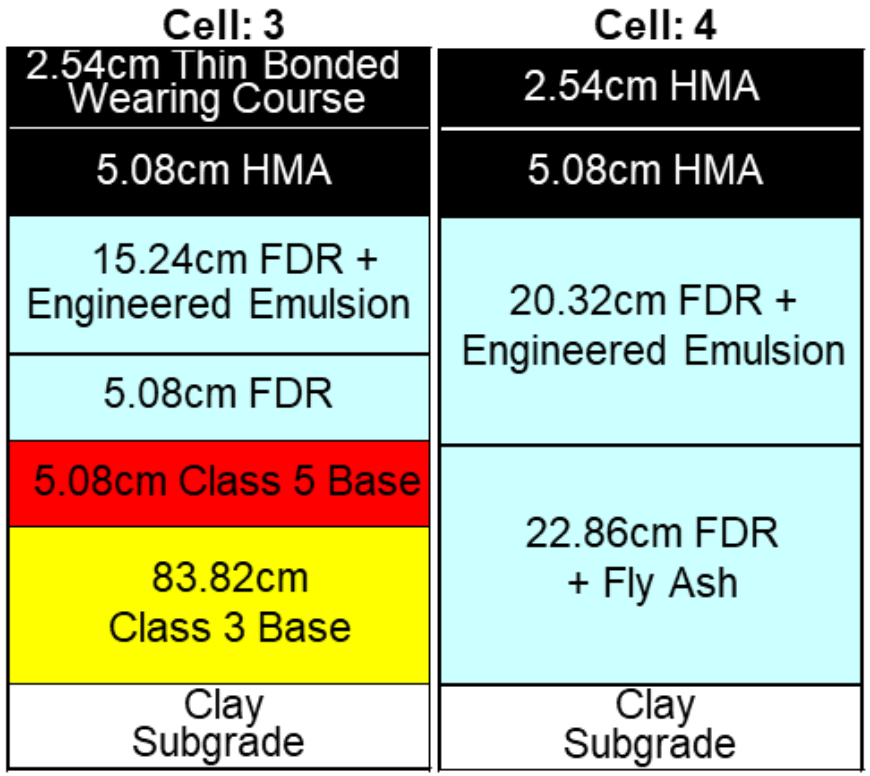
Overlay construction performed:

- Immediately after milling
- 1 week after milling
- 2 weeks after milling

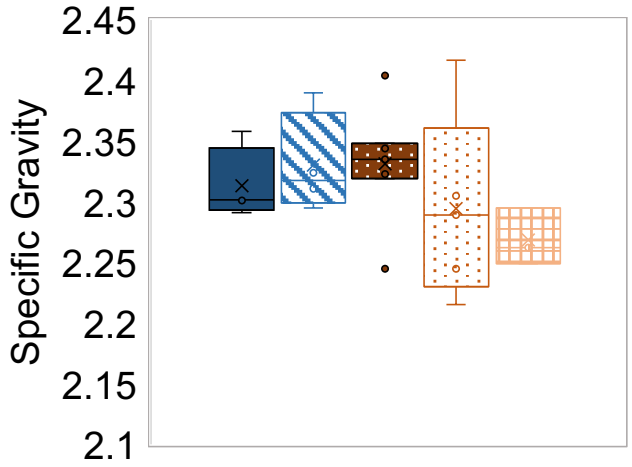
Increased time

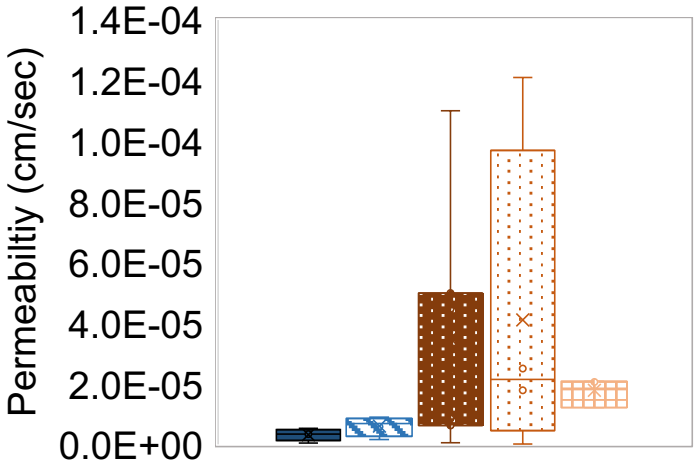
↓

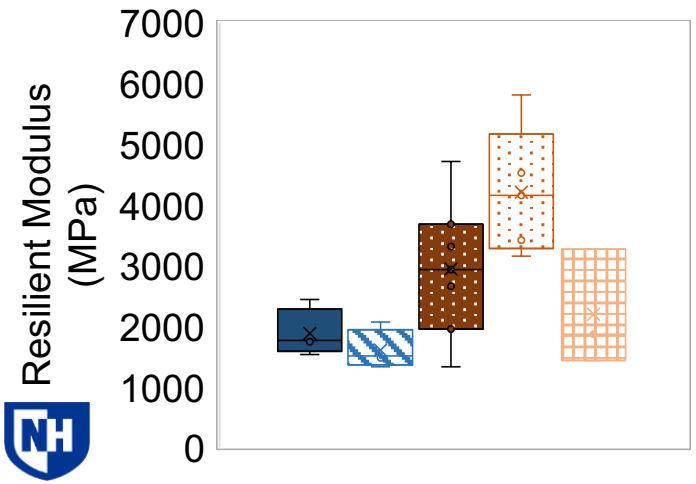
Increased exposure of milled surface to traffic loading and weather conditions

