WisDOT Non-Cementitious Repair Materials Study

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Study Objectives

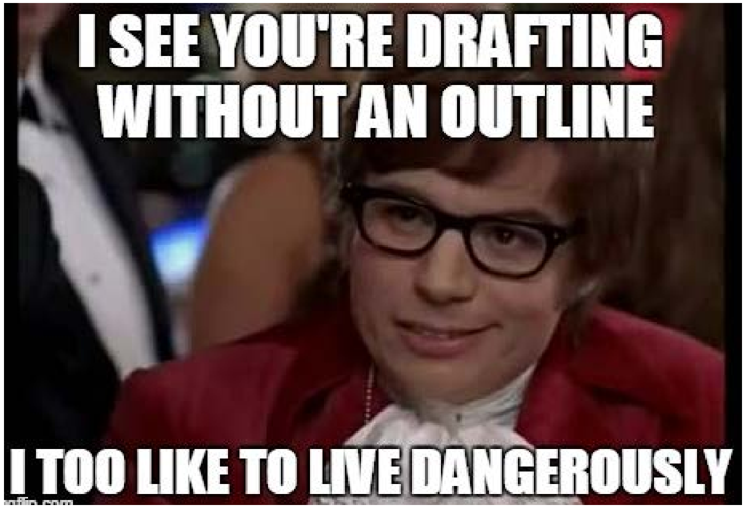
- Develop recommendations regarding proper selection and application of non-cementitious repair materials for concrete pavements
  - Evaluate availability and applicability of non-cementitious materials
  - Evaluate performance of installed non-cementitious repairs
  - Develop recommendations for WisDOT specs and manuals

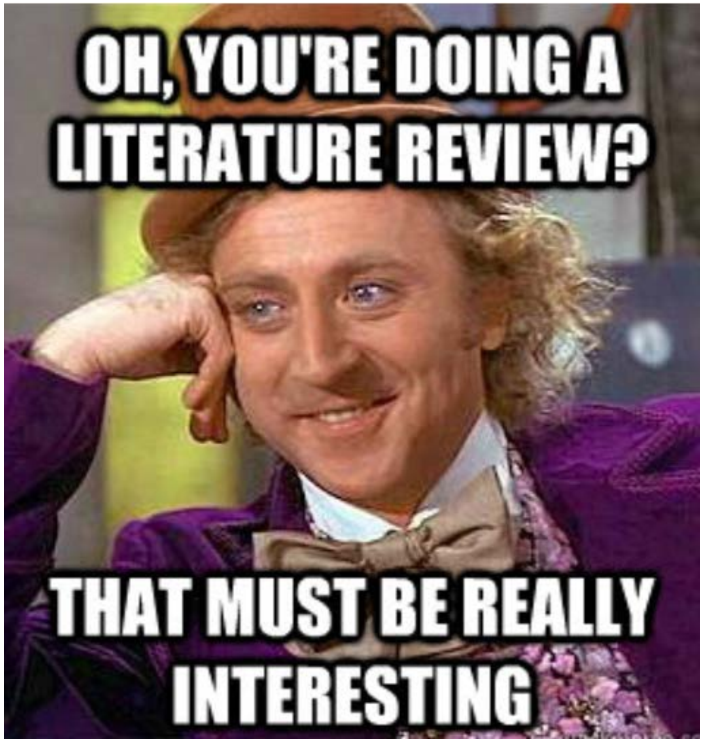
Project Team

- Applied Pavement Technology, Inc. (APTech)
  - Prashant Ram: PI
  - Kurt Smith: Co-PI
- Consultants:
  - Dr. Tom Van Dam (NCE)
  - Dr. Larry Sutter
- Lab Testing: Purdue University
  - Dr. Jan Olek and Dr. Ayesha Shah

Presentation Outline

- Literature review summary
- Field condition evaluation
- Laboratory testing
- Conclusions
- Recommendations





Literature Review Summary

Literature Review Summary (1/2)

- Non-cementitious materials not as commonly used as cement-based materials
- Some agencies have developed limited specifications for acceptance and testing
- General properties of non-cementitious materials:
  - Low elastic modulus
  - High CTE
  - High initial shrinkage
  - Opening-to-traffic time depends on material composition, generally <6 hours

Literature Review Summary (2/2)

- No discernible relationship between testing temperature and shrinkage, bond strength
- Future rehab activities should be given due consideration:
  - Bonding issues with concrete overlay
  - Diamond grinding issues
- Repair performance heavily depends on condition of existing concrete pavement

