Composite Pavement Technology

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Transportation Learning Network and the NDLTAP

STRATEGIC HIGHWAY RESEARCH PROGRAM

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

Presentation Outline

- Background & Introduction
- MnROAD Test Section Construction
- Instrumentation, Material Properties, and Performance
- Performance Predictions Using MEPDG
- Cost Estimating Scenario (Contractor)
- TICP Pooled Fund Study

Acknowledgements

- Shreenath Rao, Applied Research Associates
- Mark Watson, Mn/DOT
- Tony Johnson, C.S. McCrossan
- Derek Tompkins, University of Minnesota
- Mike Darter, Applied Research Associates
- Luke Johanneck, University of Minnesota

What is a Composite Pavement?

- AC/PCC or PCC/PCC pavement constructed as an integrated system
- Provides strong, durable, safe, smooth, and quiet surface
- Requires minimal maintenance

Strategic Highway Research Program

- Established by Congress in 2006
- Short term program of focused research
  - Safety
  - Renewal
  - Reliability
  - Capacity

R21 Composite Pavement Systems

Prime Contractor	Applied Research Associates, Inc.
Sub Contractors	U. Minnesota, U. California, U. Pittsburgh, Mn/DOT (CS McCrossan, Agg Industries, WSB & Associates)
Key Staff	Darter, Rao, Khazanovich, Von Quintus, Harvey, Signore, Worel, Clyne, Watson, Palek, Vandenbossche, Tompkins
Duration	48 Months
Start Date	September 2007

This project focuses on two applications of intentionally designed composite pavement systems:

1. Asphalt over concrete (JPC, CRC, RCC)
2. Concrete surface over concrete (wet on wet)

R21 Objectives

- Determine the behavior and identify critical material and performance parameters
- Develop and validate mechanistic-empirical performance models and design procedures consistent with the Mechanistic-Empirical Pavement Design Guide (MEPDG)
- Recommend specifications, construction techniques and quality management procedures and guidelines

European Survey

- Visited Germany, Austria, Netherlands
- Europe has built composite pavements for many years
- Why?
  - Surface Characteristics
  - Economical
  - Sustainable

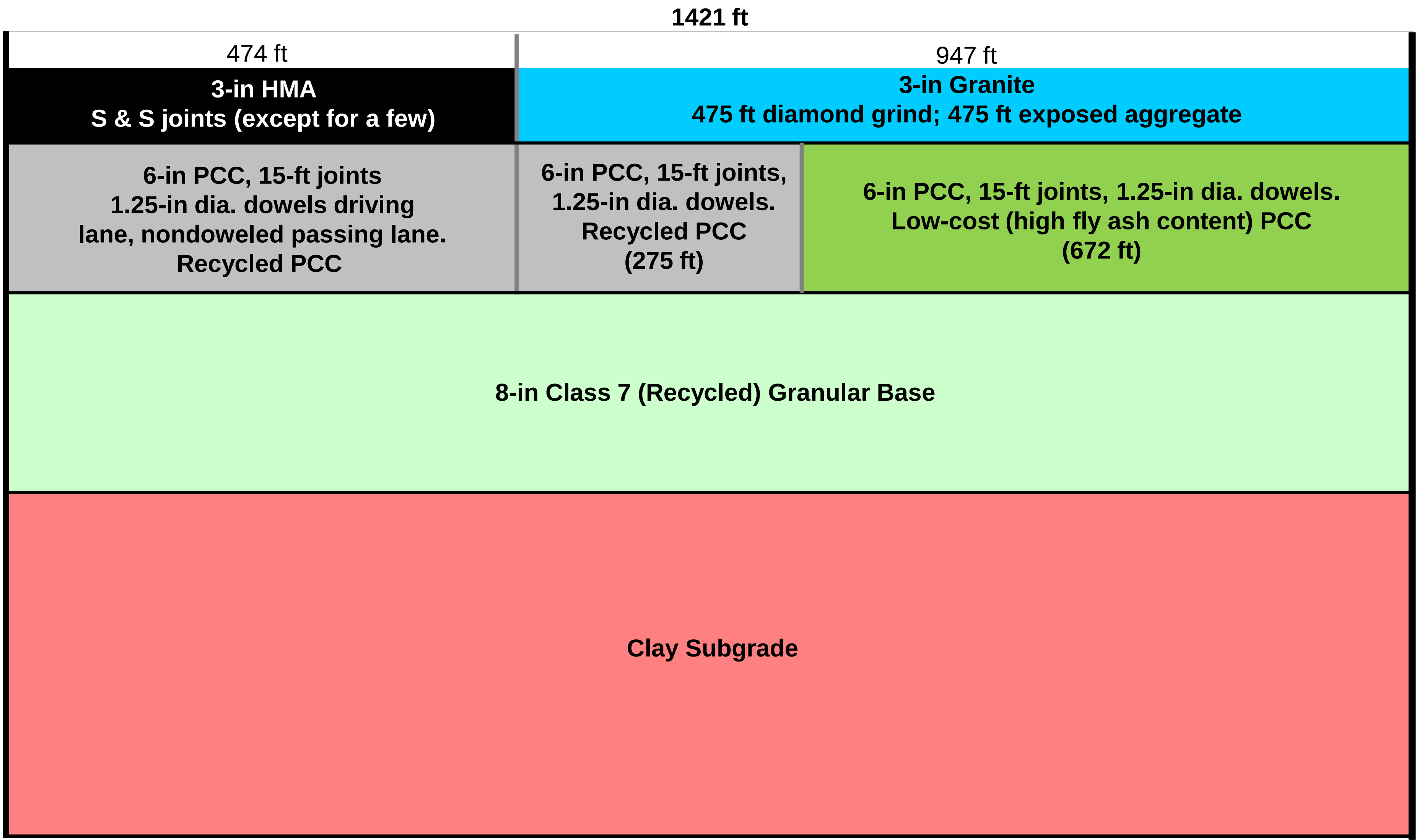
http://www.trb.org/Main/Blurbs/2008_Survey_of_European_Composite_Pavements_163693.aspx