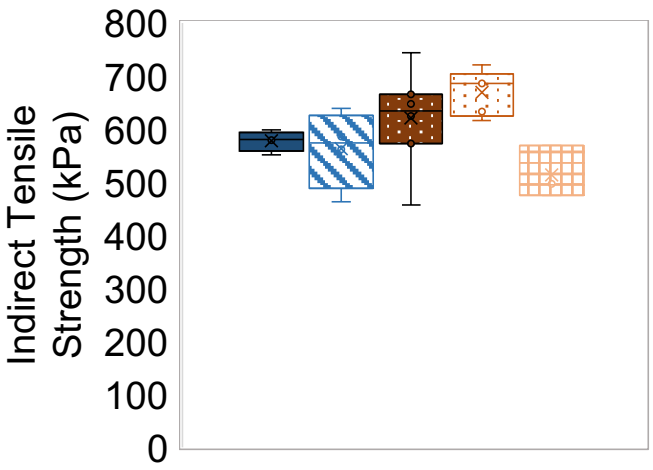


Time between Milling and Overlay Construction





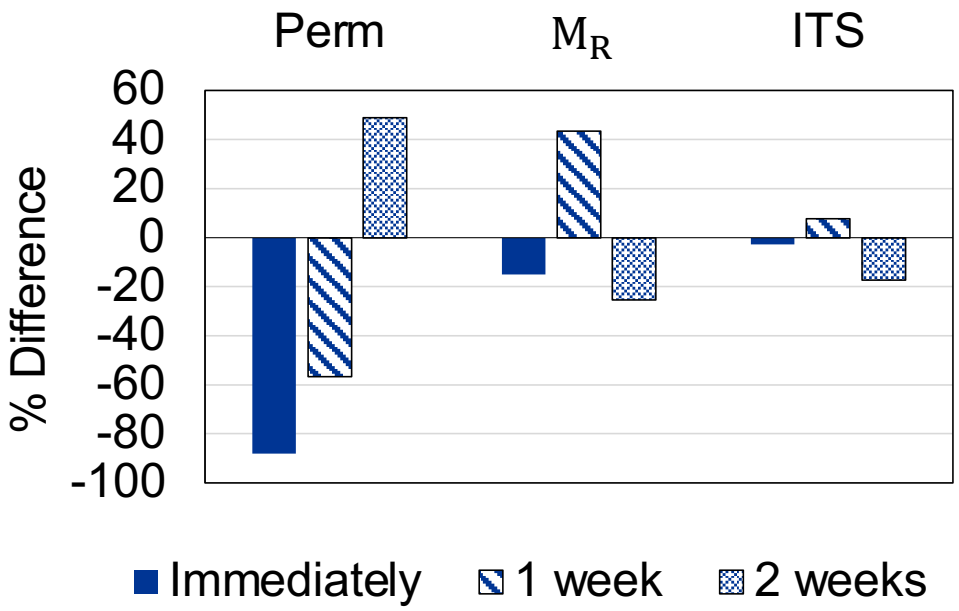




- Pre-milling cores MnROAD Cell 3
- Post-milling cores MnROAD Cell 3 Collected directly after milling
- Pre-milling cores MnROAD Cell 4
- Post-milling cores MnROAD Cell 4 Collected 1 week after milling
- Post-milling cores MnROAD Cell 4 Collected 2 weeks after milling

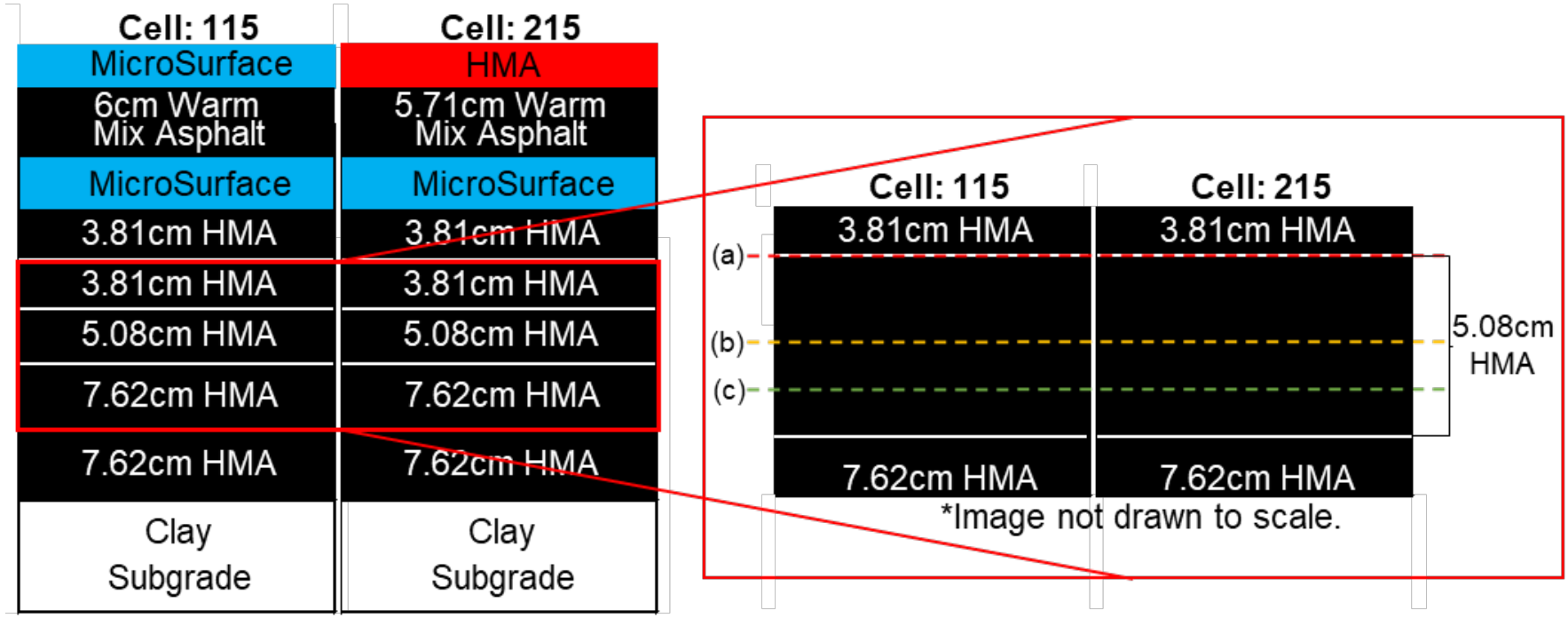
Time between Milling and Overlay Construction

- After 2 weeks: significant decrease in specific gravity and ITS
- No significant difference directly after, or one week after milling
- Pavement evaluation for 2 weeks exposure
  - Thin structure: no effect on expected pavement life
  - Thick structure: expected pavement life decreased by 13.3%