Field Condition Evaluation of Repairs

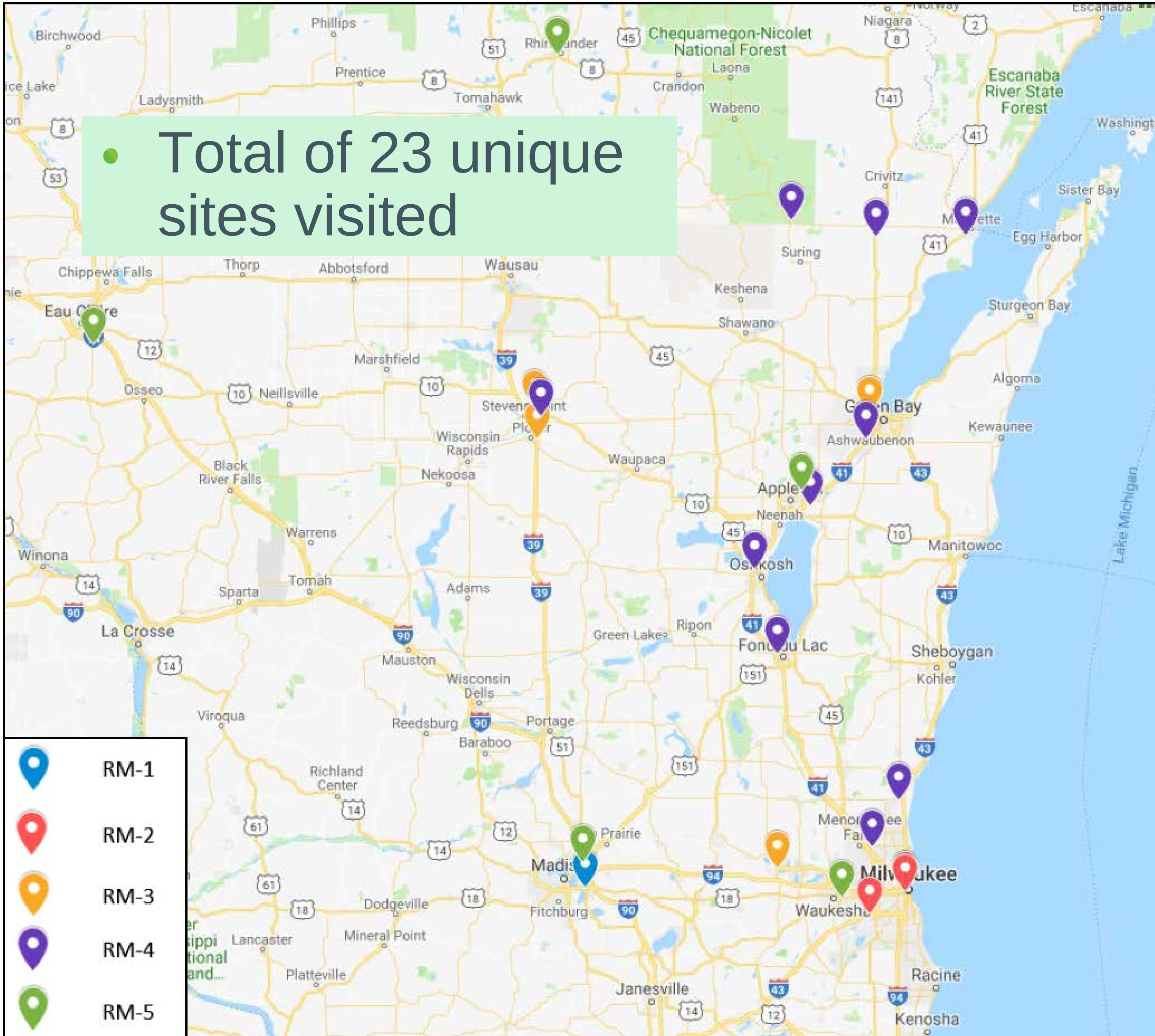
Final Testing Matrix

Repair Material	Material Type
RM-1 (Field)	Hot-applied flexible material formulated with polymer modified resins, fiberglass, mineral fillers, and high-quality aggregates
RM-2 (Lab, Field)	Polyester polymer concrete
RM-3 (Field)	Hot-applied polymer modified asphalt repair mastic
RM-4 (Lab, Field)	Hot-applied polymer-modified synthetic resin with fibers, fillers, fines, and high-quality aggregate
RM-5 (Lab, Field)	Hot-applied polymer modified asphalt with engineered aggregates and modifiers