Construction of Composite Test Sections at UCPRC for HVS Testing

- Several Test Sections
- HMA/PCC Only
- Instrumentation
- Rutting & Cracking Behavior

Test Section Construction at MnROAD

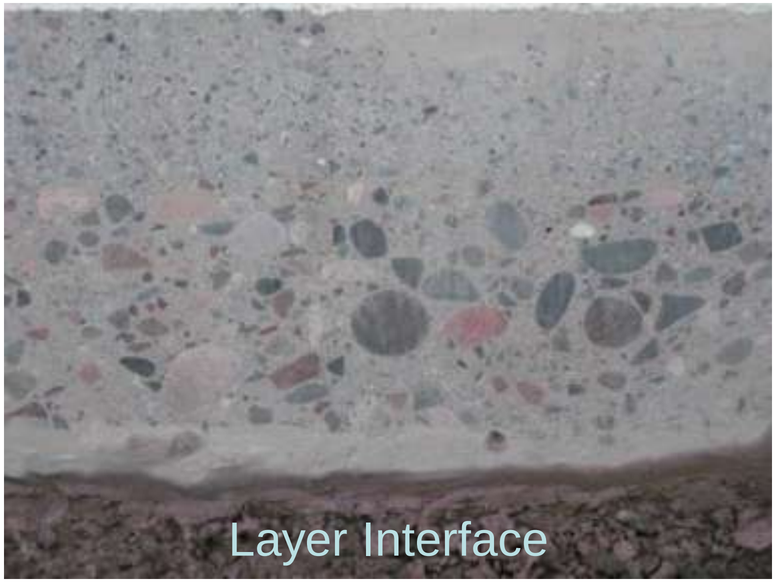
Experimental Plan for MnROAD



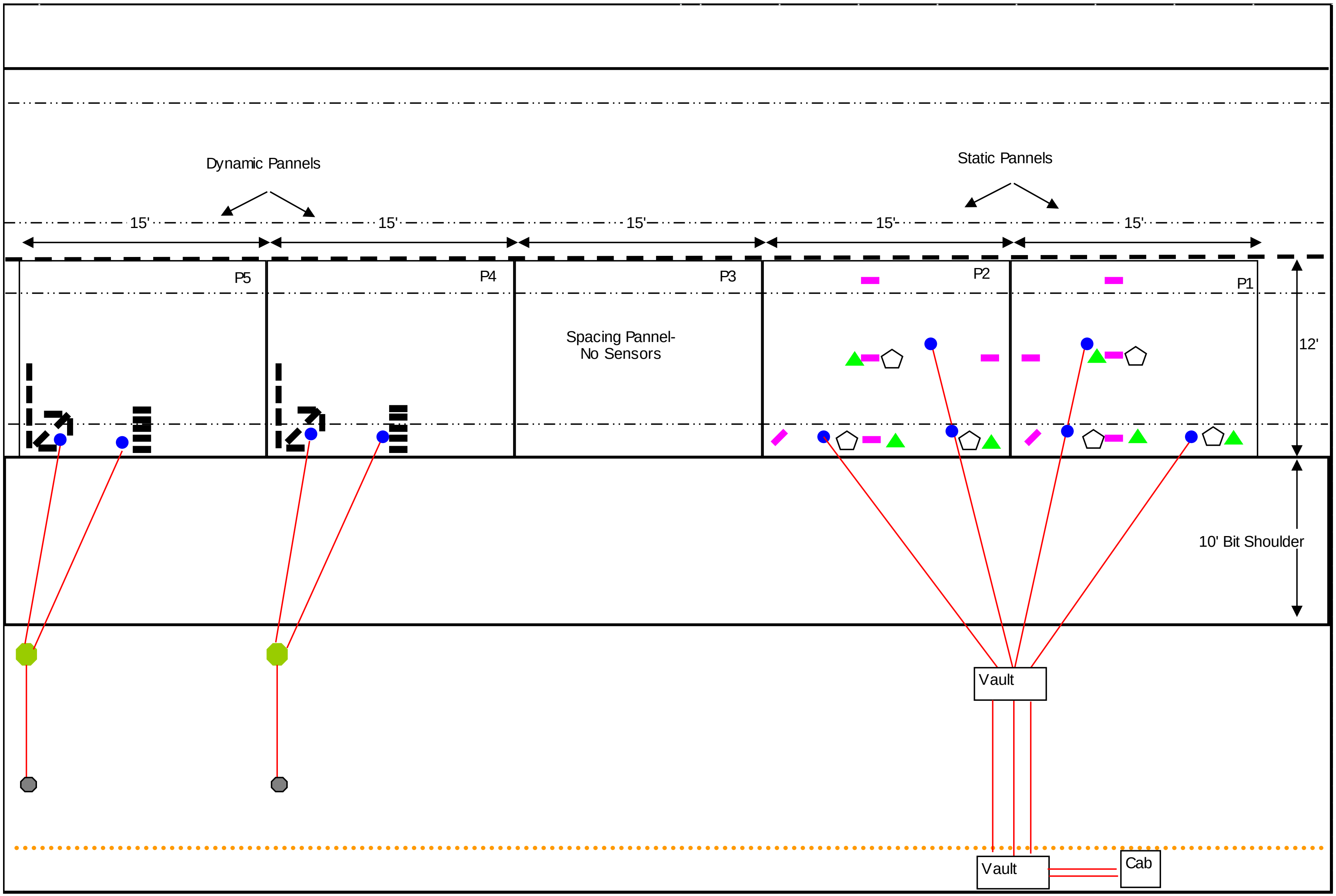
RCA Salvage Operations

RCA Percent Absorption 2.93%

Demonstration Slab



Instrumentation Plan



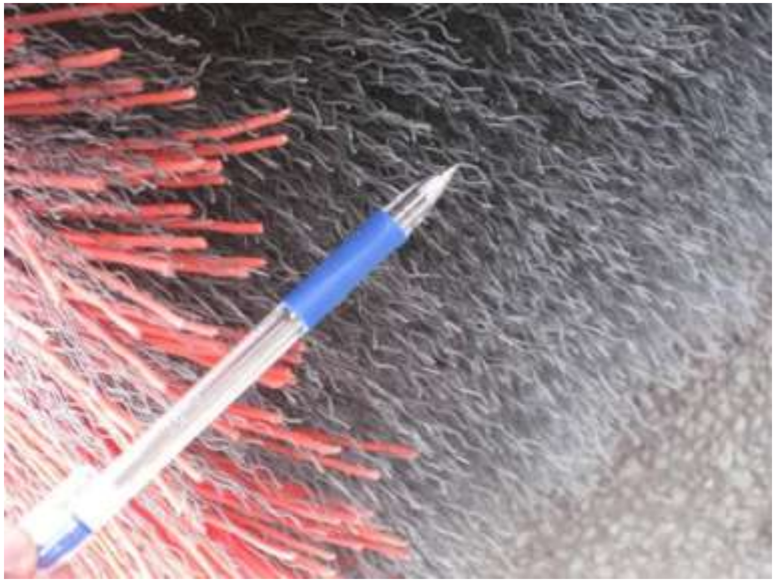
Temperature, Moisture, Static & Dynamic Strain Gauges

