



Evaluation of Current WI Mixes Using PEM Testing Protocols

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Report: <https://wisconsindot.gov/documents2/research/0092-17-07-final-report.pdf>



Research Objectives

Phase I

- Use performance-based testing on current WisDOT concrete mixtures
- Create a database of results on WisDOT mix designs and compare to proposed Performance-Engineered Mixtures (PEM) specifications

Phase II

- Evaluate 1.5-inch aggregate in the Tarantula Curve
- Evaluate MinT consolidation vs. rodding during Super Air Meter (SAM) testing
- Test resistivity using multiple curing conditions

Summary of Phase I and Phase II

○ Phase I

- 8 project field visits
- Strength Testing
 - ✓ Compressive
 - ✓ Flexural
- Workability
 - ✓ Box
 - ✓ Vibrating Kelly
- Durability
 - ✓ Air & Super Air Meter
 - ✓ Hardness
 - ✓ Formation Factor
 - ✓ Coefficient of Thermal Expansion

○ Phase II

- Lab Aggregate Study
 - ✓ Evaluate 1 ½ inch aggregate
 - ✓ Box test
 - ✓ Shrinkage
- 5 project field visits
- Strength Testing (same)
- Workability
 - ✓ Box only
- Durability
 - ✓ Air and Super Air Meter
 - ✓ Resistivity
 - ✓ Pore Solution



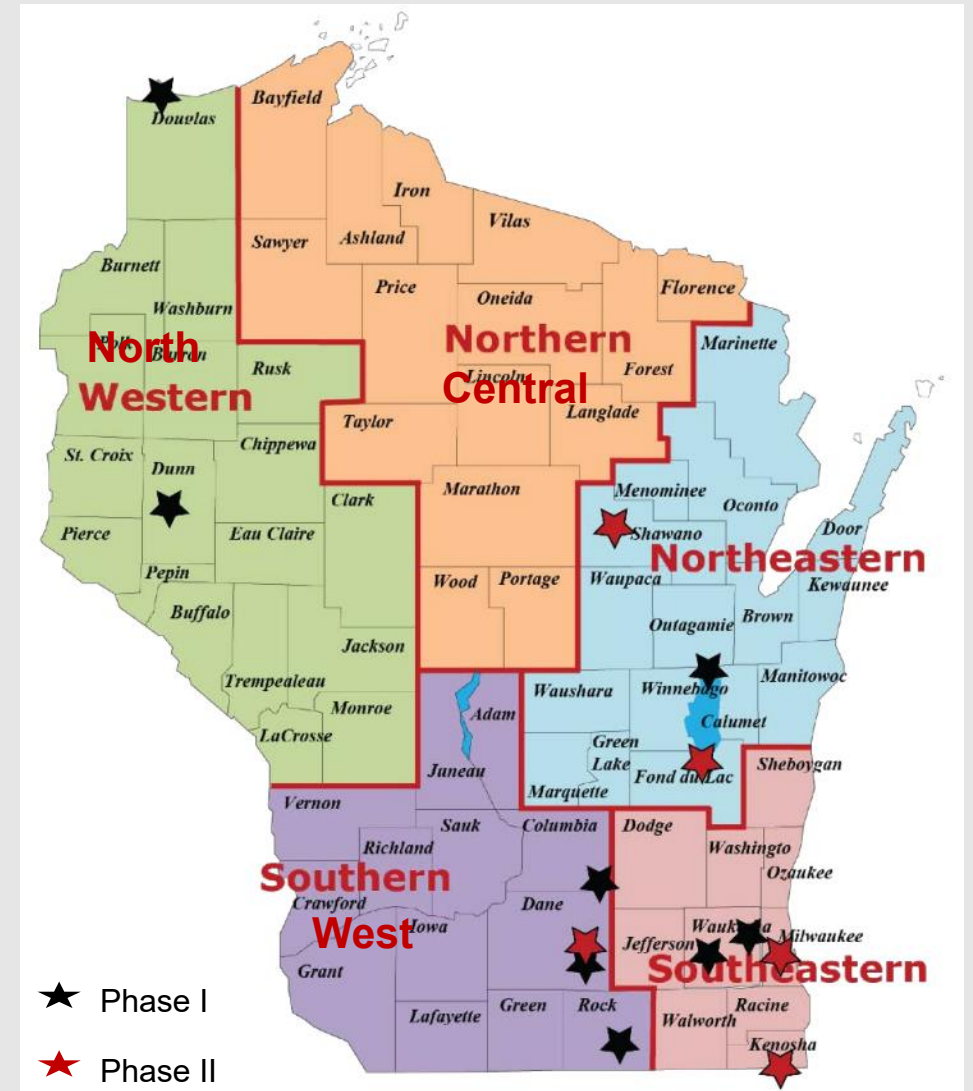
Project Locations

○ Phase I:

- Appleton – USH 10 to STH 441
- Waukesha – STH 190
- City of Columbus – STH 16
- City of Superior – USH 2
- West Waukesha Bypass
- Rock County – IH 39
- Dane County – IH 39
- Menomonie – IH 94

○ Phase II:

- Shawano County – STH 29
- Kenosha County – STH 50
- Fond Du Lac County – STH 23
- Dane County – IH 39
- Milwaukee County – USH 45

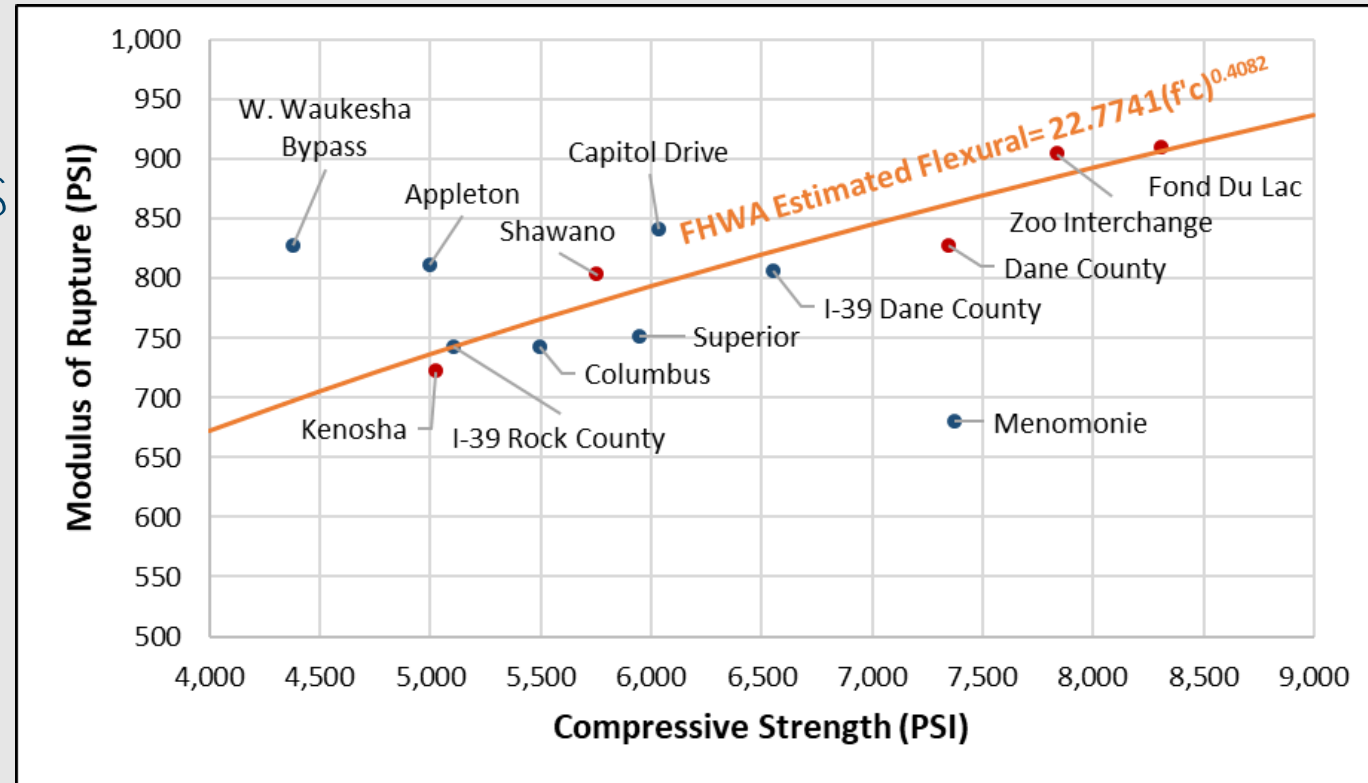




STRENGTH RESULTS

Strength Correlation – Phase I and Phase II

- Mixtures exhibiting higher **compressive strength didn't always** correspond to higher flexural strengths
 - No direct correlation between compressive and flexural for this dataset
- Flexural strength could indicate other qualities of interest