Field Condition Evaluation

- Traffic control arrangements coordinated by WisDOT
- Visual investigation: subjective condition evaluation of repair patches and surrounding concrete pavement
- NDT: PSPA Testing
- Coring (2 cores per material)

- Total of 23 unique sites visited



Coring and PSPA Testing Summary

Site ID	Core #	Repair Material	Average Ambient Temp, °F (°C)	Coring Summary			PSPA Testing Summary	
				Repair Material Thickness (inch)	PCC Thickness (inch)	Bond Condition	RM Dynamic Modulus (ksi)**	PCC# Dynamic Modulus (ksi)**
1	1	RM-1	87 (31)	2.50	8.50	Debonded	2,600	5,338
1	2	RM-1	88 (31)	2.25	7.75	Debonded	1,853	3,940
1	3	RM-1	83 (28)	3.00	N/A*	Debonded	2,280	4,808
5	1	RM-3	26 (-3)	3.00	N/A*	Debonded	NR*	4,633
8	1	RM-3	13 (-11)	1.50	N/A*	Debonded	1,670	4,010
9	1	RM-4	28 (-2)	2.50	7.25	Debonded	1,947	5,993
11	1	RM-4	12 (-11)	4.0	N/A*	Debonded	650	5,143
20	1	RM-5	23 (-5)	3.25	N/A*	Debonded	450	4,580
21	1	RM-5	24 (-4)	4.00	N/A*	Debonded	730	5,233

*Underlying PCC pavement was deteriorated; core could not be extracted
**Average of three readings recorded from one location
#Measurement performed on PCC pavement close to the PDR

RM-1

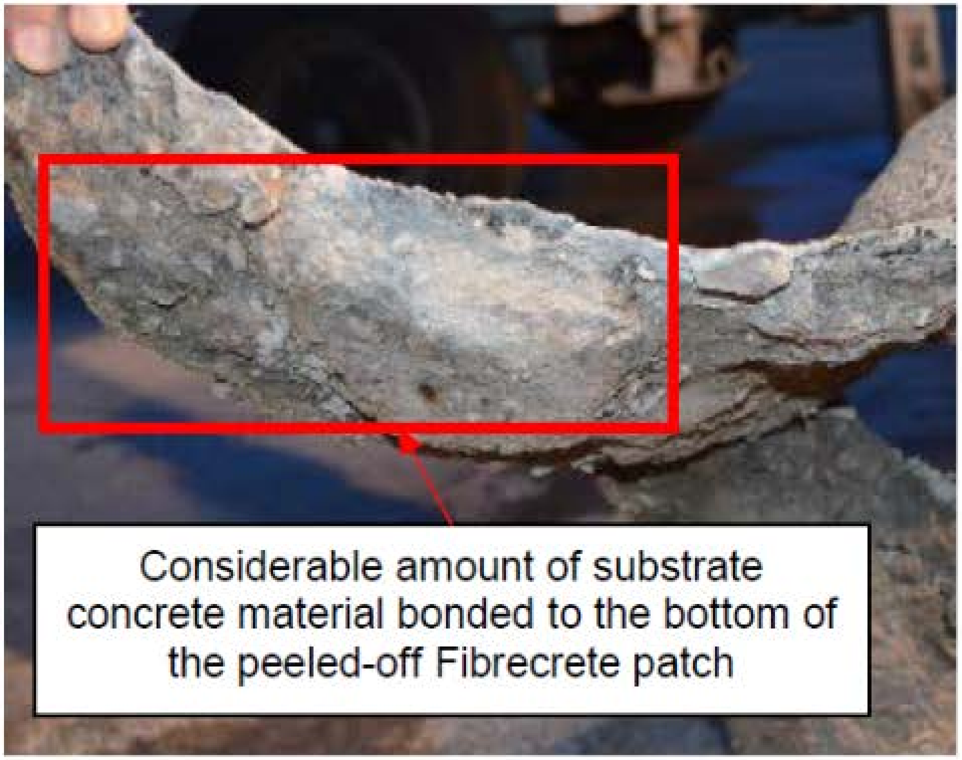
Hot-applied flexible material formulated with polymer modified resins, fiberglass, mineral fillers, and high-quality aggregates