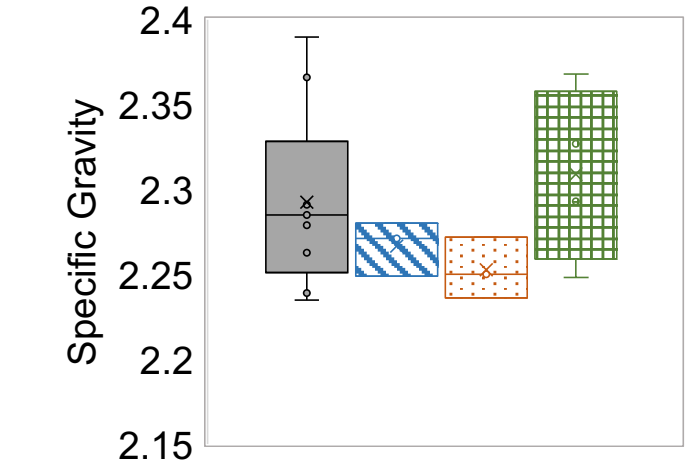


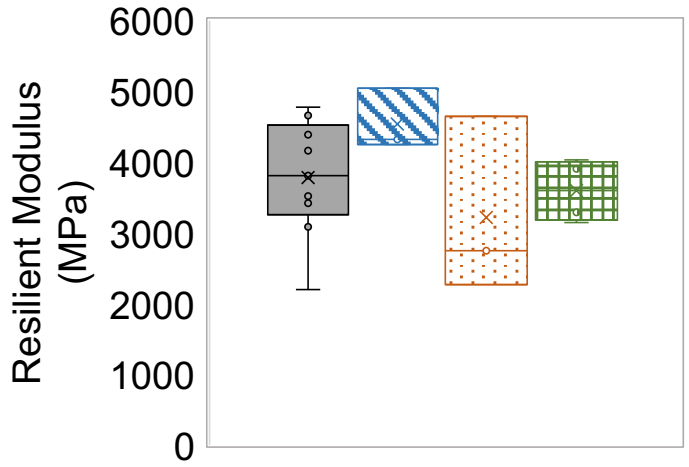
Depth of Milling Relative to Layer Interface

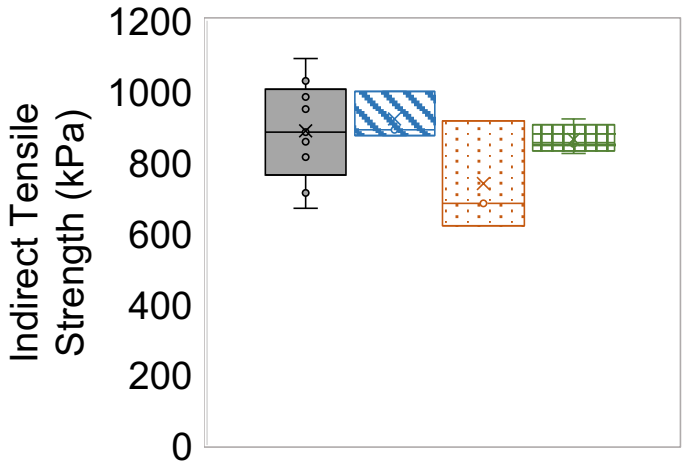
(a) to layer interface (b) ½ through lift (c) ¾ through lift



Depth of Milling Relative to Layer Interface







Pre-milling cores

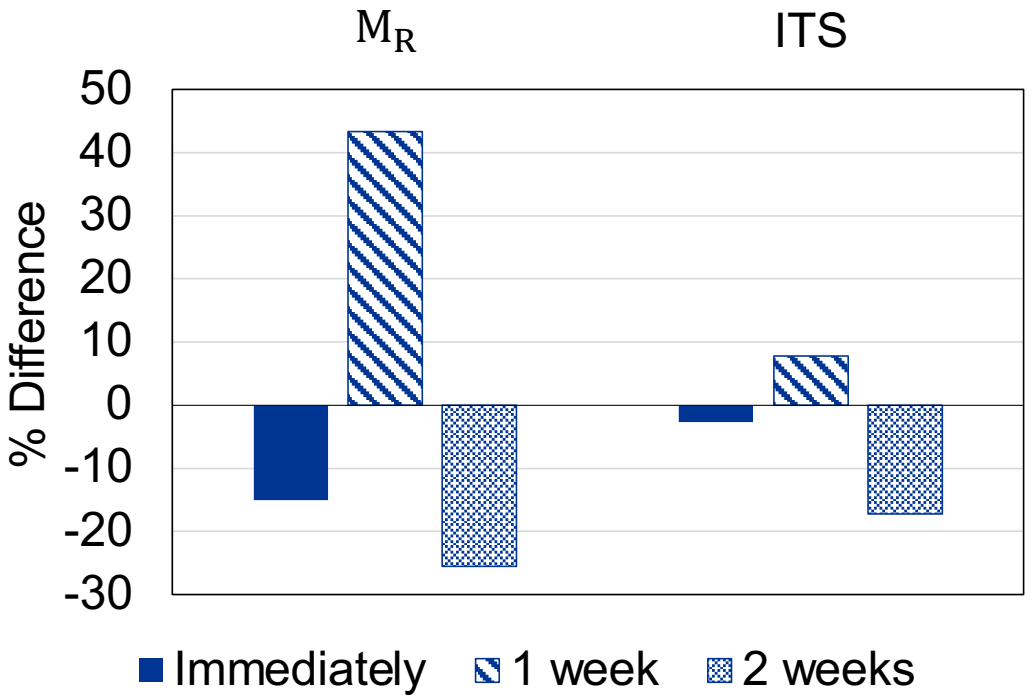
Post-milling cores
Milling depth: To layer interface

Post-milling cores
Milling depth: Halfway through lift

Post-milling cores
Milling depth: Three-quarters through lift

Depth of Milling Relative to Layer Interface Analysis of Results

- Increase in the average M_R when milling was performed to the layer interface
- Decrease in the average M_R and ITS when milling was performed to ½ and ¾ through the lift
- No statistically significant differences