Vibrating Wires, Moisture/Humidity Sensors, CE Strain Gauges

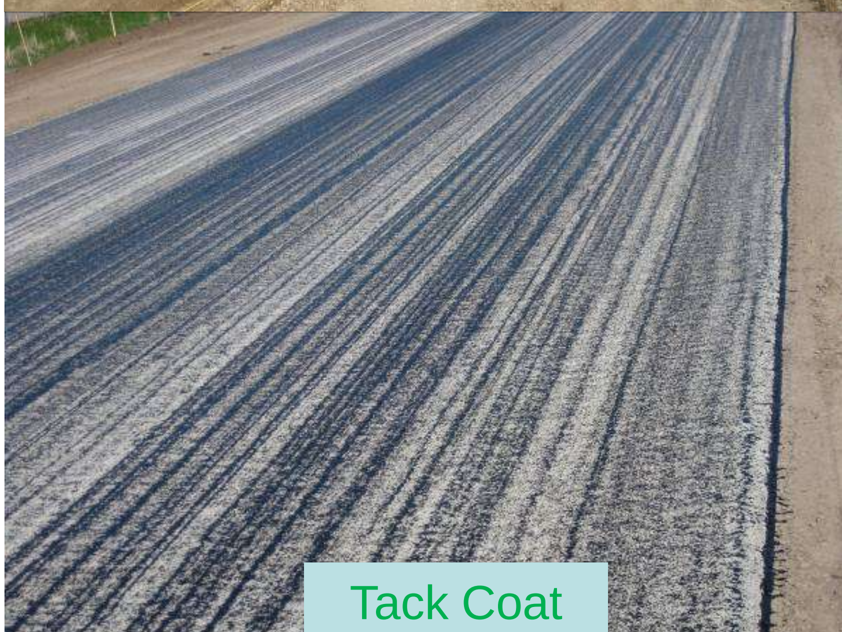
Wet-on-Wet PCC/PCC Paving

PCC Placement

Exposed Aggregate Concrete Texture



HMA/PCC Construction



Sawing and Sealing

– 100 ft: no seal

– 375 ft: saw & seal

  - 1 ft into shoulder
  - 1 ft away from edge of shoulder

MnROAD Test Sections

Challenges: Mix Consistency

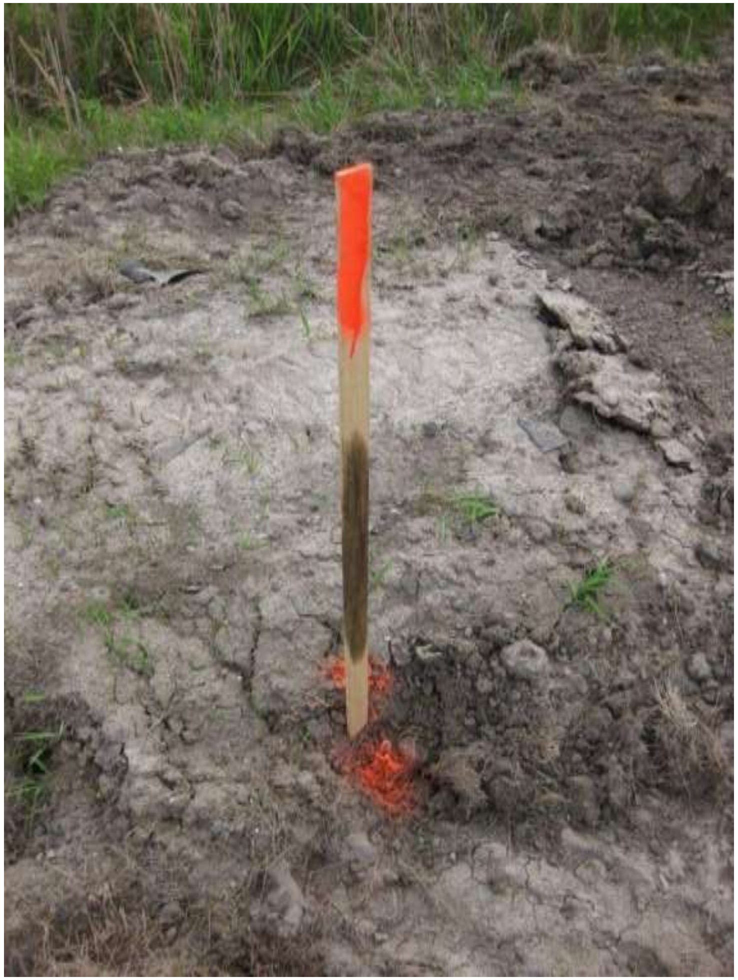
- Short Test Cells
- Stiff Mix
- Sensitive to Adjustments

Challenges: Mix Delivery

- Deliver PCC to top layer
- Keep mixes straight

Lessons Learned: Brushing Time

Challenges: Locating PCC Joints



What Worked Well: Demonstration Slab

- Dress Rehearsal
- Value as Research and Preparation
- Sensor Installation Techniques
- Construction Techniques
- Materials Sampling and Testing
- Video, Photographer

What Worked Well: Sensors

- Live as Concrete was Placed
- More than 500 Sensors!



What Worked Well: Diamond Grinding

Cell 71 = 96.8dBA (Quieter than HMA!)

Material Properties, Instrumentation, and Performance

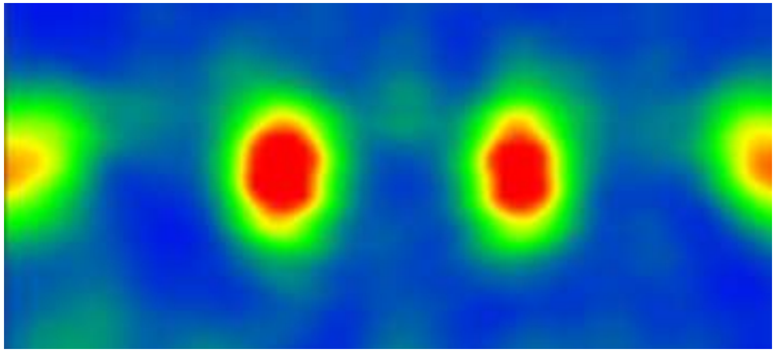
EAC-RCC Material Properties

PCC mix	Compressive strength (psi)			Modulus of rupture (psi)	
	7 day	14 day	28 day	7 day	28 day
EAC	5044	5315	5601	739	846
RCA	3599	4117	4509	578	658
Low-cost	3773	4364	5003	468	575