RM-1 Overview

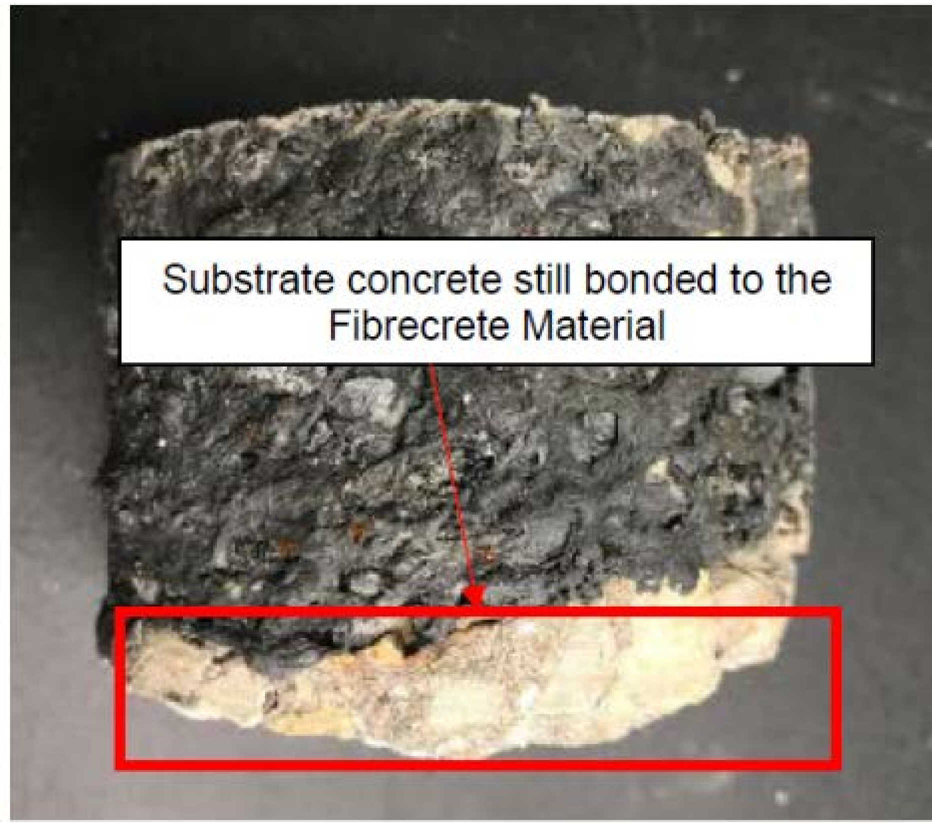
- 8000 PDRs on the Madison Beltline in 2014 and 2015
- Jan 2016: Several instances of sudden failures
  - » WisDOT investigation showed underlying concrete to be in deteriorated condition
- Jan 2018: Another round of failures
- Summer 2018: Removal and replacement of all RM-1 repairs

RM-1 Repairs (1/2)

RM-1 Repairs (2/2)



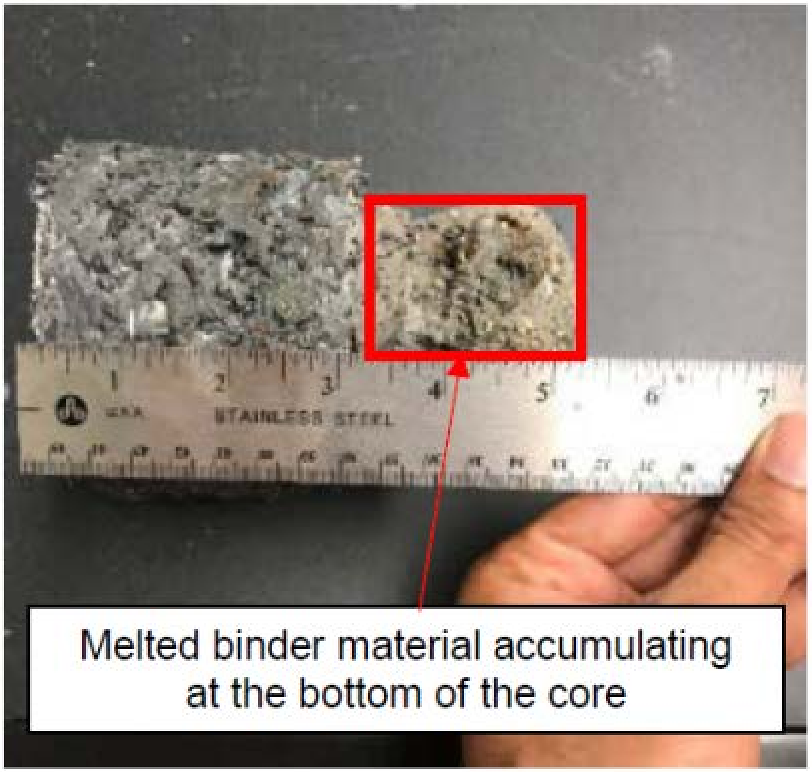
RM-1 Cores (1/2)