Pavement Surface Temperature at Time of Milling

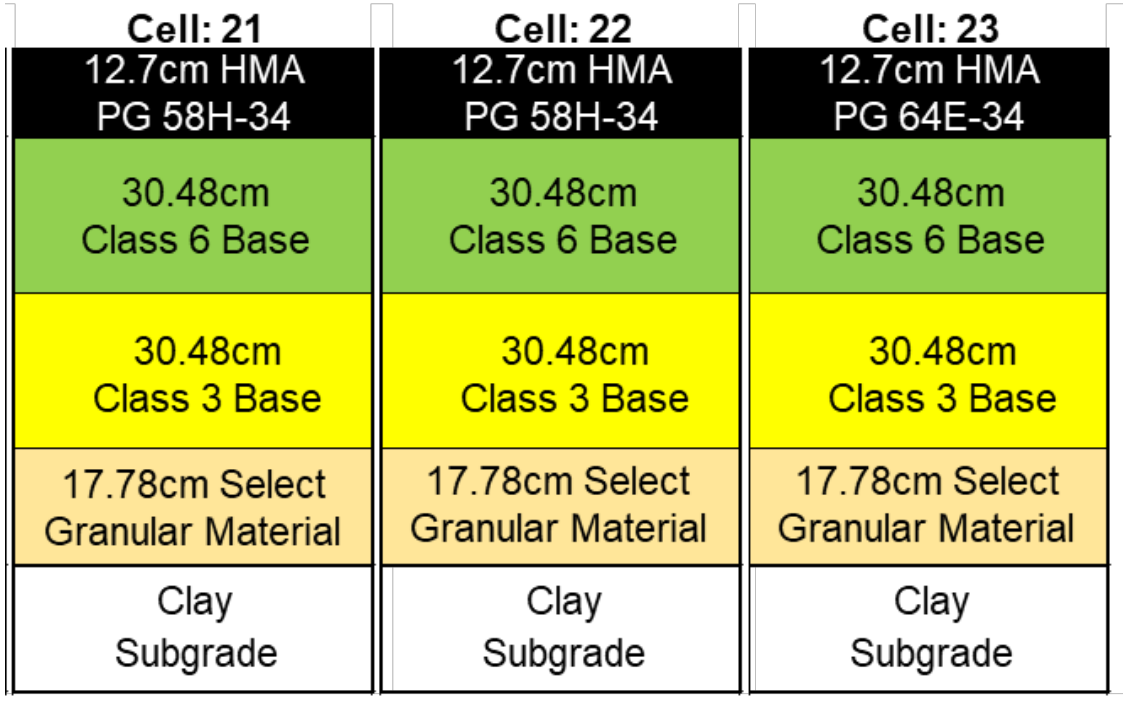
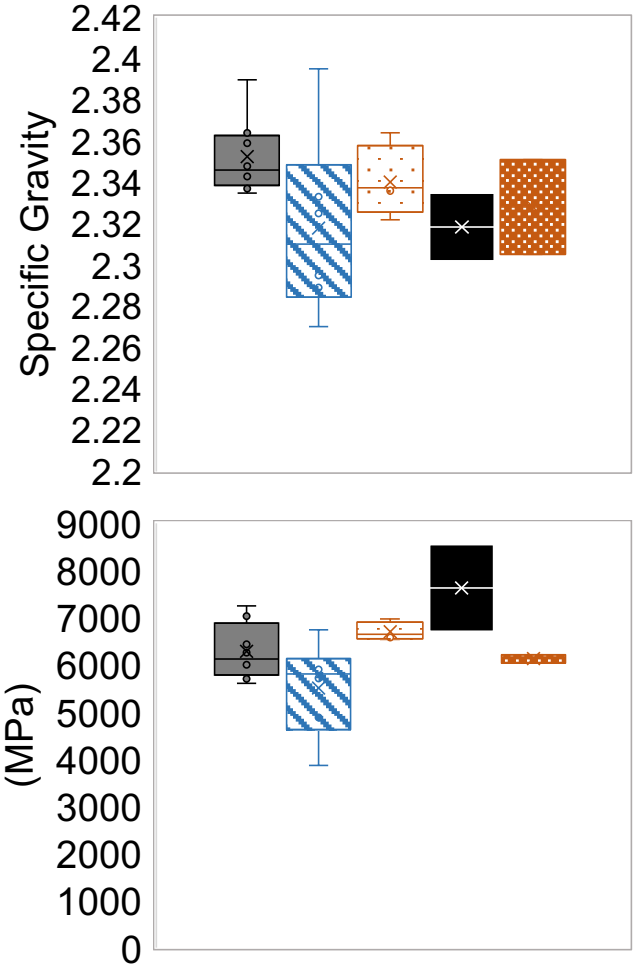


*Image not drawn to scale.

- Milling depth of 7.6 cm (3”)
- Cooler pavement temperature:
  (12.2ºC – 15.6ºC)
- Warmer pavement temperature:
  (33.3ºC – 47.2ºC)

Pavement Surface Temperature at Time of Milling



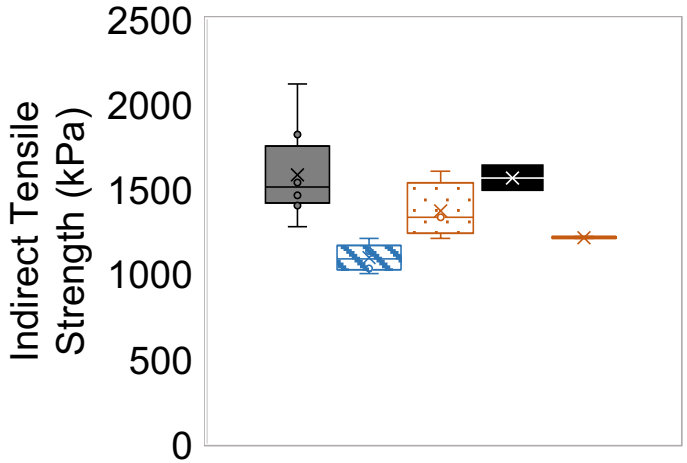
Pre-milling cores, MnROAD Cells 21+22

Post-milling cores, MnROAD Cells 21+22
Milling at cooler pavement temp. (12.2°C - 15.6°C)

Post-milling cores, MnROAD Cell 22
Milling at warmer pavement temp. (33.3°C - 47.2°C)

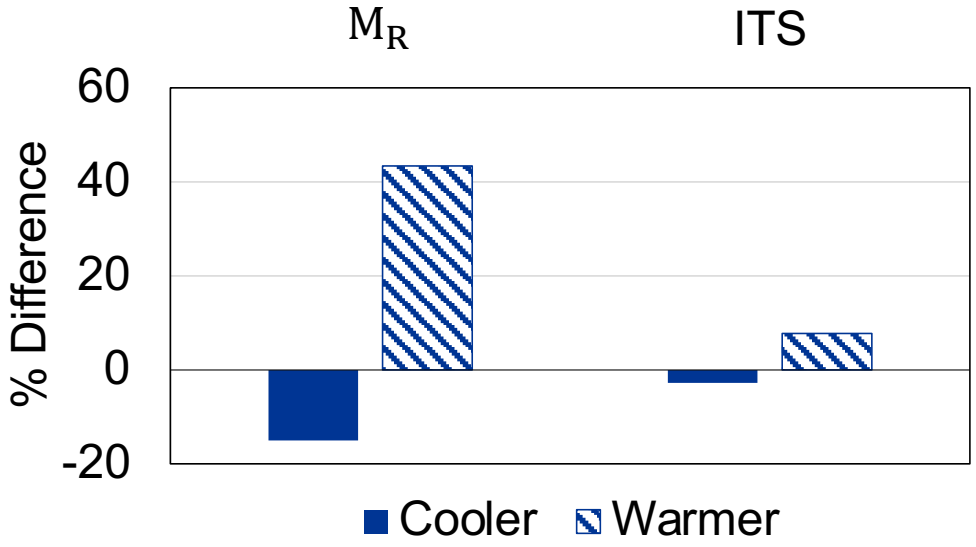
Pre-milling cores, MnROAD Cell 23

Post-milling cores, MnROAD Cells 23
Milling at warmer pavement temp. (33.3°C - 47.2°C)



Pavement Temperature while Milling Analysis of Results

- 12-15°C milling temperature: decrease in average M_R and statistically significant decrease in ITS
- 33-47°C milling temperature: smaller decrease in IDT but no statistically significant differences
- Pavement evaluation for cooler temperature
  - Thin structure: expected pavement life decreased by 8.33%
  - Thick structure: expected pavement life decreased by 5%