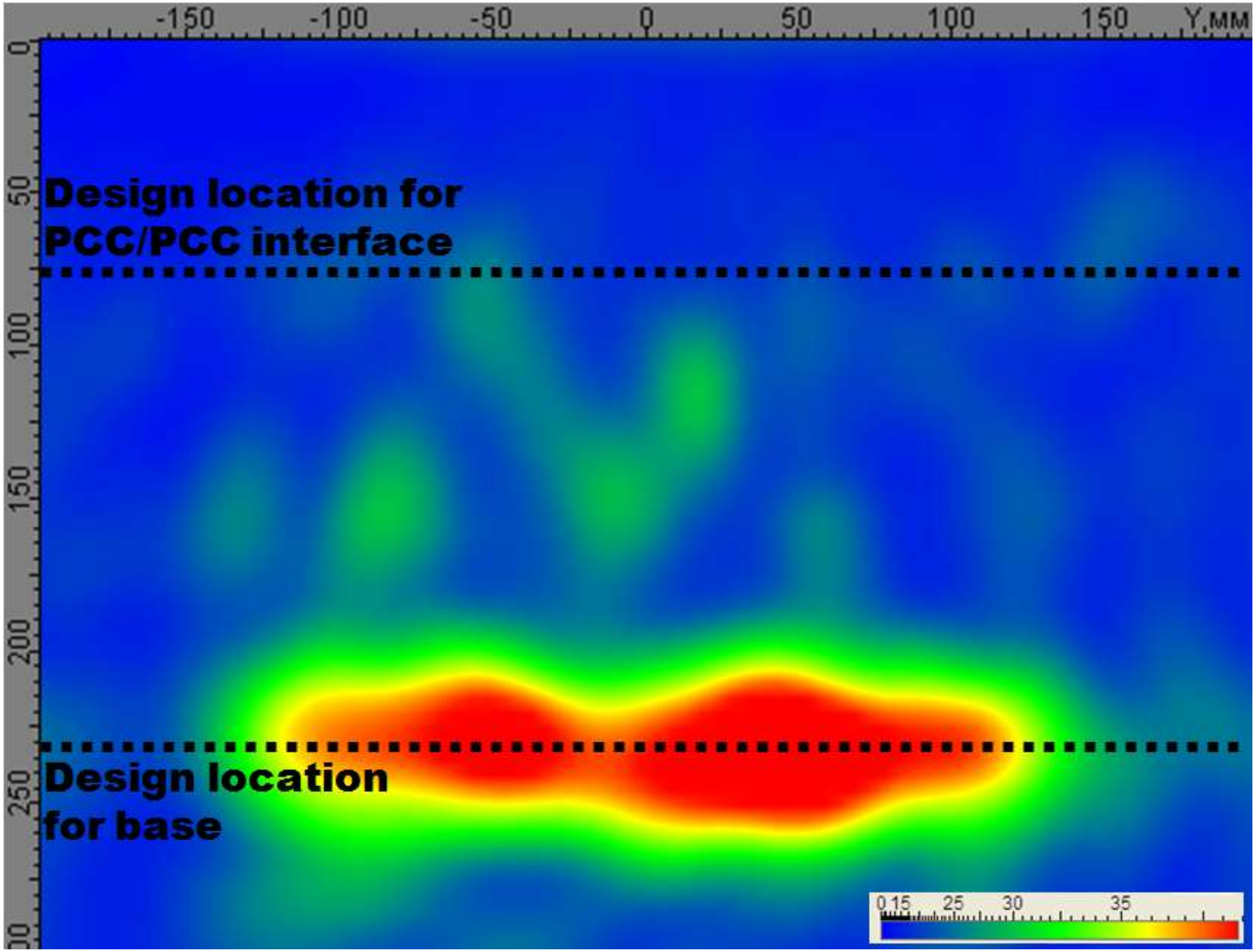
- Above are average values for tests conducted on 80+ specimens
- Overall compressive and flexural strengths for all 3 concretes are more than adequate
- Thanks to the FHWA Mobile Concrete Lab