Substrate concrete still bonded to the Fibrecrete Material

RM-1 Cores (2/2)

- Multiple parallel cracks through the entire depth
- Potentially suggests freeze-thaw-related damage

Coring Issues



RM-2

Polyester Polymer Concrete

RM-2 Overview

- Not used on PDR applications in Wisconsin
- Used in a few bridge deck overlay projects in the Milwaukee area
  - Overlays typically 0.75-inches thick
  - Used to resurface decks with moderate amounts of cracking and spalling (National Bridge Inventory rating of 5)

RM-2: Issues Noted

- Top 0.25-inches peeling off; isolated to edge
- Potential causes: under-catalyzed binder, moisture in mix aggregates, accumulation of excess moisture

RM-3

Hot-applied polymer modified asphalt repair mastic

RM-3 Overview

- Popular repair material for asphalt pavements
  - » Widely used in SE Region
- Limited use on PCC pavements
  - » Maintenance personnel noted good performance in joint and spall repairs
  - » Mostly used as stop-gap fix

RM-3 Repairs



RM-4

Hot-applied polymer-modified synthetic resin with fibers, fillers, fines, and high-quality aggregate

RM-4 Overview

- Most popular non-cementitious material used in PCC PDR applications
  - Particularly popular in NC and NE Regions
- Also used for bridge deck repairs
- Big marketing presence in Wisconsin
- Material very similar to RM-1 in chemical composition

RM-4 Repairs—Pavement

RM-4 Repairs—Bridge

Surface map cracking on some bridge deck repairs

RM-5

Hot-applied polymer modified asphalt with engineered aggregates and modifiers

RM-5 Overview

- Only used in experimental demonstrations in Wisconsin at five sites
- Material appears to be similar to RM-3 with larger aggregates
- Mastic formulation also available: “Gap Mastic”
  - Primarily for crack repair applications

RM-5 Repairs


Site #19, Eau Claire
Site #20. Madison
Core Location
Site #21, Appleton
Site #22, Rhinelander
Core Location
Site #23, Waukesha

Laboratory Testing

Overview

- Limited testing to study bond and dimensional stability aspects of: RM-2, RM-4, and RM-5
- Primary intent was to evaluate behavior at different testing temperatures

Bond Testing

- Pull-off method (ASTM C1583)
- Testing temperatures:
  - » 23 °C, -23 °C, and -10 °C



Bond Testing Issues: RM-4 and RM-5

- Specimen prep issues due to material melting
- Specimen too soft; unable to support loading from testing equipment
- Test largely unsuccessful

Bond Strength Results

Material	Average Pull-off Bond Strength (psi)		
	23 °C	-10 °C	-23 °C
RM-2	172*	291*	197**
RM-4	NR	159#	NR
RM-5	NR	126##	NR

NR: No Result, test was unsuccessful
*Average value of three specimens tested, failure within repair material at 23 °C and -10 °C
** Only one specimen resulted in a successful test and failure was observed at interface b/w PCC and repair material, bond between specimen and steel disc failed for other specimens tested
#Average value of two specimens tested (219 psi and 99 psi); pull-off test performed from concrete side.
##Only one specimen tested; pull-off test performed from concrete side.