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Conclusions

From the conditions evaluated in this study, it was found that:

- Average decrease in M_R or ITS
  - Milling to halfway or three-quarters of the way through lift.
- Significant decrease in M_R or ITS
  - Cooler pavement temperature
  - Milled pavement exposed for 2 weeks prior to overlay
- Inconsistent or no trends
  - Different pavement structures
  - Different rotor speeds

Future Study Possibilities

- Evaluate additional samples under these milling parameters to confirm these preliminary outcomes and to determine if there is a need to develop milling parameter guidelines

- Further, there are many additional milling parameters that could be evaluated, such as:
  - Milling machine moving speed
  - Conditions of milling teeth
  - Milling drum diameter
  - How each of the parameters impact the milled surface

Acknowledgements

- Kaleigh Miech, graduate student
- This research was funded by the National Road Research Alliance
- MnDOT staff member Emil Bautista and Caterpillar for their help in field sampling

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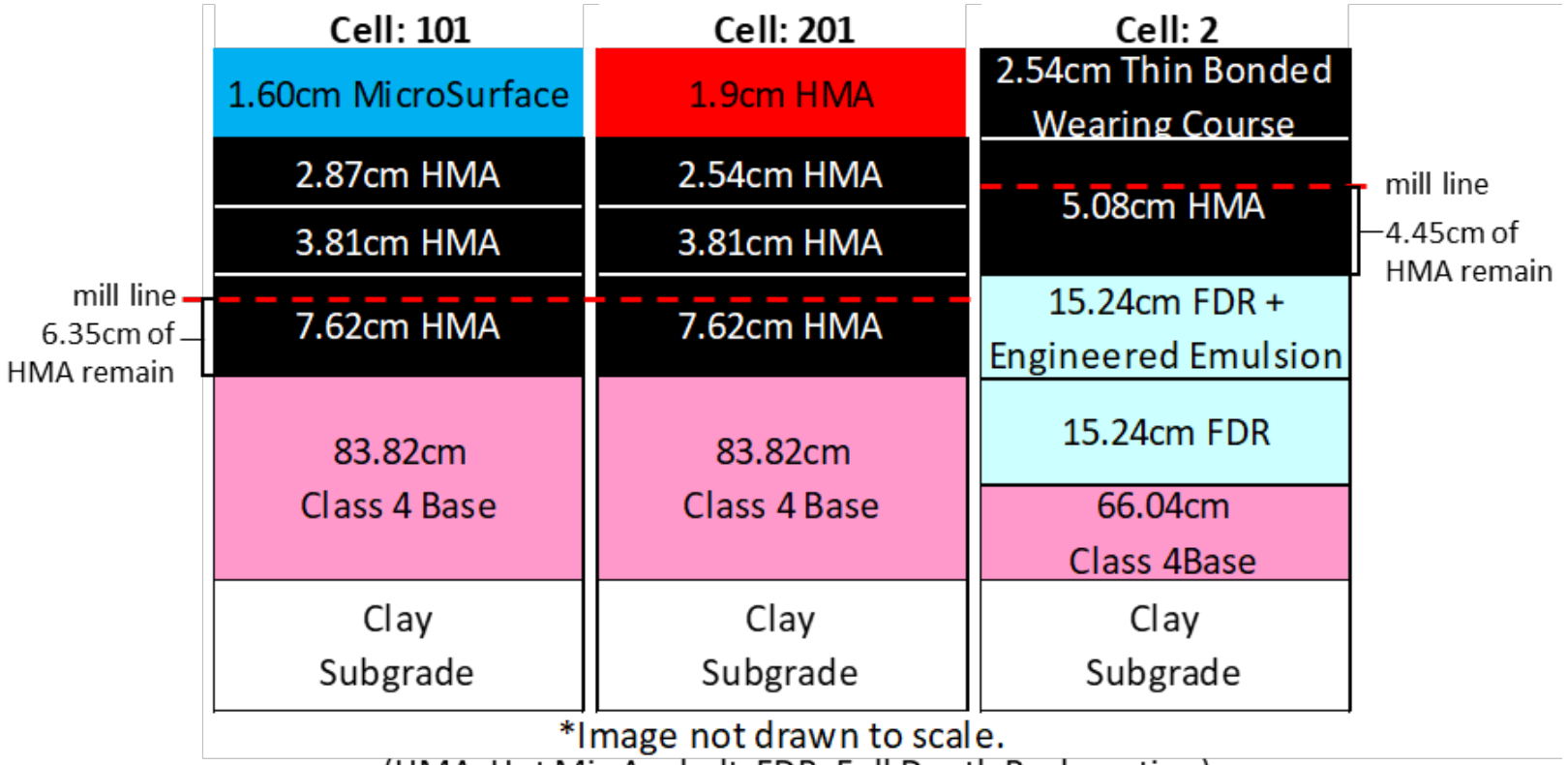
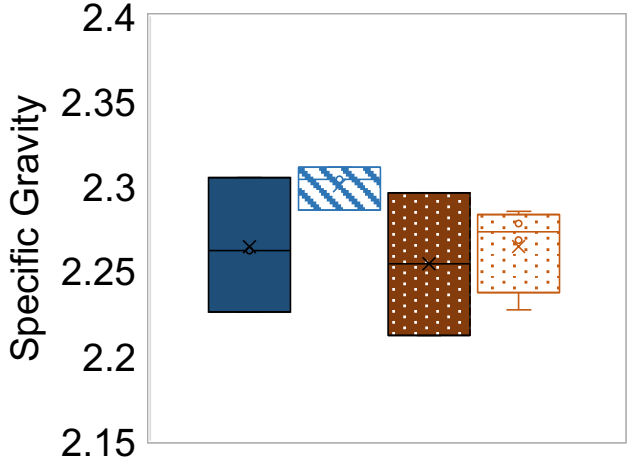
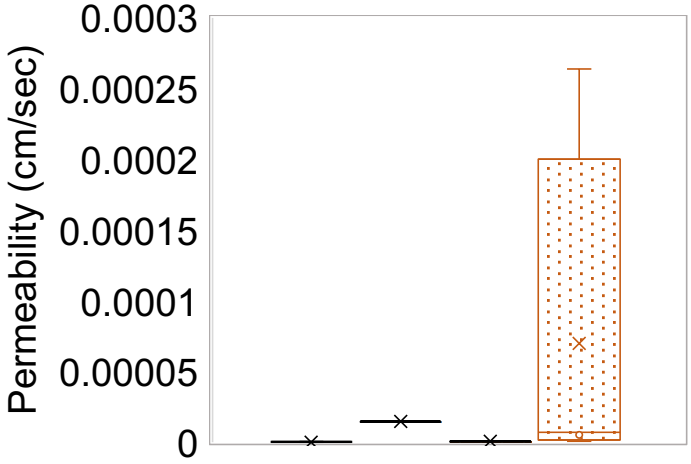
Existing Pavement Structure