NDT Evaluation, Ultrasound Imaging

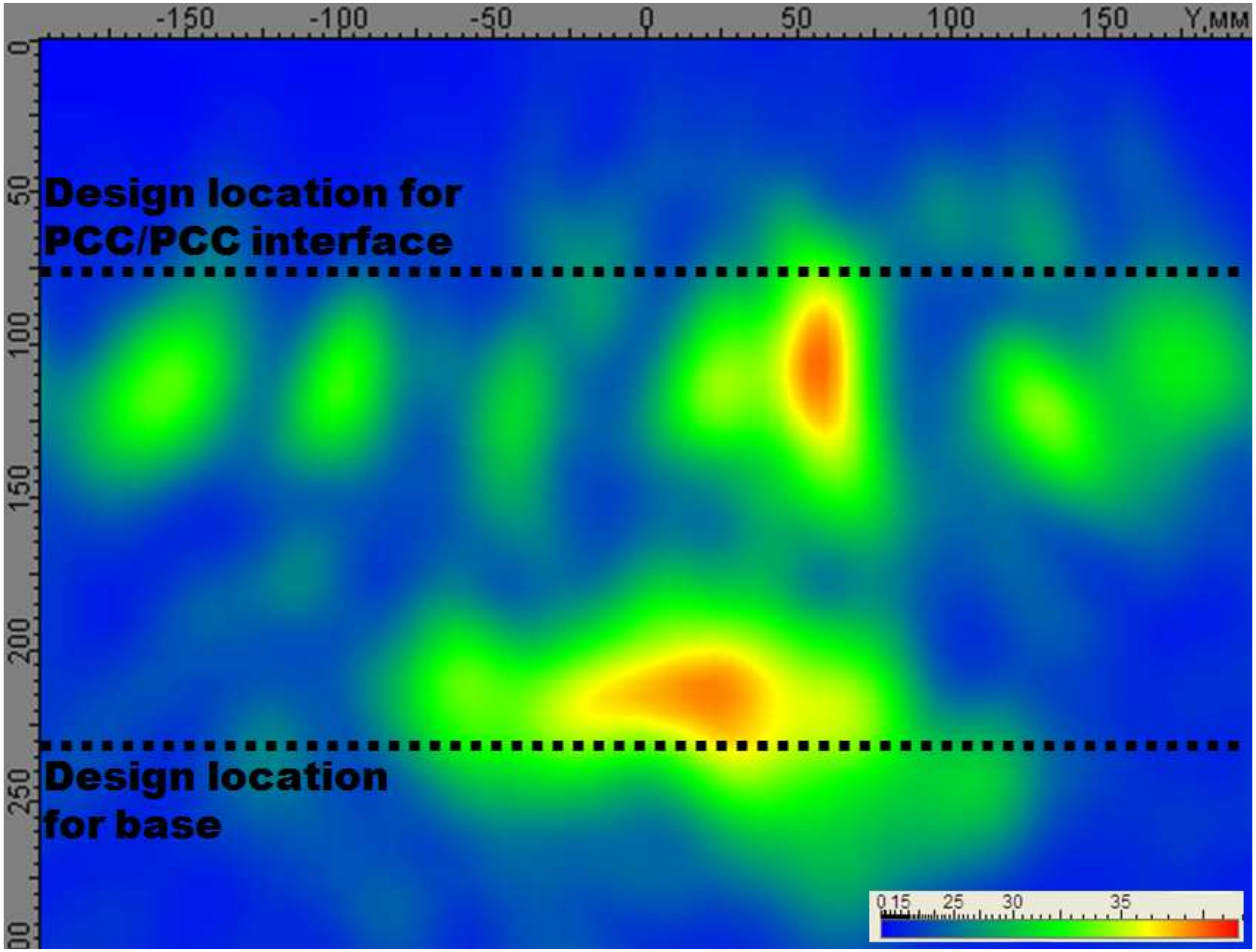
- Ultrasonic tomography used to evaluate PCC-PCC non-destructively
- Use technique to get quicker QA without sacrificing reliability
- Device used on R21 MnROAD demo slabs and mainline section



Tomogram of Sound PCC-PCC Interface



Tomogram of Poor PCC-PCC Interface



Instrumentation

- 6.5% failure rate overall
- Strains, joint opening, temperature, moisture data
- Will use this response data to validate MEPDG models

Performance Predictions Using the MEPDG

Performance Measures

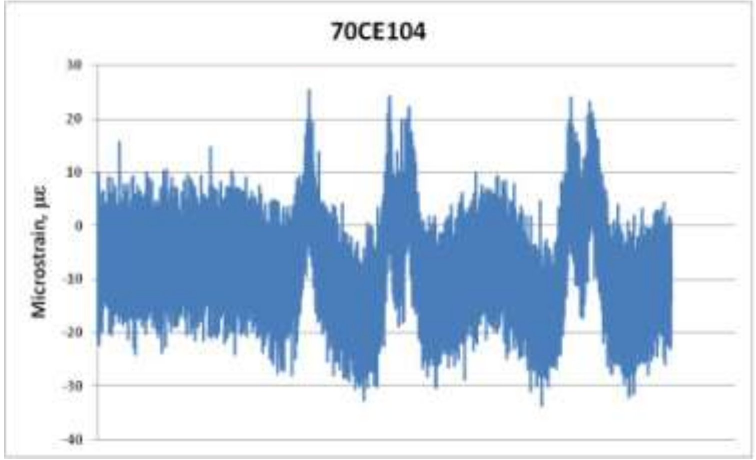
- HMA Surface on RCA: Initial & Over Time
  - Smoothness, IRI
  - Texture Depth
  - Noise
  - Friction
  - Fatigue Cracking (transverse, longitudinal)
  - Rutting
  - Joint Reflection Cracking (HMA)
    - No treatment
    - Saw & Sealed joints cut in HMA

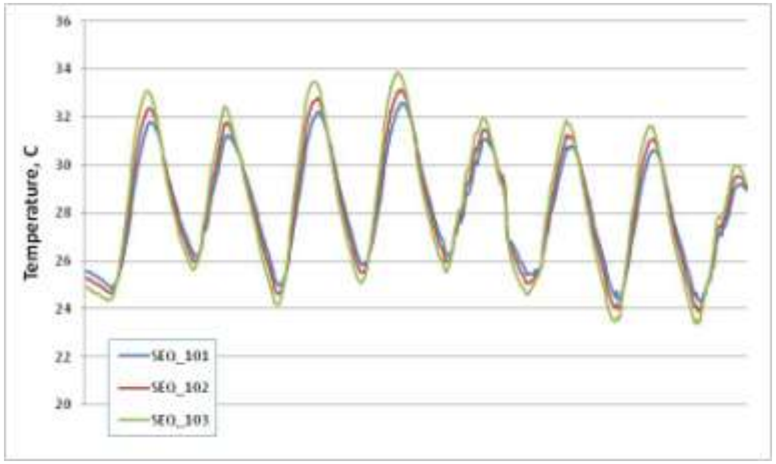
Performance Measures

- EAC Surface of RCA & Low Cost Concrete: Initial & Over Time
  - Smoothness, IRI
  - Texture Depth
  - Noise
  - Friction
  - Fatigue Cracking (transverse, longitudinal)