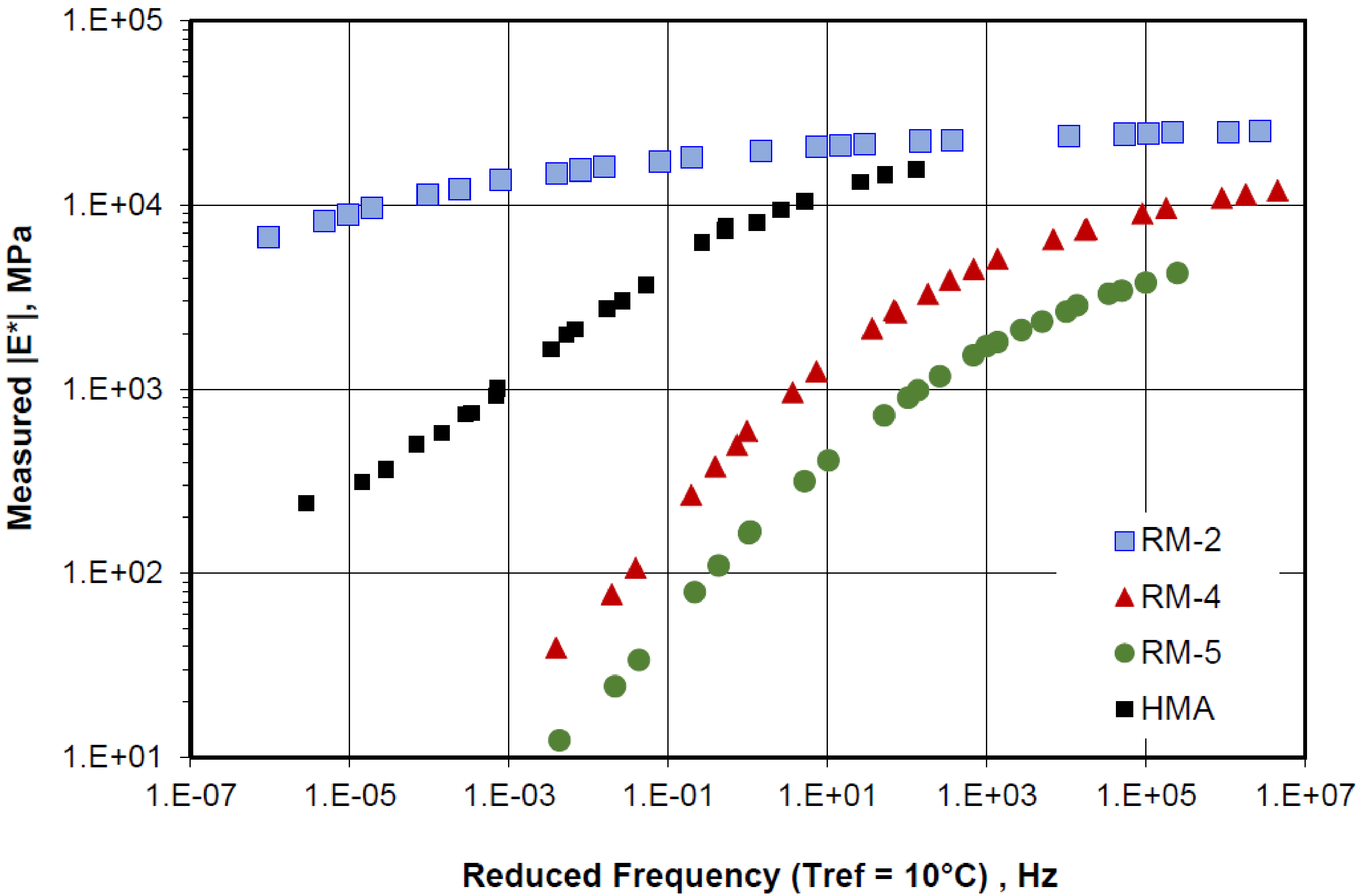
Static Elastic Modulus

- Performed in accordance with ASTM C469
- Testing temperatures:
  - » 23 °C, -23 °C, and -10 °C
- Test applicable only for KwikBond:
  - » 1.4 million psi at 23 °C
  - » 3.3 million psi at -10 °C
  - » 3.6 million psi at -23 °C
- Test not suitable for flexible materials like TechCrete and Gap Patch

Dynamic Elastic Modulus

- Performed in accordance with AASHTO T342
- Suitable for materials exhibiting viscoelastic behavior
- Material stiffness varies with time, temperature, loading frequency
- Testing temperatures:
  - RM-2: 37 °C, 21 °C, 4 °C, and -10 °C
  - RM-4, RM-5: 21 °C, 3 °C, -10 °C, and -22 °C