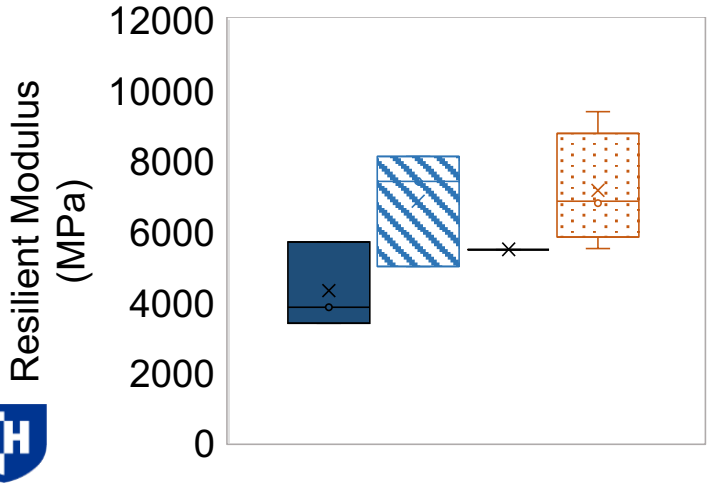
Three different pavement structures were evaluated in this study:

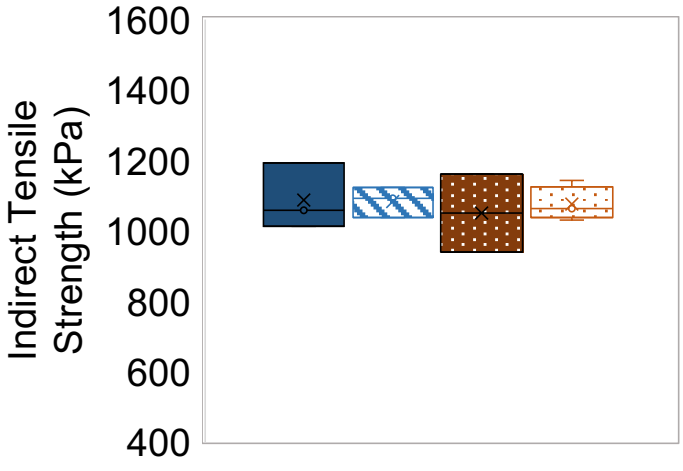


Existing Pavement Structure – MnROAD Cell 101









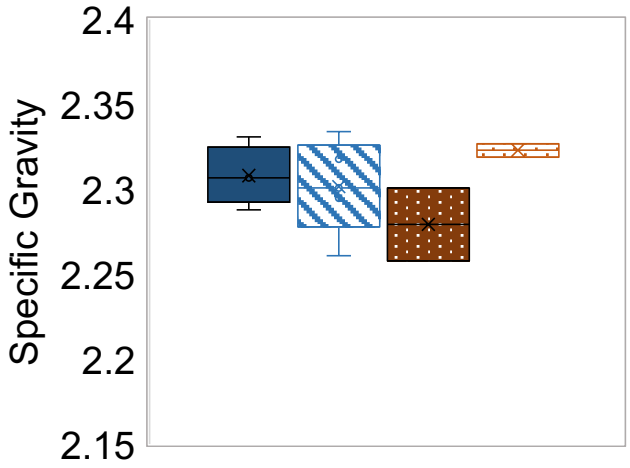
Pre-milling cores MnROAD Cell 101 Driving lane

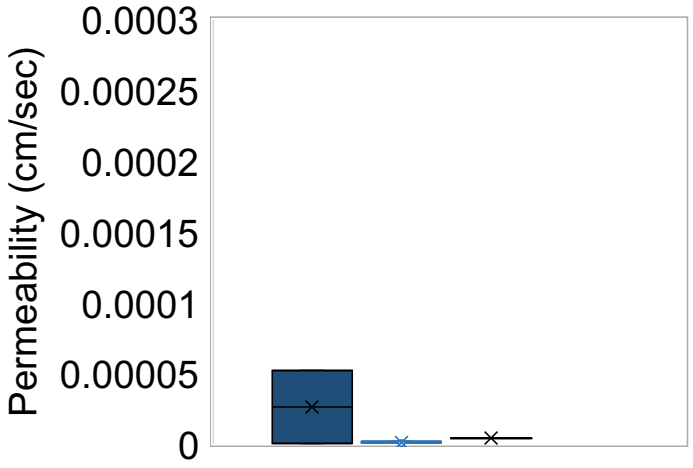
Post-milling cores MnROAD Cell 101 Driving lane

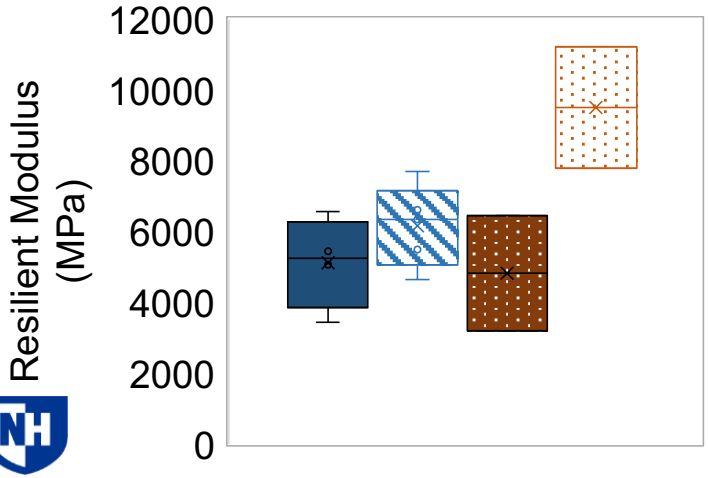
Pre-milling cores MnROAD Cell 101 Passing lane

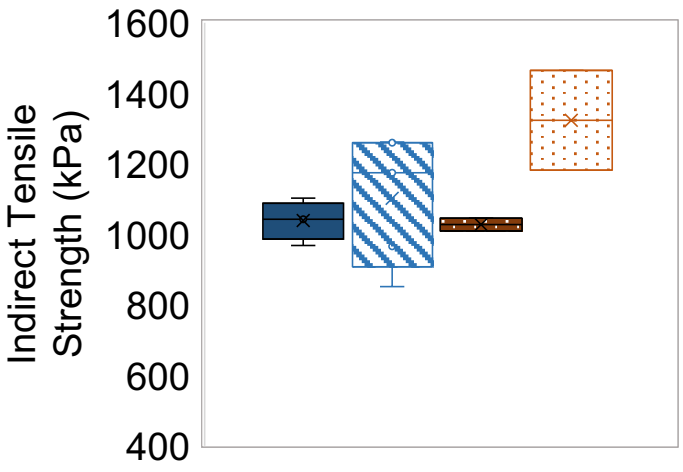
Post-milling cores MnROAD Cell 101 Passing lane