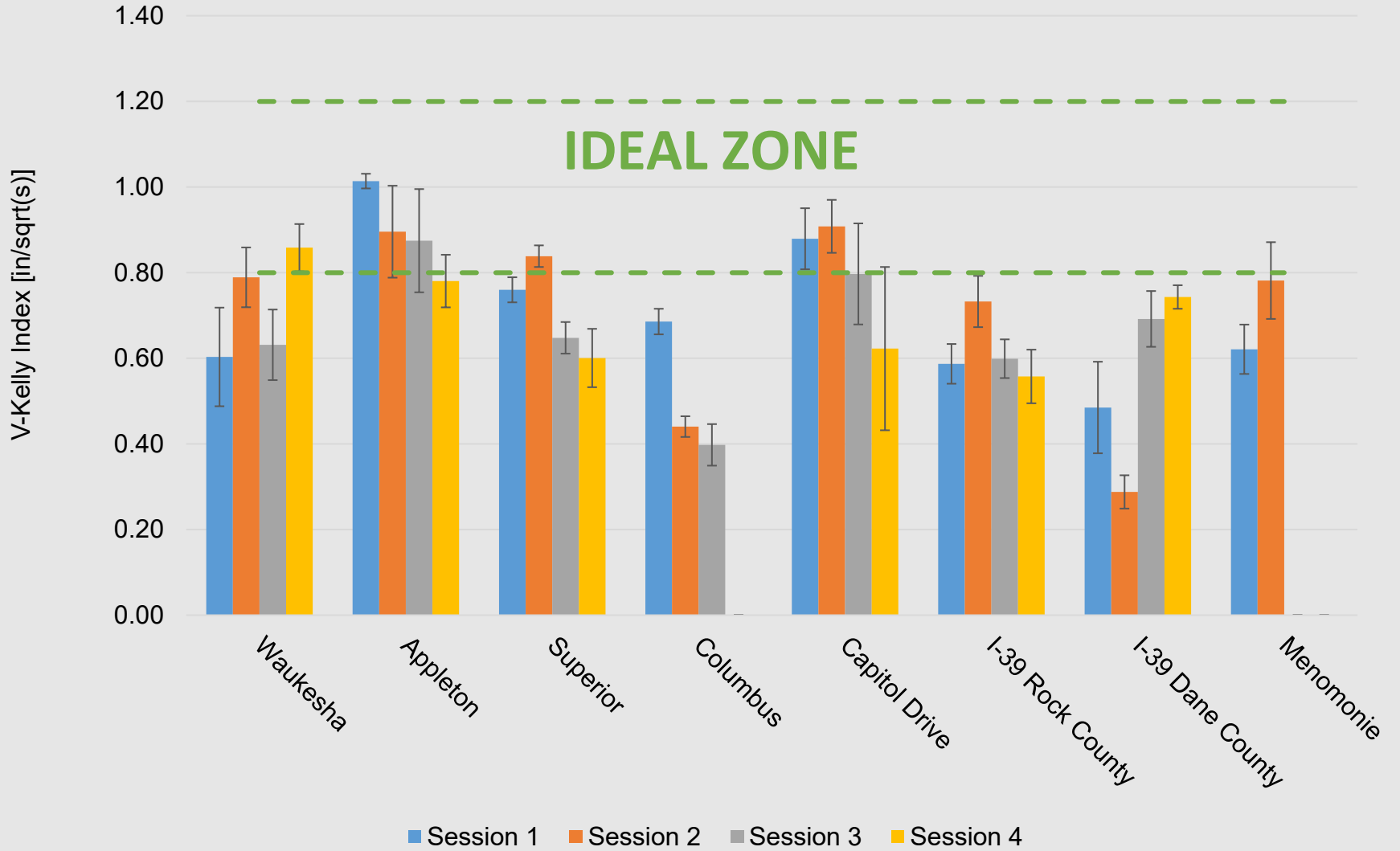
PEM Recommendations

PEM Test	Current WisDOT Practice	Proposed PEM Recommendation	Specification
Compressive Strength	28-day	No Change	AASHTO T 22
Flexural Strength	28-day	No Change See sec. 4.2	AASHTO T 97