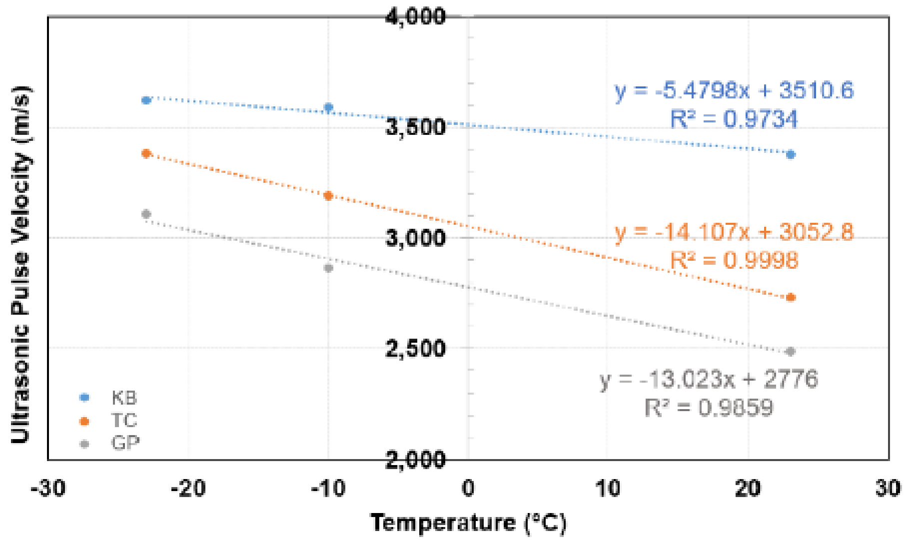
Mastercurves

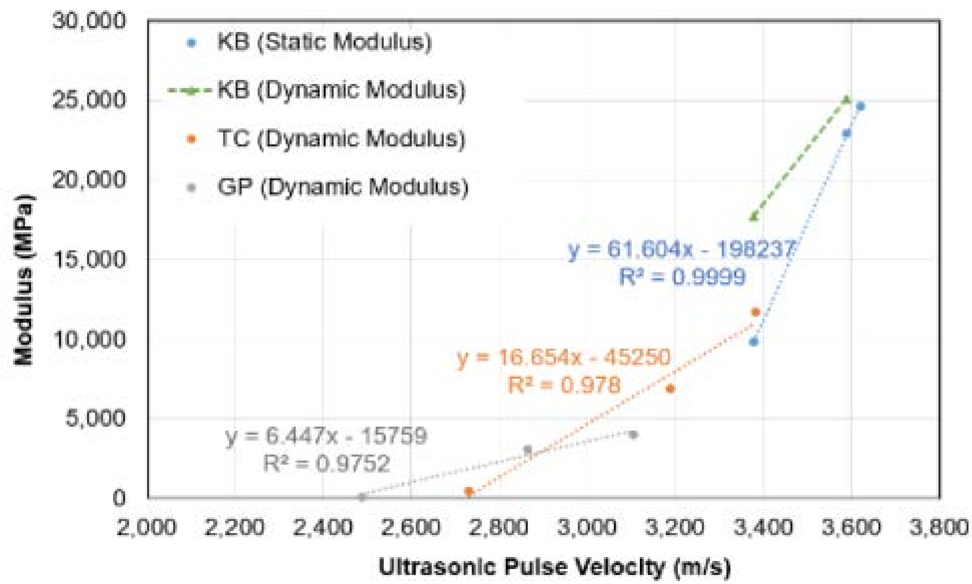


Dynamic Modulus Testing Summary

- RM-2 at lower temperatures: behavior similar to hot mix asphalt
- All materials become stiffer at lower temperatures, but modulus values still lower than PCC
- RM-4 and RM-5 very sensitive to temperature and loading rate
  - Rutting concerns at very high temperatures
  - Higher flexibility → better ability to withstand thermal stresses at lower temperatures

Ultrasonic Pulse Velocity vs. Temperature and Modulus





- Good correlations between UPV and testing temperature, modulus

Concluding Remarks

Summary (1/2)

- Non-cementitious repair materials typically used to repair heavily distressed areas in Wisconsin: spalled joints, transverse cracks, corner breaks, MRD
- Repair boundaries not demarcated using saw-cuts for vast majority of repairs
- Coring materials was challenge since binder melts and gums up coring drill
  - Diamond grinding concerns

Summary (2/2)