Performance Measures

- Instrumentation results (not exactly performance measures, but affect they may performance)
  - Temperature gradations
  - Moisture gradations
  - Dynamic strains (from moving wheel loads)
  - Vibrating wire strains (due to temperature & moisture)





Initial Results: Noise

Surface	Sound Intensity Level
HMA	100.5 dBA
Exposed Aggregate Concrete	101.6 dBA
Conventional Diamond Grind of EAC	100.2 dBA
Next Generation Concrete Surface (Special Grinding) of EAC	96.9 dBA

Initial Results: Texture

Surface	Texture Depth, in
HMA	0.334
Exposed Aggregate Concrete	0.784
Conventional Diamond Grind of EAC	To be measured
Next Generation Diamond Grind of EAC	1.127

Initial Results: Friction

Surface	Dynamic Friction Tester	Skid Trailer
HMA	0.66	53.2
Exposed Aggregate Concrete	0.62	46.5
Conventional Diamond Grind of EAC	0.72	49.2
Next Generation Diamond Grind of EAC	0.55	44.9

Prediction of Future Performance

- AASHTO Mechanistic-Empirical Pavement Design Guide
  - Overlay design procedure for HMA OL of JPCP & Bonded Concrete OL of JPCP
  - Use for new composite pavements?
    - Some limitations, but with proper inputs can be used.
  - Inputs for new composite pavements for 3 MnRoad sections
- Thickness designs were intended for practicality of two layer constructability. They are not intended for long life.