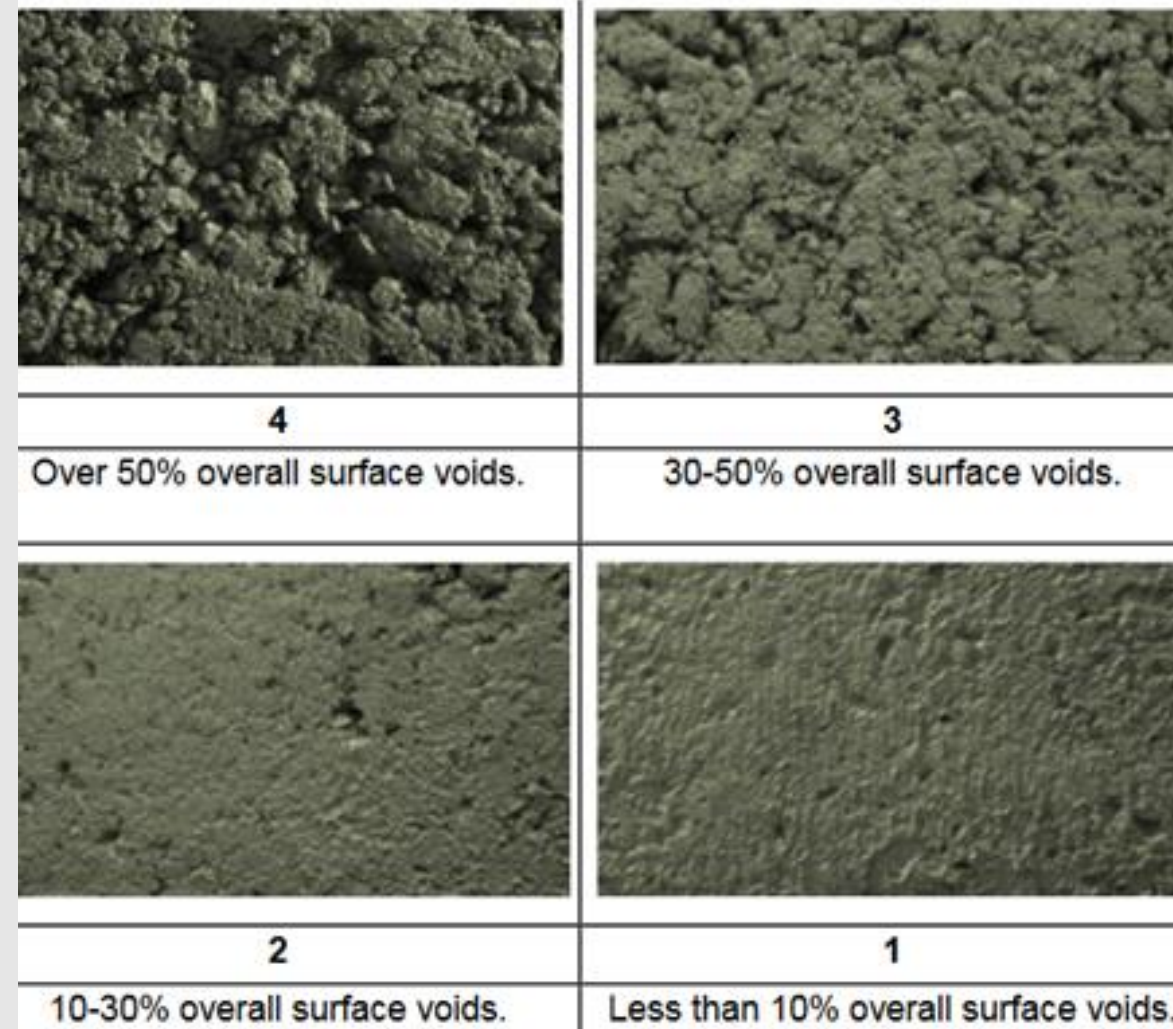
WORKABILITY RESULTS

Workability: V-Kelly



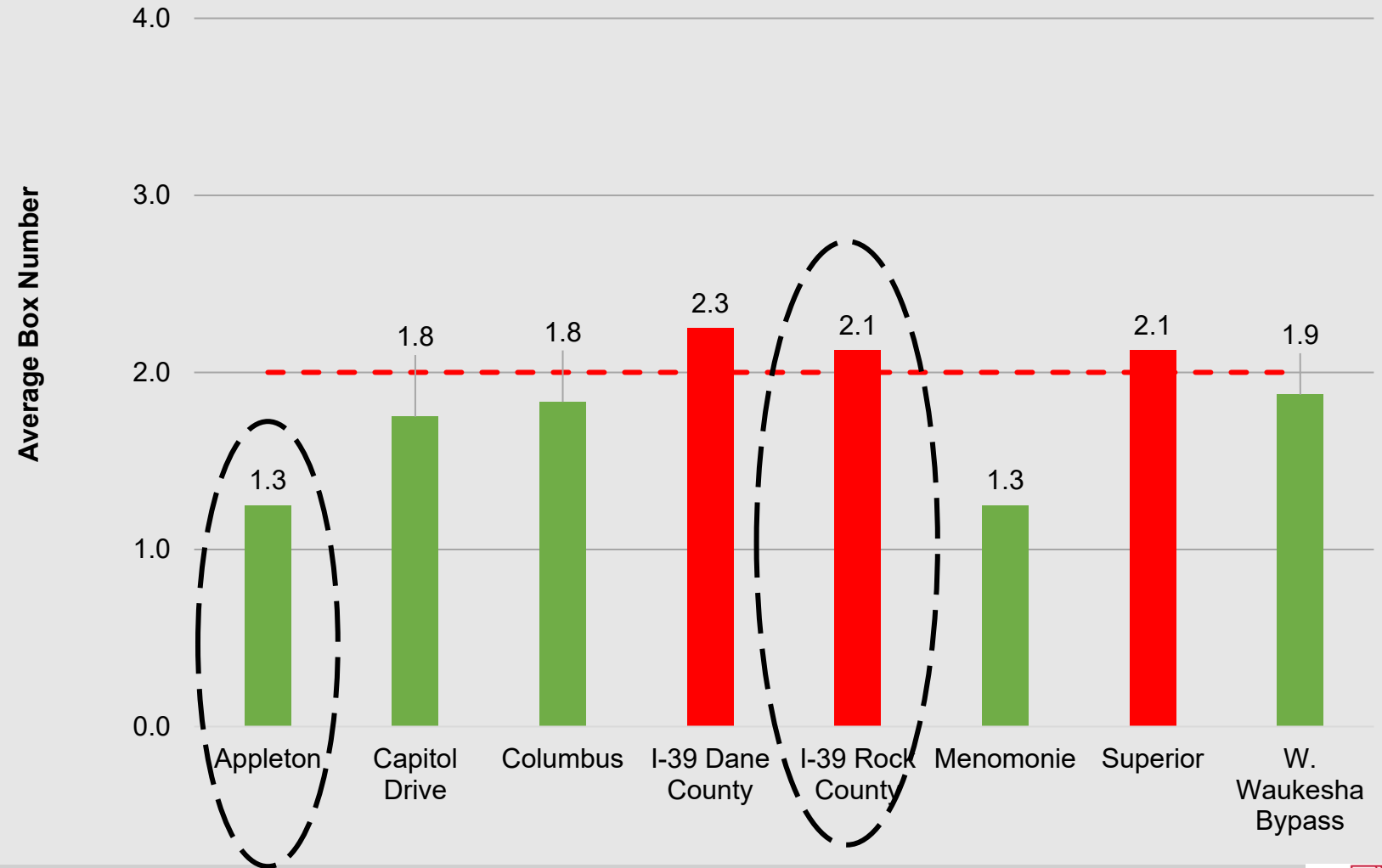
What is a Box Test?

- A mixture for a slip-formed paver requires the concrete to be flowable enough for consolidation, but still hold an edge
 - The Box Test was developed to visually quantify the workability based on comments from the slip-formed paving industry
 - This test has successfully been used as a tool during the trial batching process to understand the performance response to vibration and the ability of the mixture to hold an edge
- Visual Grading System
 - 1, 2 - Passing
 - 3, 4 - Failing



Workability: Box Test (Phase I)

- 3 locations > 2.0
 - Many and/or larger surface voids
 - Mixtures may have poor “finishability”
- 5 locations < 2.0
 - Mixtures that have small and/or a small number of surface voids
 - Good “finishability”