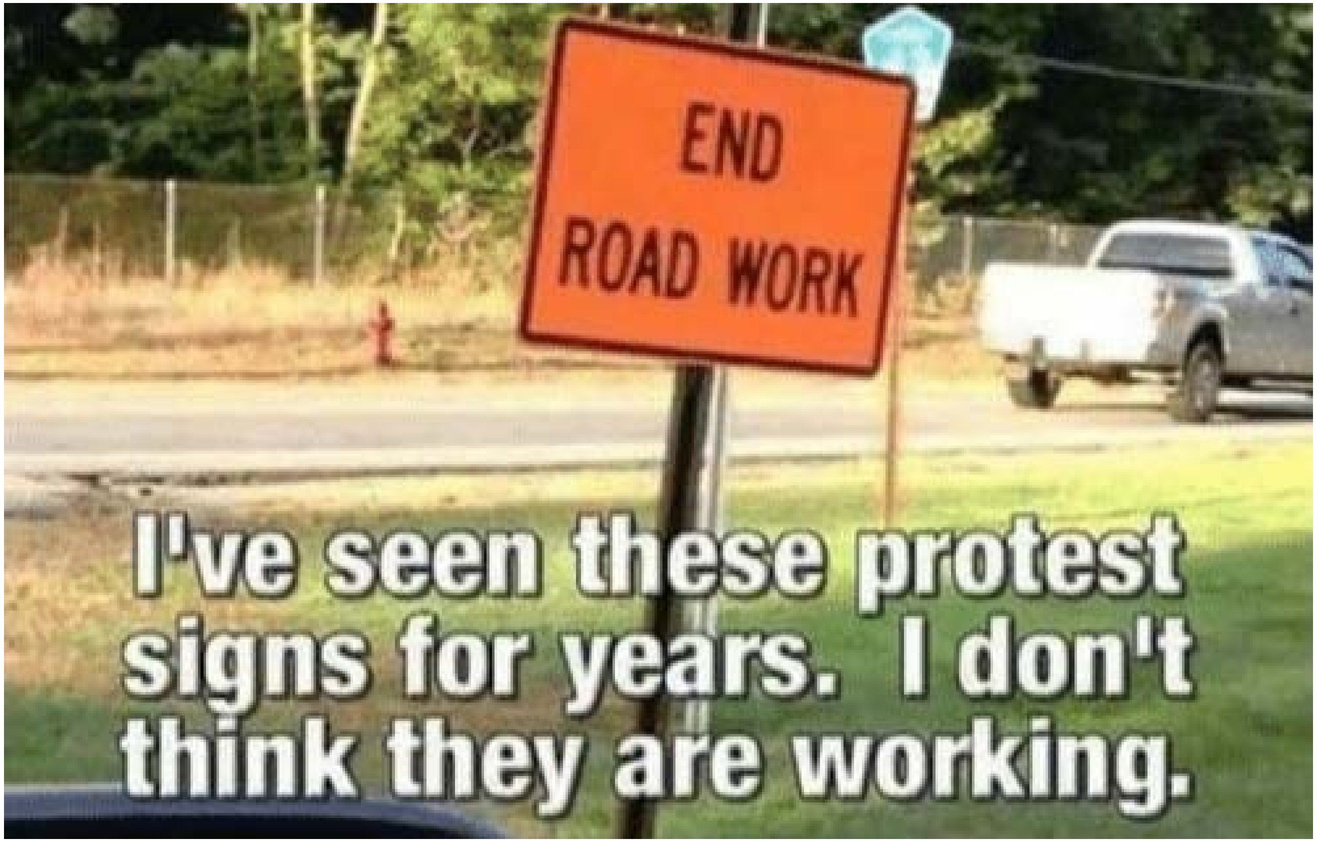
- Potential reasons for abrupt failure of some RM-1 PDRs:
  - Failure to remove all unsound concrete
  - Continued deterioration of substrate
  - Inconsistency in site-produced mixes
- Materials become stiffer at colder temperatures
  - Modulus variations not expected to adversely impact bond between repair material and sound substrate concrete
  - Bond failures are very likely for repairs on unsound substrate

Recommendations (1/2)

- Minimize size of repairs (≤ 4 ft^2), particularly in severely distressed areas
- Remove all unsound concrete
- Surface must be clean and dry, use bonding agent specified by manufacturer
- Strictly adhere to mixing and placement temperature requirements
- Surface of repaired area may be covered with surfacing aggregate per manufacturer guidelines
- Take extra care for hot-applied materials: heat, fumes

Recommendations (2/2)

- Diamond grinding of flexible materials
  - Reducing loading and time of grinding operations to the extent possible
  - Avoid grinding at high ambient temperatures
  - Keep grinding head as cool as possible
- For long-term repairs consider petrographic evaluation of existing concrete to check for materials/durability issues



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