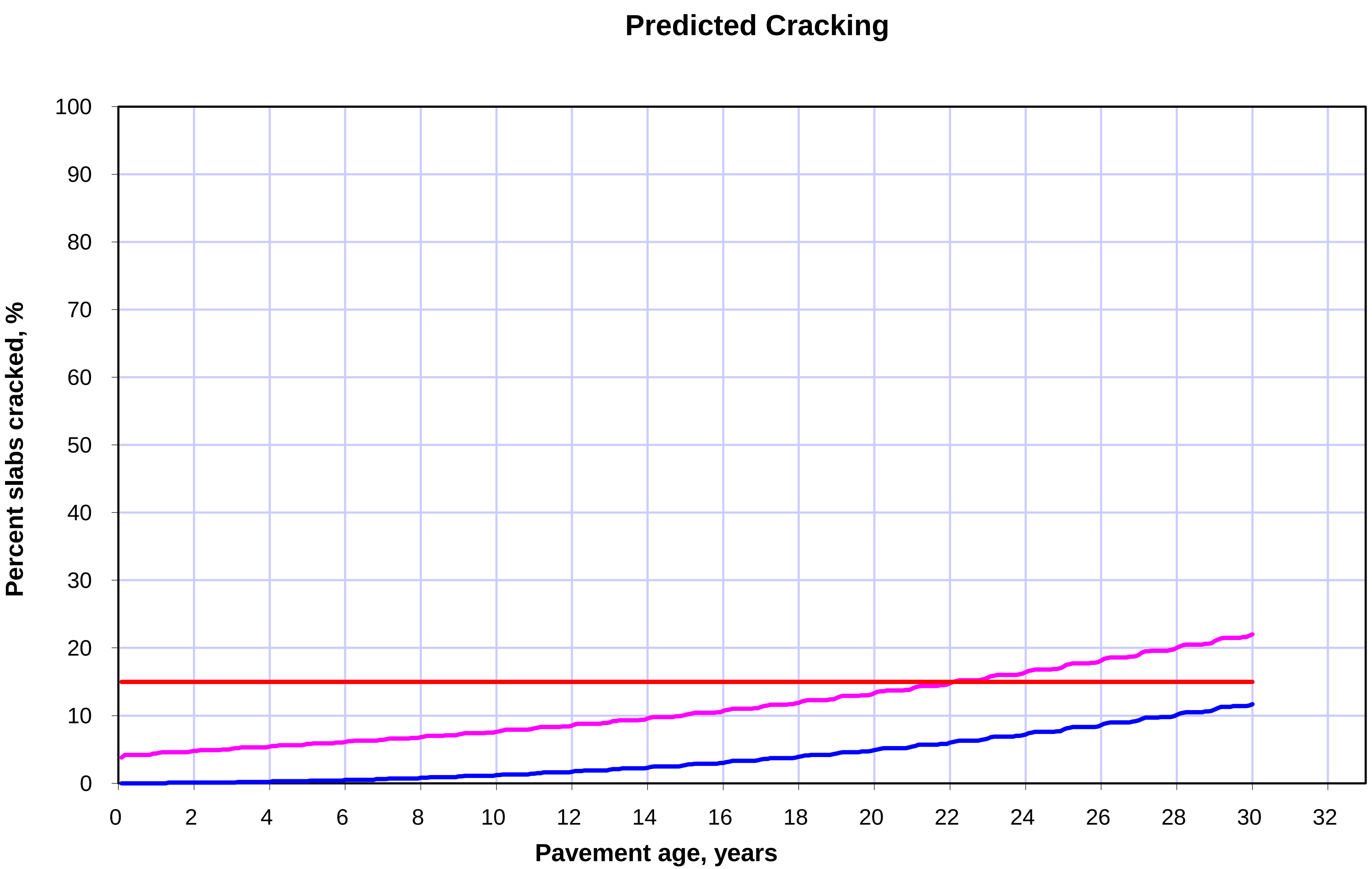
MEPDG Inputs

- Traffic: I-94 WIM data
- Climate: Nearest weather stations
- HMA: Test data from Mn/DOT
- Concrete: EAC, RCA, LCC test data from FHWA mobile trailer
- Subgrade: test data from Mn/DOT & backcalculation of modulus