Workability: Box Test Comparison

Appleton
Average Box Number: 1.3

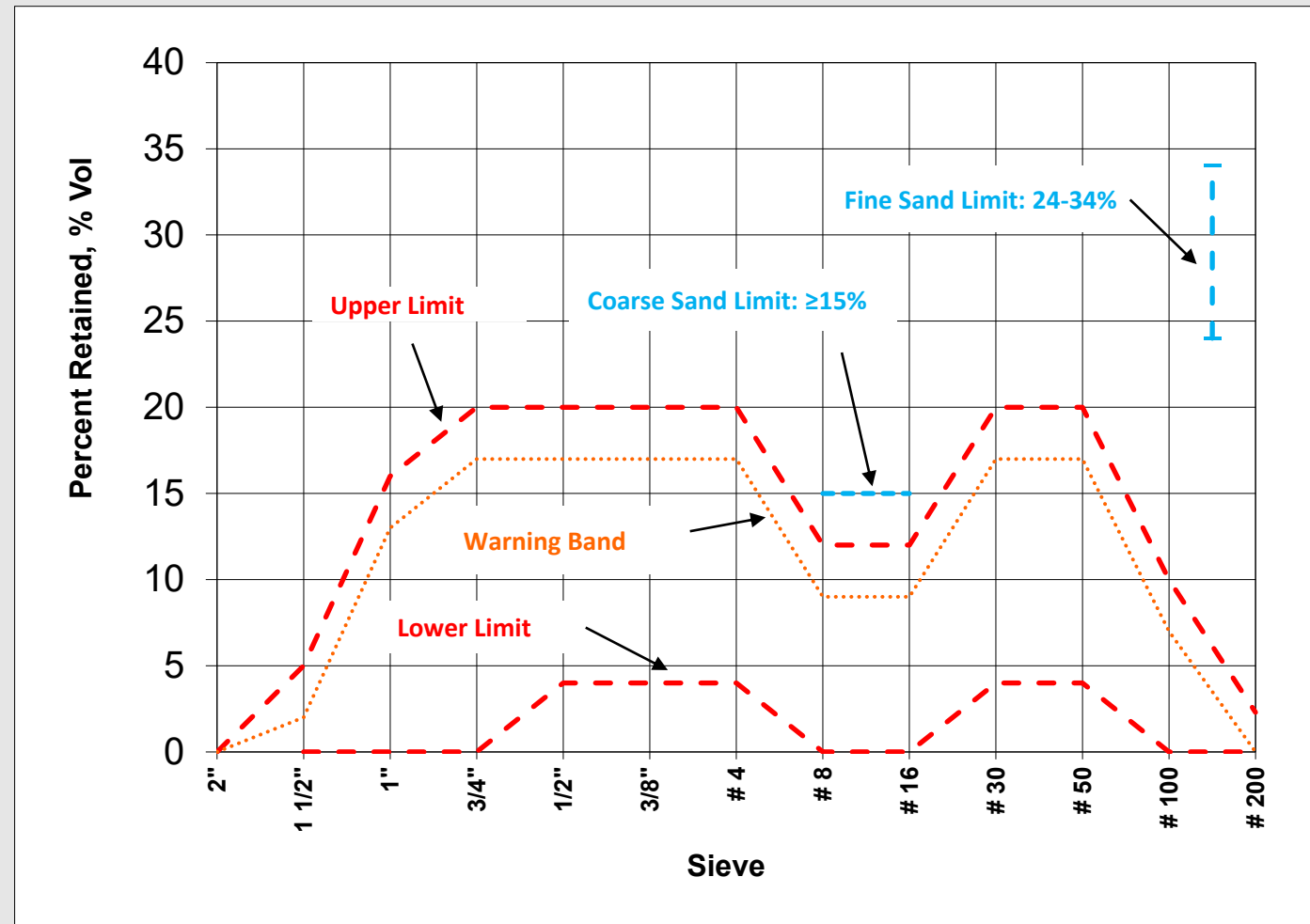


Rock County
Average Box Number: 2.1

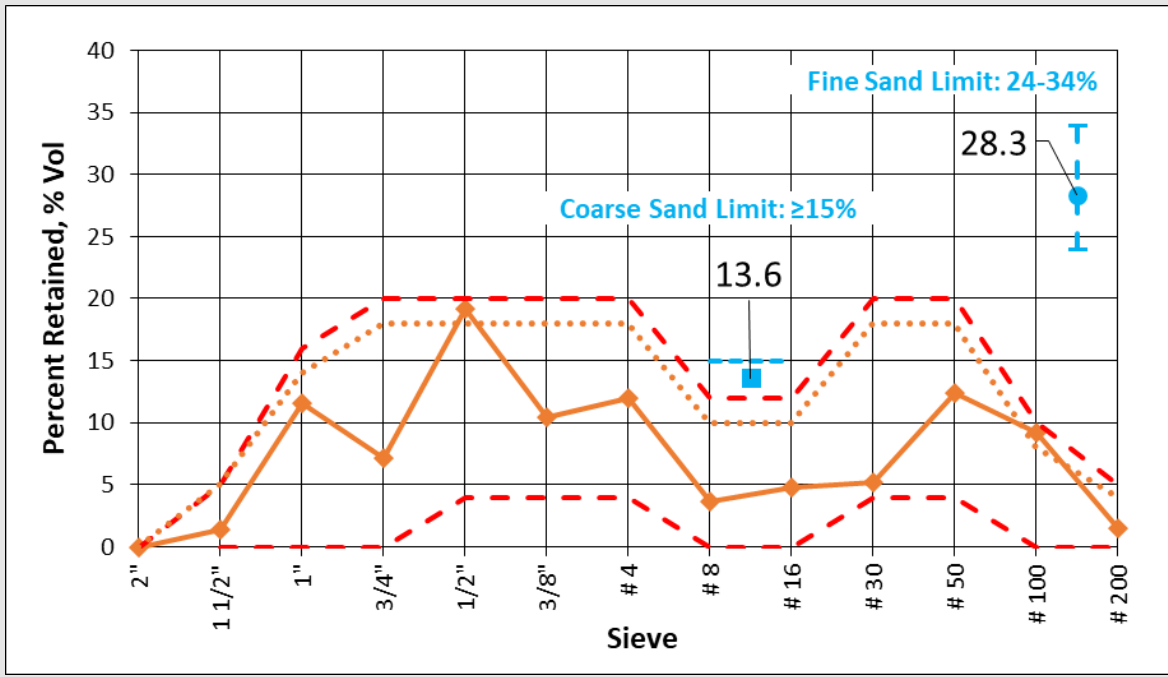


Optimized Gradation/Tarantula Curve

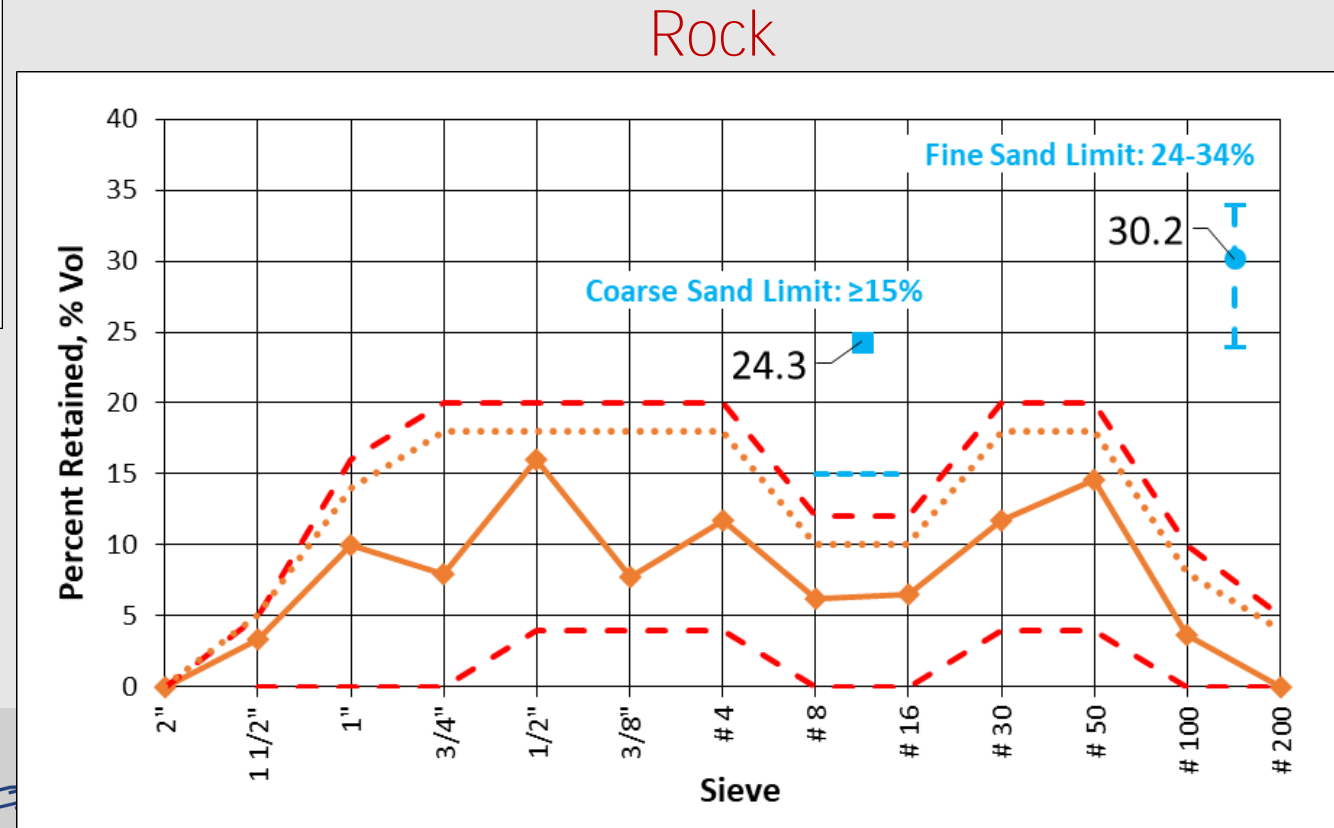
- Developed to produce concrete mixtures with adequate workability without detrimental effects to performance
- Optimized gradation sieve limits per WisDOT CMM 8-70.2.2.3
- Coarse and Fine Sand limits based on OSU research
 - Coarse Sand (#8 to #30): Cohesion properties
 - Fine Sand (#30 to #200): Finishability, Consolidation, and richness properties
- Warning band at 3% below the upper limit
 - To account for variability during production



Optimized Gradation/Tarantula Curve Comparison



Appleton



Phase II Work Plan Regarding OAG

- Evaluate the use of 1.5-inch (38.1 mm) coarse aggregate
- Compare mixtures with and without 1.5-inch CA
- Adjust the Tarantula Curve accordingly





Quarry: Haas

Contractor:
Concrete Chippewa
Services

County: Eau Claire



Quarry: Lathers Pit

Contractor: Michels

County: Rock



Quarry: Franklin

Contractor: Zignego

County: Kenosha

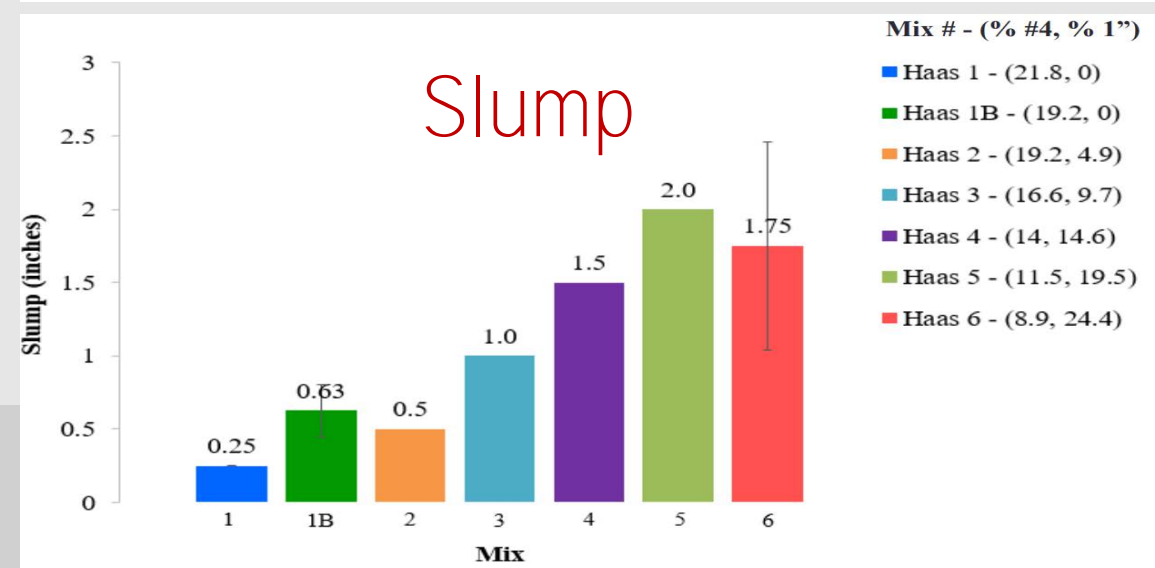
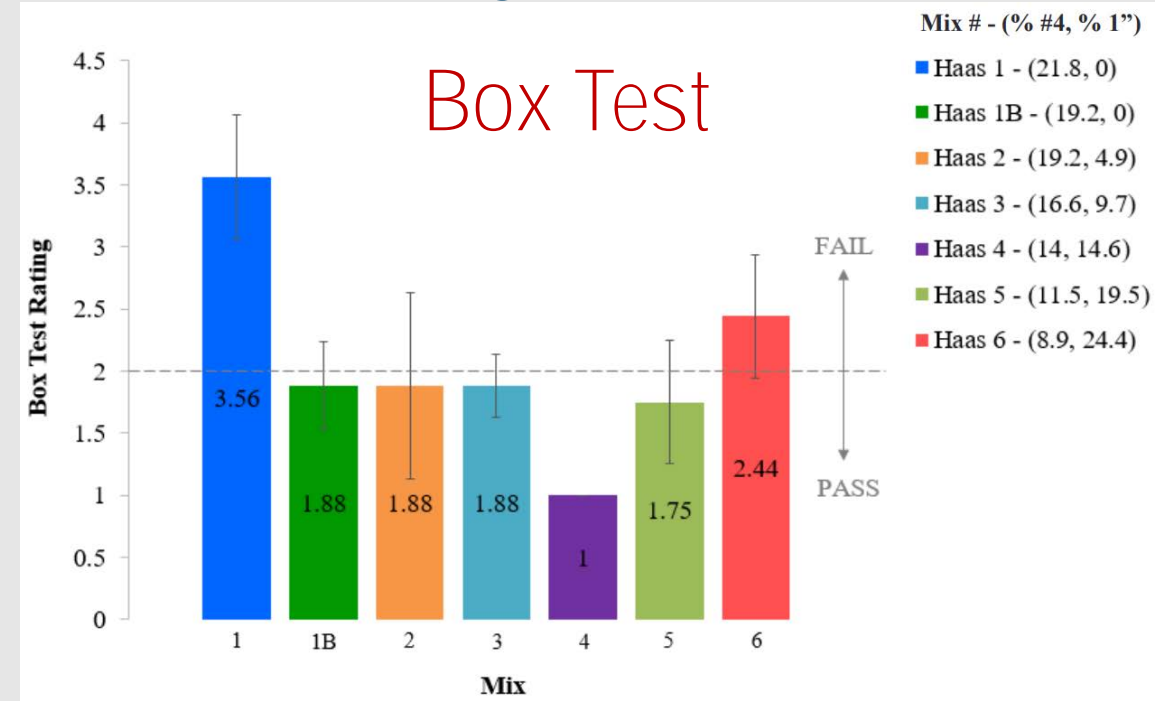
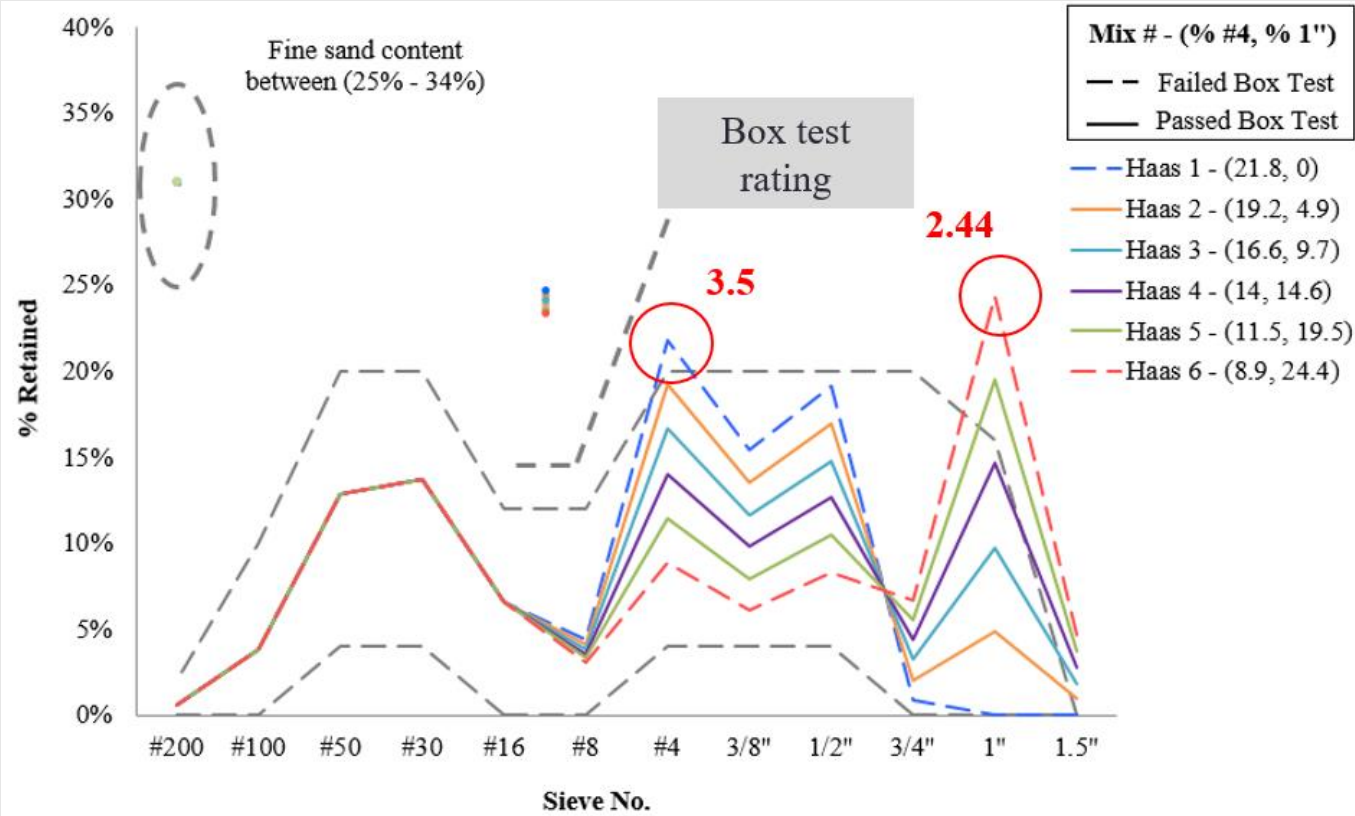