Existing Pavement Structure – MnROAD Cell 201









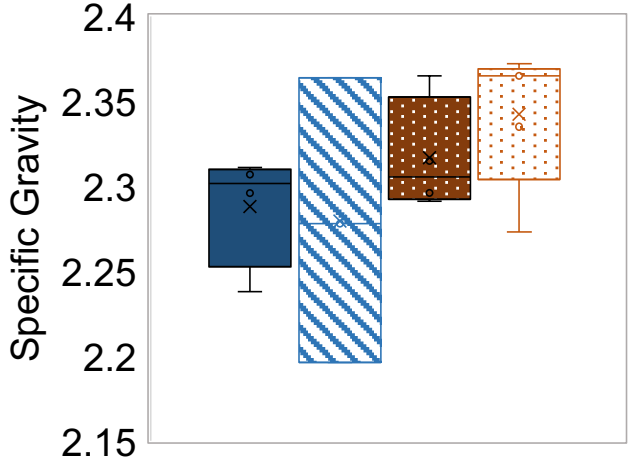
Pre-milling cores
MnROAD Cell 201
Driving lane

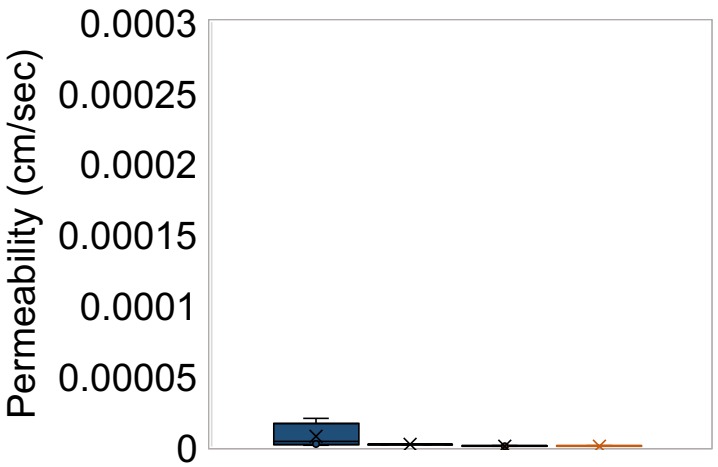
Post-milling cores
MnROAD Cell 201
Driving lane

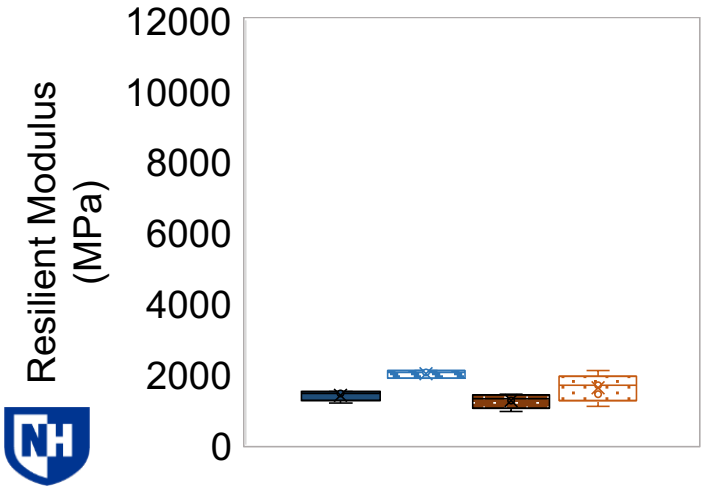
Pre-milling cores
MnROAD Cell 201
Passing lane

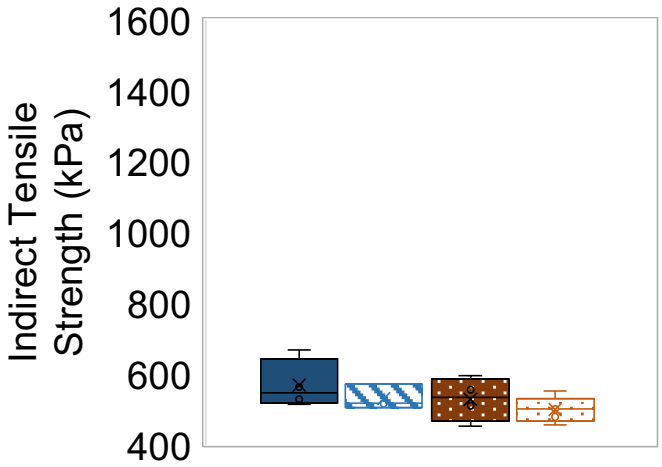
Post-milling cores
MnROAD Cell 201
Passing lane

Existing Pavement Structure – MnROAD Cell 2









Pre-milling cores MnROAD Cell 2 Driving lane

Post-milling cores MnROAD Cell 2 Driving lane

Pre-milling cores MnROAD Cell 2 Passing lane

Post-milling cores MnROAD Cell 2 Passing lane

Existing Pavement Structure Analysis of Results

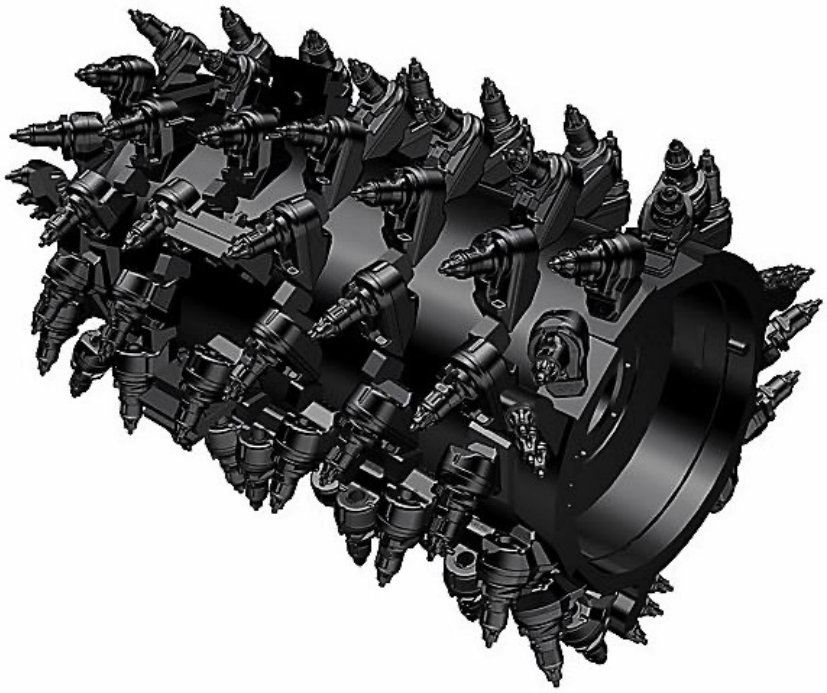
- Milling did not have a statistically significant impact on the specific gravity, MR, or ITS of MnROAD Cells 101 or 201
- Post-milling, there was a statistically significant increase to the resilient modulus of the HMA below the mill line in the driving lane of Cell 2, but not in the passing lane
- Thus, there were not consistently different impacts to the HMA below the mill line for the three cells with different structures