Quarry: Badgerland
Aggregates

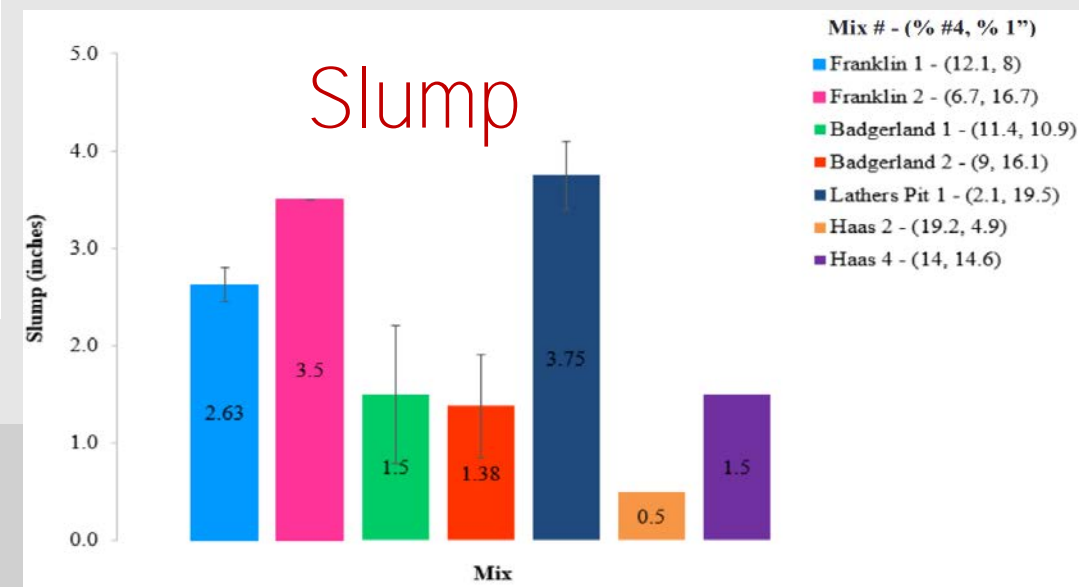
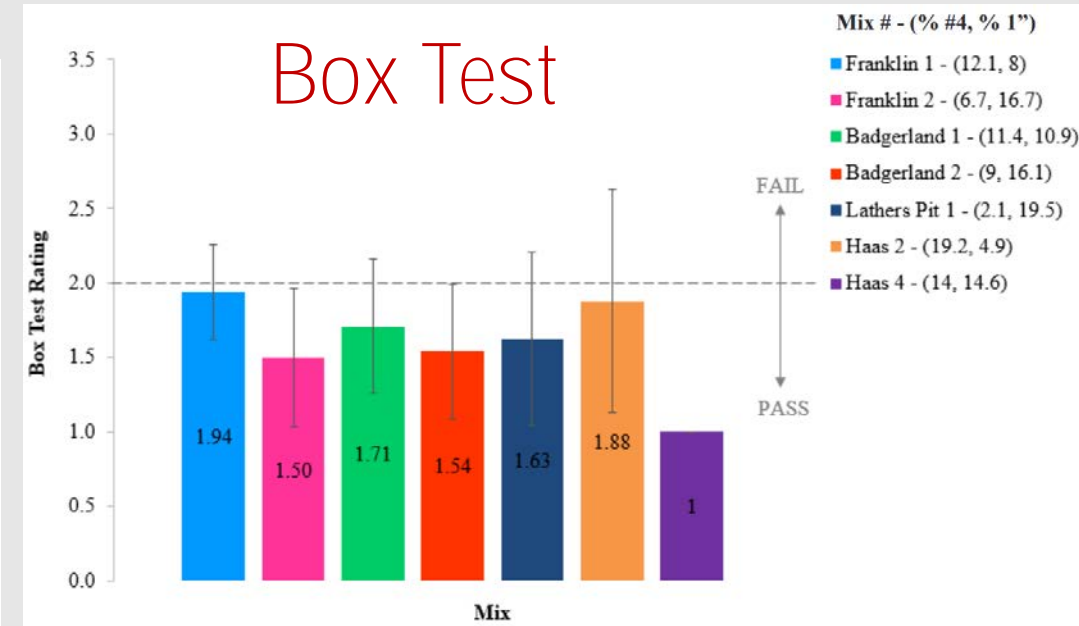
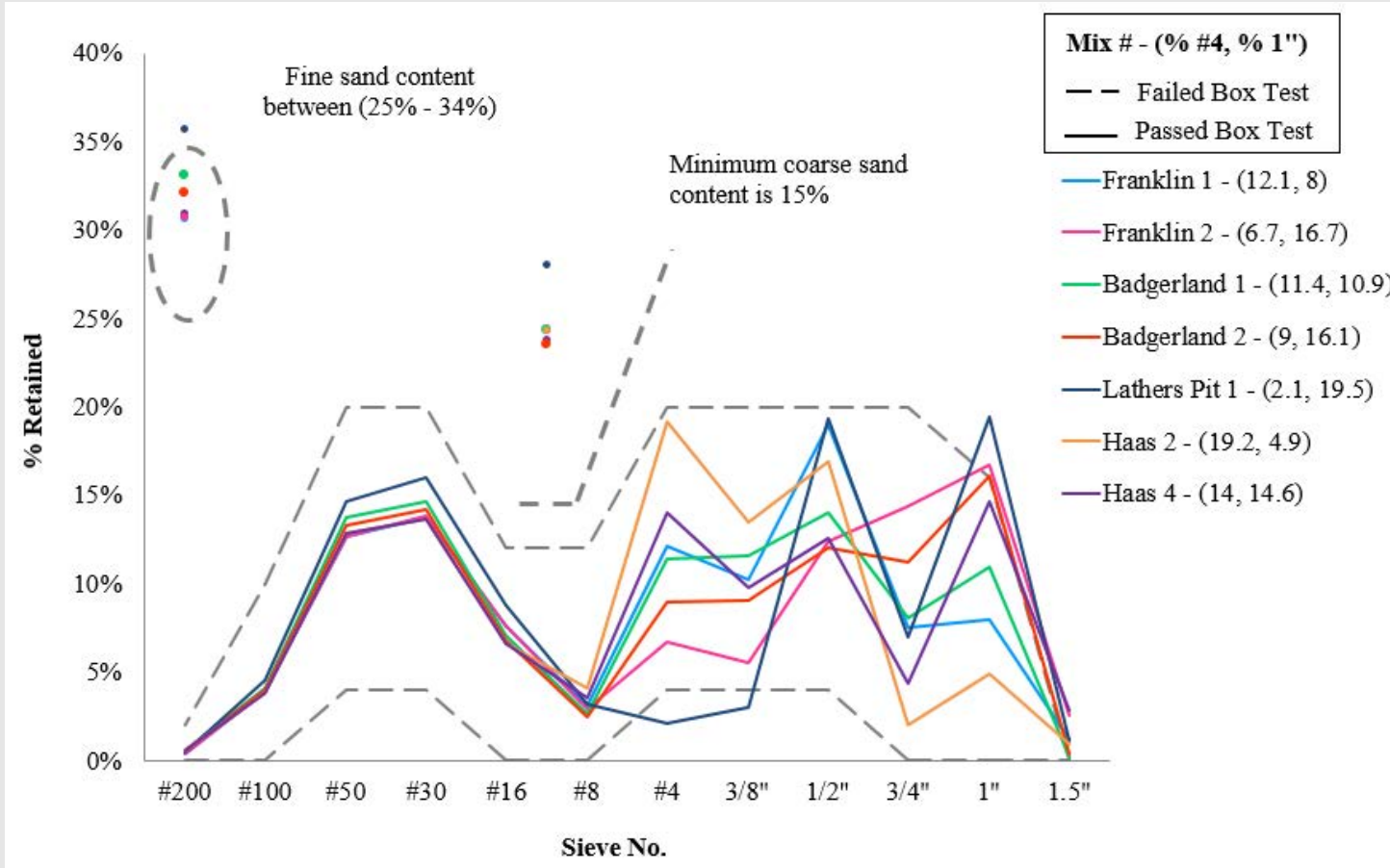
Contractor: Vinton

County: Manitowoc

Workability – Haas Quarry



Workability – All Quarries



PEM Recommendations

PEM Test	Current WisDOT Practice	Proposed PEM Recommendation	Specification
Optimized Aggregate Gradation	Optional Spec.	Implement a warning band. Fine/Coarse Limits	CMM 8-70.2.2.3
Slump	WisDOT Section 415.2.1(3) Slip-Formed 2.5 inches or less	Consider removing slump from the requirements for paving concrete.	AASHTO T119
Vibrating Kelly Ball	N/A	Do not recommend incorporation into WisDOT specifications.	AASHTO TP 129
Box Test	HTCP PCC II	Recommend during Trial Batches, to replace the Slump Test with the Box Test and require <2.0. Consider using the Box Test during production to help identify inconsistency.	AASHTO TP 137

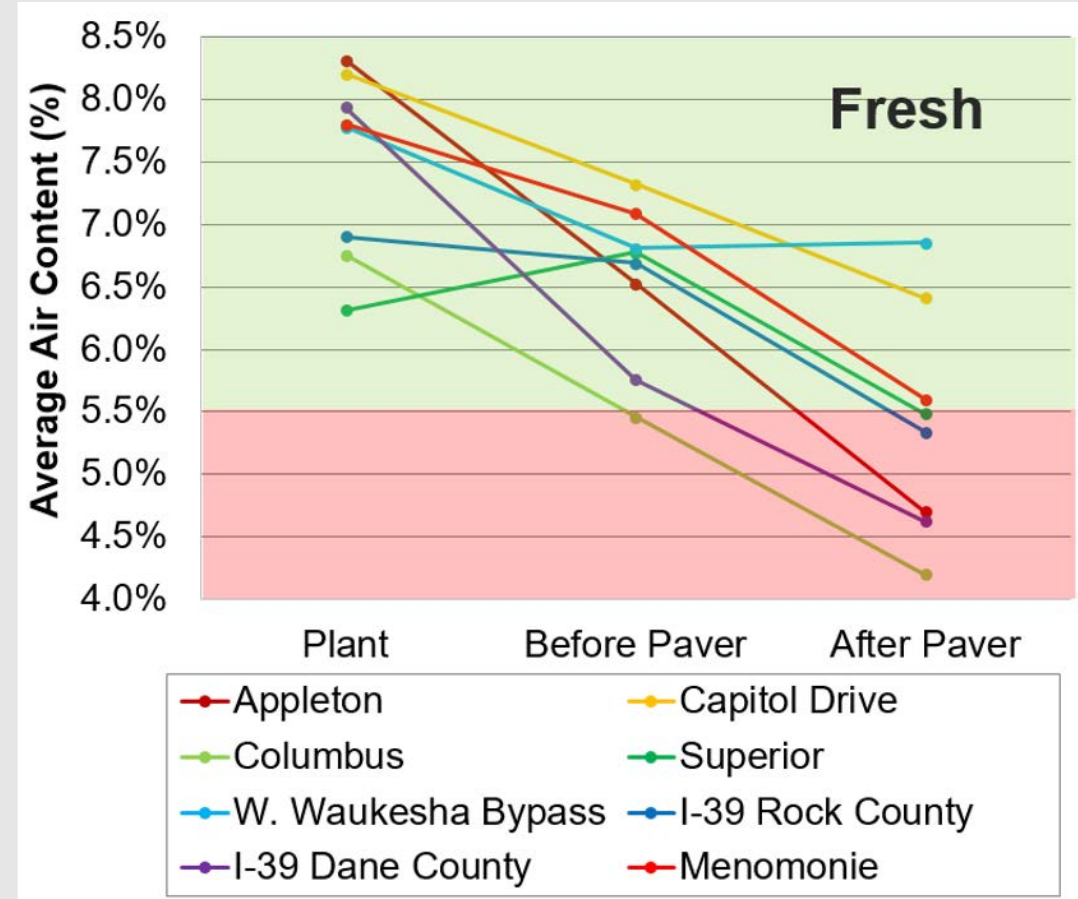


DURABILITY RESULTS

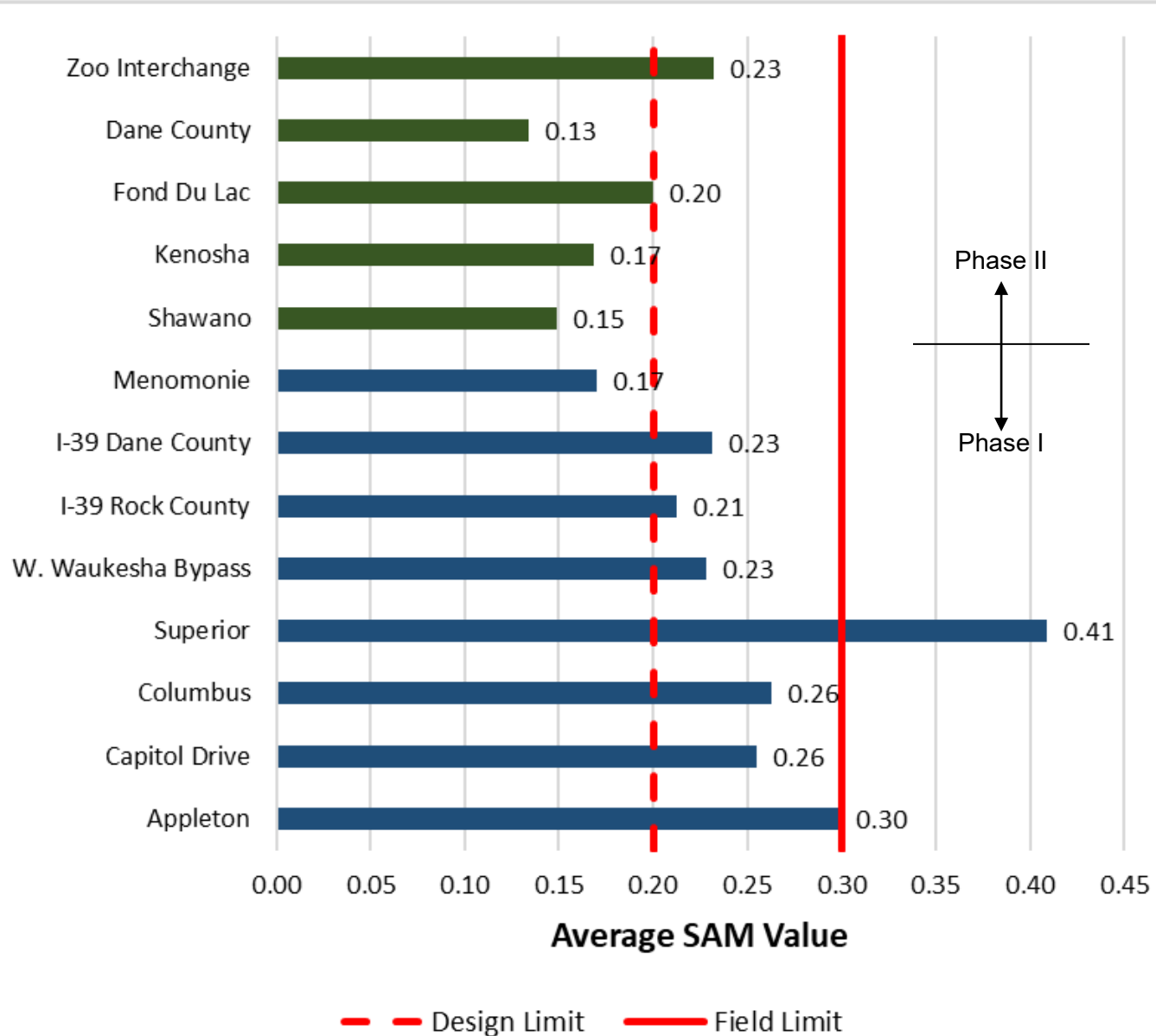


Durability: Air Content

- Air content typically dropped from the plant until after the paver by as much as 3.5%
- Hardened air content has a similar trend to fresh