- In the driving lane of Cell 2, there was an
  - Expected pavement life underestimation of 11% for the thin structure, and an
  - Expected pavement life underestimation of 18% for the thick structure

Operational and Equipment Parameters

Parameter Variations: Rotor Speed

- 100 RPM
- 109 RPM
- 118 RPM



Other equipment variations in this study:

- Spacing between teeth
- Rotor type

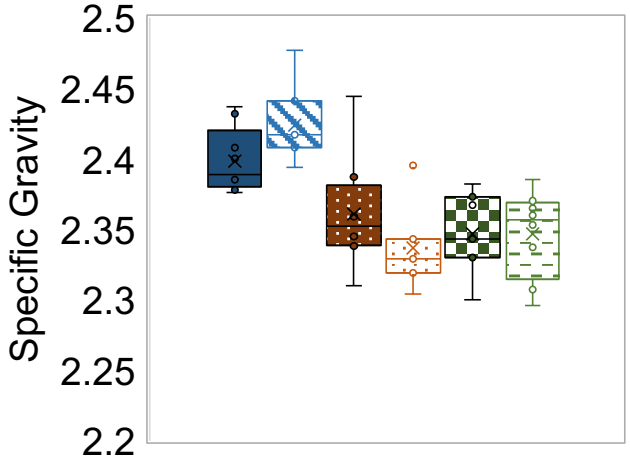
Operational and Equipment Parameters

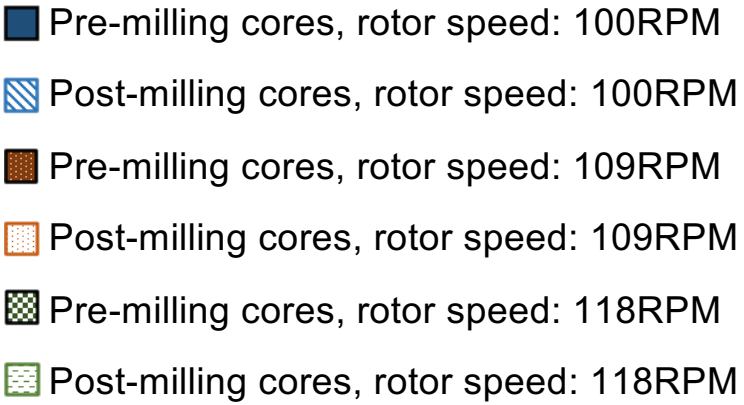
Cores to evaluate rotor speed along with the pavement temperature at the time of milling were collected from the same MnROAD cells.

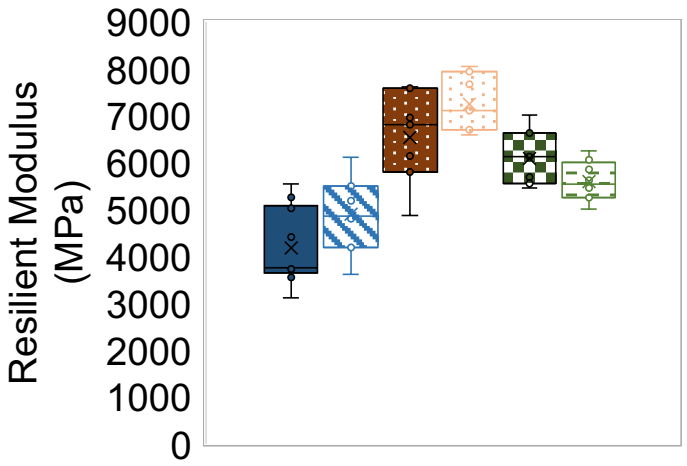
Cell: 16	Cell: 21	Cell: 22	Cell: 23
12.7cm HMA PG 64S-22	12.7cm HMA PG 58H-34	12.7cm HMA PG 58H-34	12.7cm HMA PG 64E-34
30.48cm Class 6 Base	30.48cm Class 6 Base	30.48cm Class 6 Base	30.48cm Class 6 Base
30.48cm Class 3 Base	30.48cm Class 3 Base	30.48cm Class 3 Base	30.48cm Class 3 Base
17.78cm Select Granular Material	17.78cm Select Granular Material	17.78cm Select Granular Material	17.78cm Select Granular Material
Clay Subgrade	Clay Subgrade	Clay Subgrade	Clay Subgrade

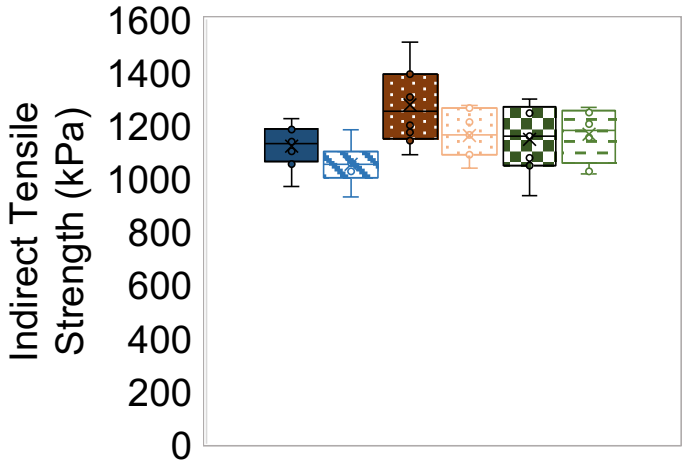
*Image not drawn to scale.

Rotor Speed while Milling









Rotor Speed while Milling
Analysis of Results

- At 100RPM, there was the greatest percent increase in MR
- At 118RPM, there was a decrease in the MR
  - The results from this study indicate that as the rotor speed increases, the MR of the post-milling cores decreased relative to the MR of the pre-milling cores
- The percent differences between the specific gravity and the ITS did not display consistent changes as rotor speed changed

- The results from this study do not indicate that there is a statistically significant impact to the properties evaluated of the HMA below the mill line, regardless of the rotor speed while milling