Durability: Super Air Meter



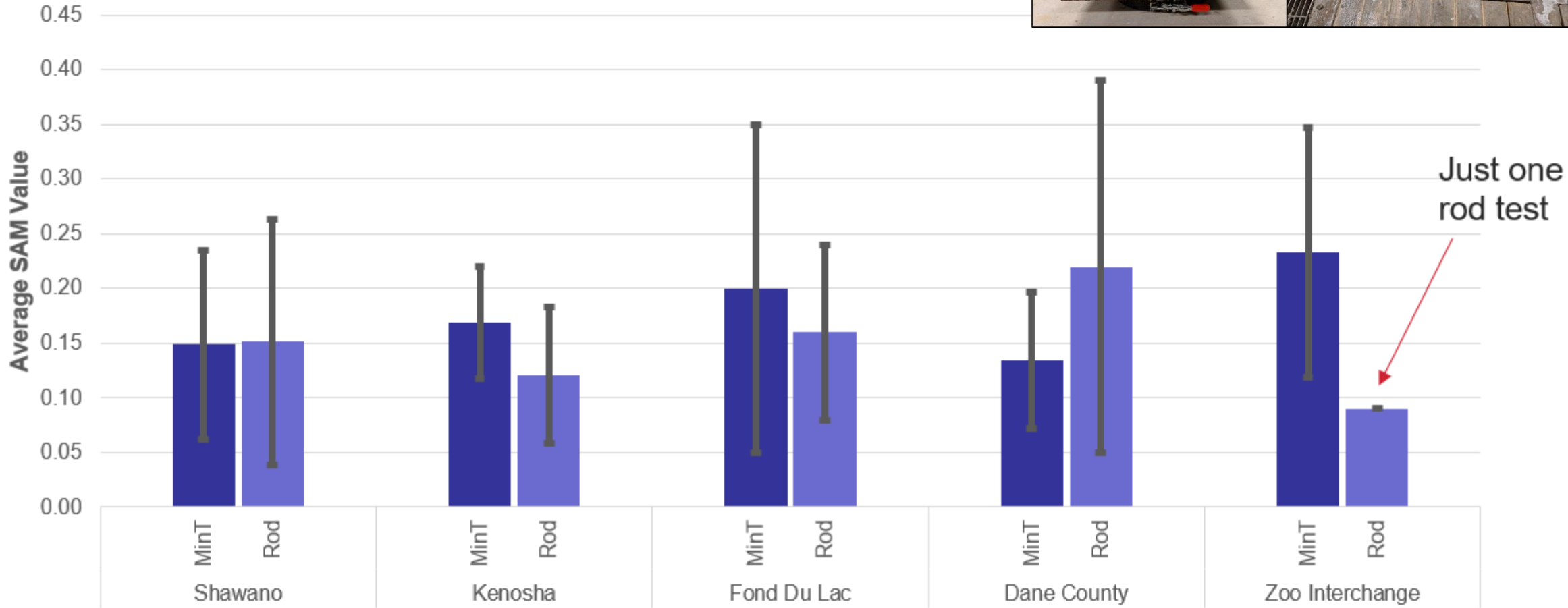
- 3 out of 8 Phase I mixtures were within the Optimized Gradation limits
- Phase II all used Optimized Gradations and were within the gradation band



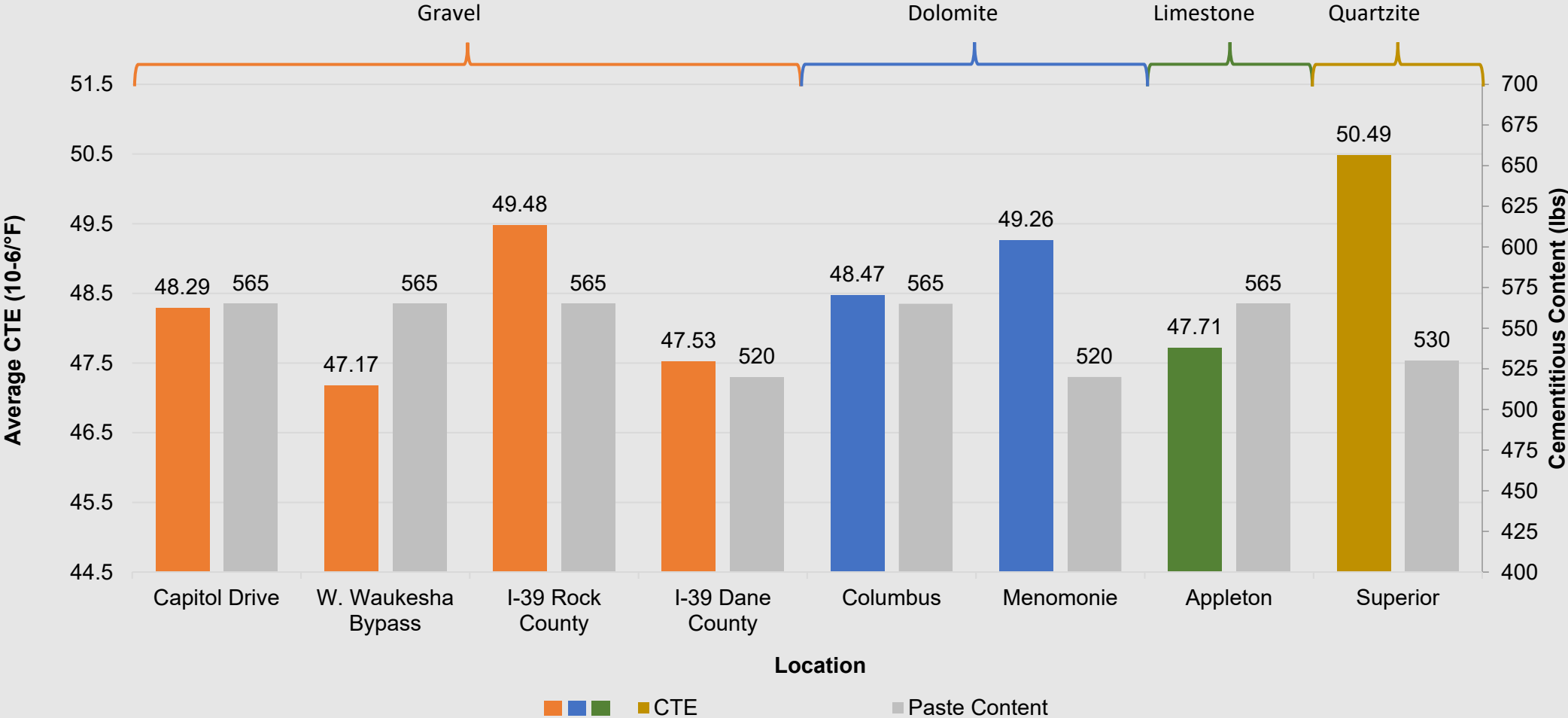
Durability: MinT vs. Rodding



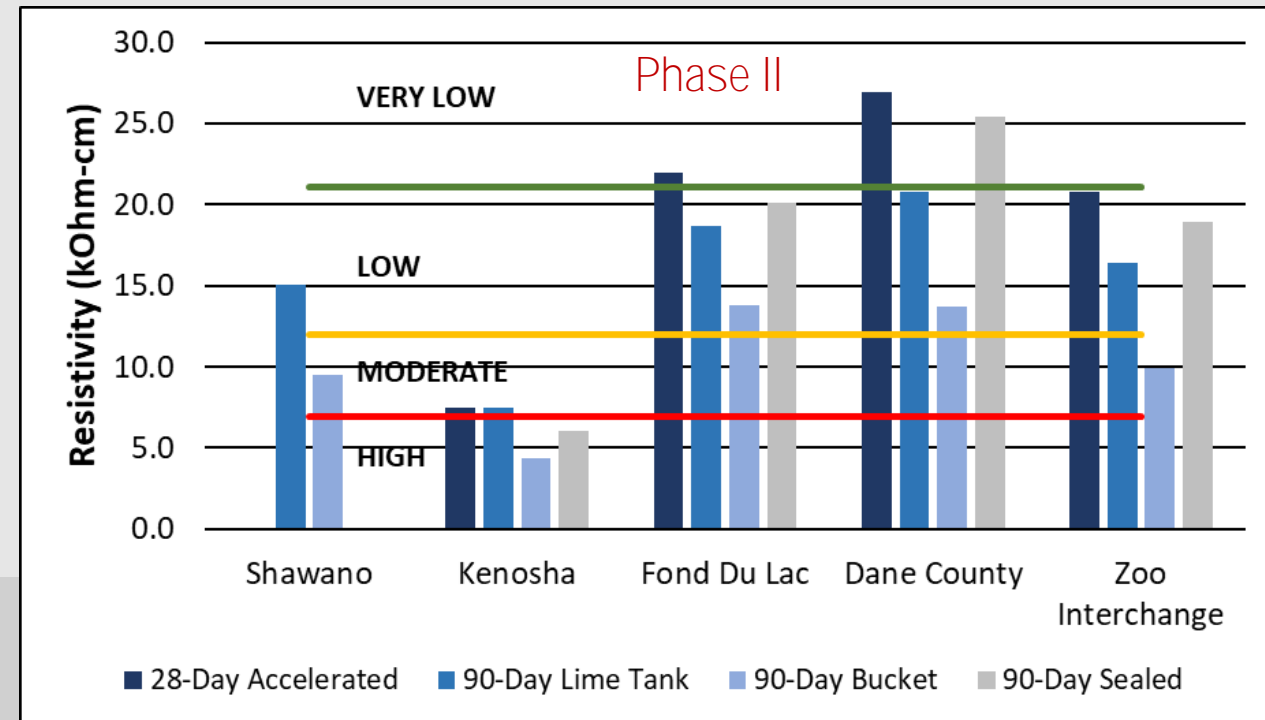
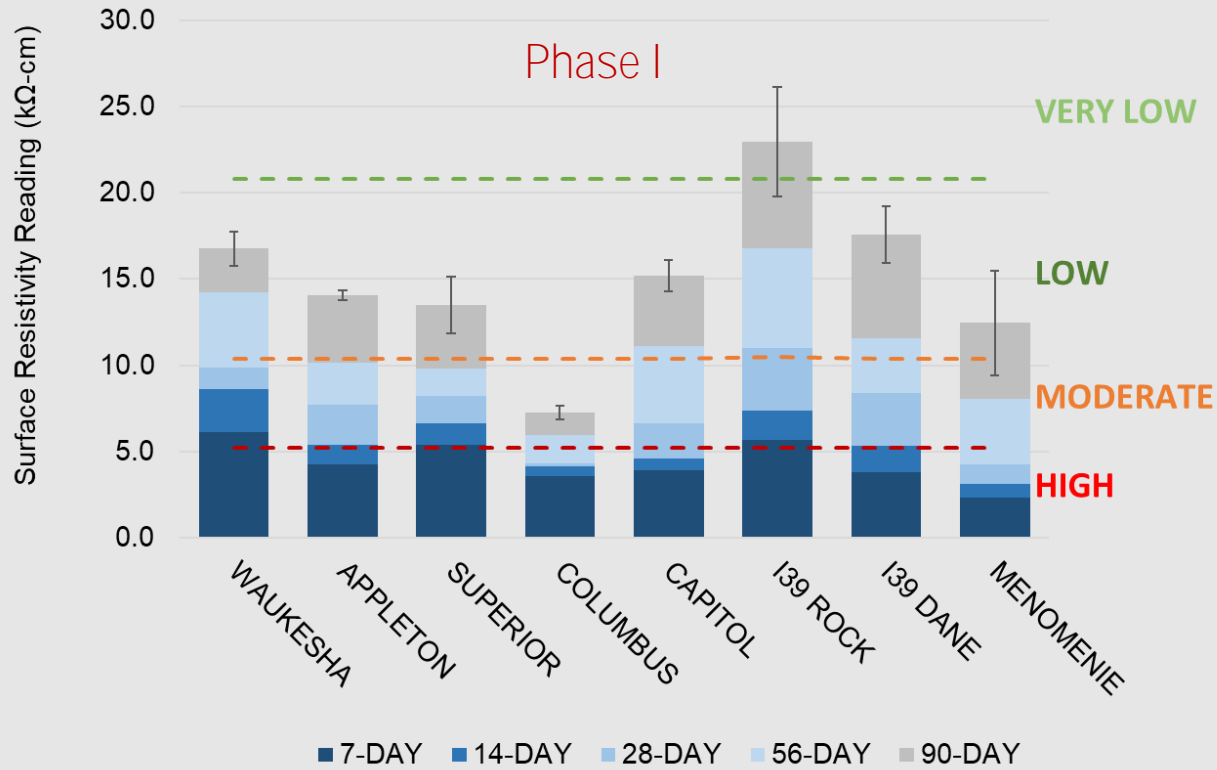
SAM Meter Field Testing



Durability: Coefficient of Thermal Expansion

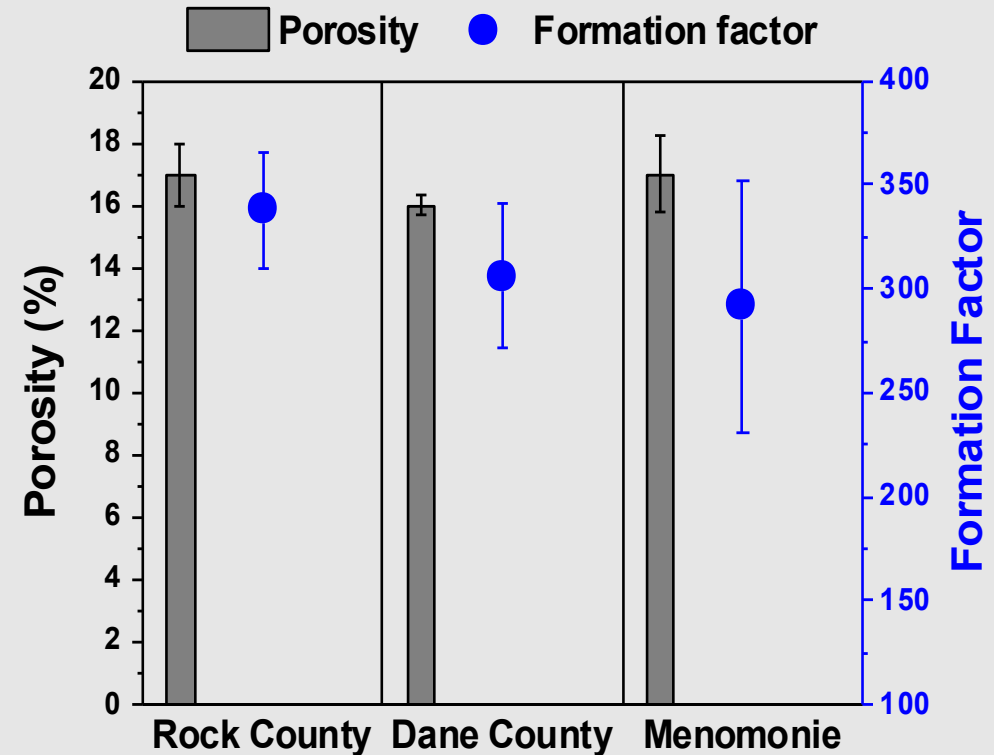


Durability: Surface Resistivity



Durability: Formation Factor

- Formation Factor is the ratio of pore solution conductivity and bulk conductivity of concrete, which gives a quantitative description of pore connectivity
 - Less pore connectivity corresponds to higher durability
 - High formation factor values are desirable and correspond to lower pore connectivity
- Formation Factor results are consistent with surface resistivity results



PEM Recommendations

PEM Test	Current WisDOT Practice	Proposed PEM Recommendation	Specification
Coefficient of Thermal Expansion	N/A	Consider as a design parameter and collect data for future consideration of implementation.	AASHTO T 336
Air Content	Std. Spec 501.3.2.4.2: 7% ± 1.5%	If the SAM number is acceptable, then allow Air Content to a minimum of 4%	AASHTO T 152
Super Air Meter	CMM 8-70 Attachment 4: No contractual specification limits, an acceptable SAM number is ≤0.25 . Acceptable SAM numbers typically require a minimum of 4.0% air. Failing SAM numbers typically do not occur above 8.0% air.	Design Limit: 0.20 Field Limit: 0.30	AASHTO TP 118
Hardened Air Voids	CMM 8-70.5.2.4: The total air content equals or exceeds the lower control limit for the in-place concrete item. AND/OR The spacing factor is less than or equal to 0.0080 in. (0.200 mm).	To be used for dispute resolution or future research.	ASTM C457
Surface Resistivity	N/A	Consider as a design parameter and collect data for future consideration of implementation. Recommend “accelerated moist-curing” conditions in T 358-21 Section 8.1.1.	AASHTO T 358 / PP 84 / TP 119-17



Recommendations for Implementation

- Continued option to use 1.5-inch aggregate size in WisDOT mixtures
- Use of the Tarantula Curve with a warning band for all WisDOT mixtures where longevity is important
- Design and production targets for the SAM meter
- Using MinT for SAM consolidation and the accelerated curing method for resistivity





Thank you!

Questions/Contact

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