- Design: joints, dowels, joint spacing, thickness of layers, shoulders

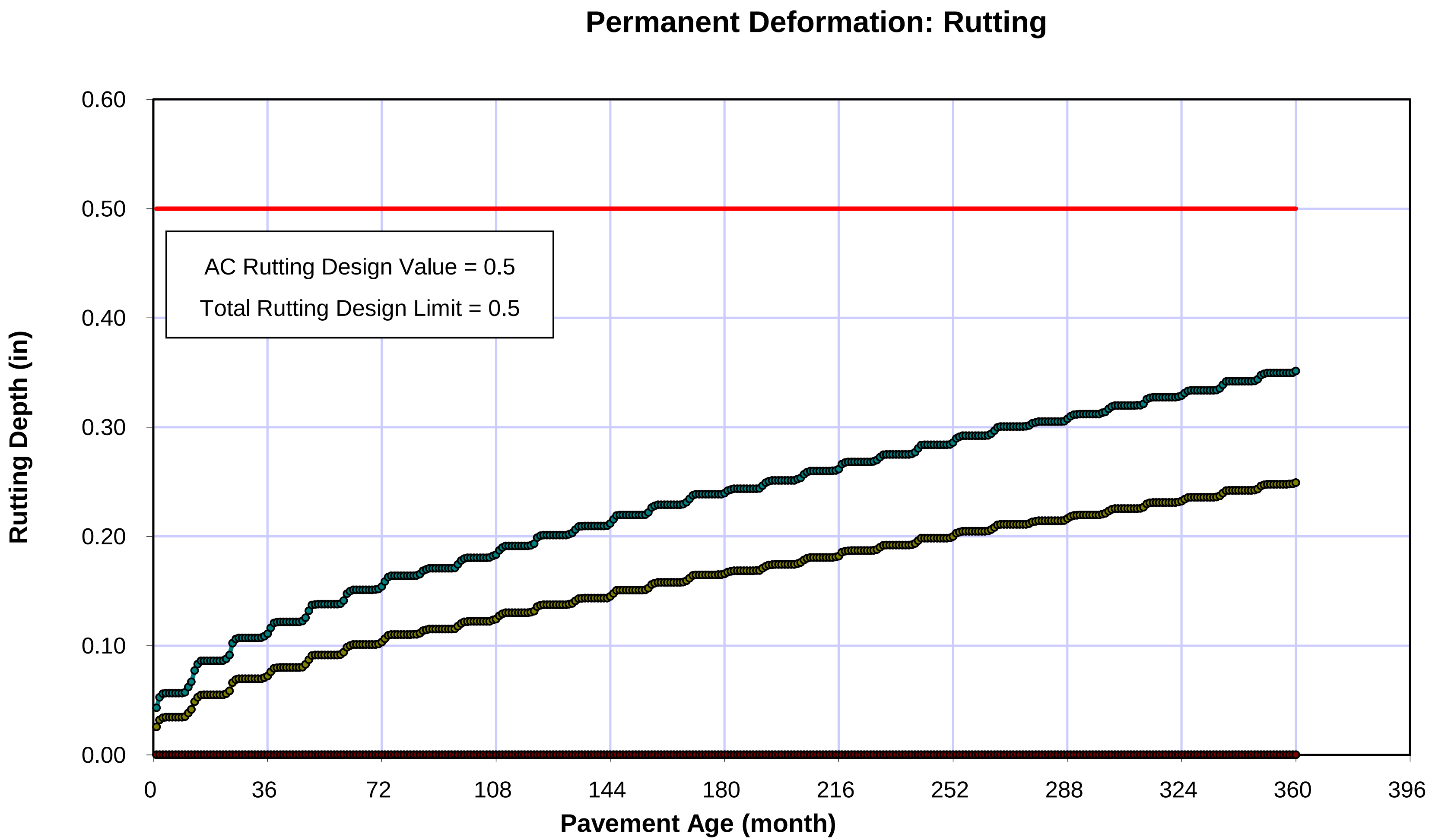
Layer Thickness
(from cores)

Section	HMA / RCA	EAC / RCA	EAC / LCC
Top Layer	3.0 in	3.5 in	2.9 in
Bottom Layer	6.3 in	5.6 in	6.7 in

Slab Cracking, 3-in HMA / 6-in RCA



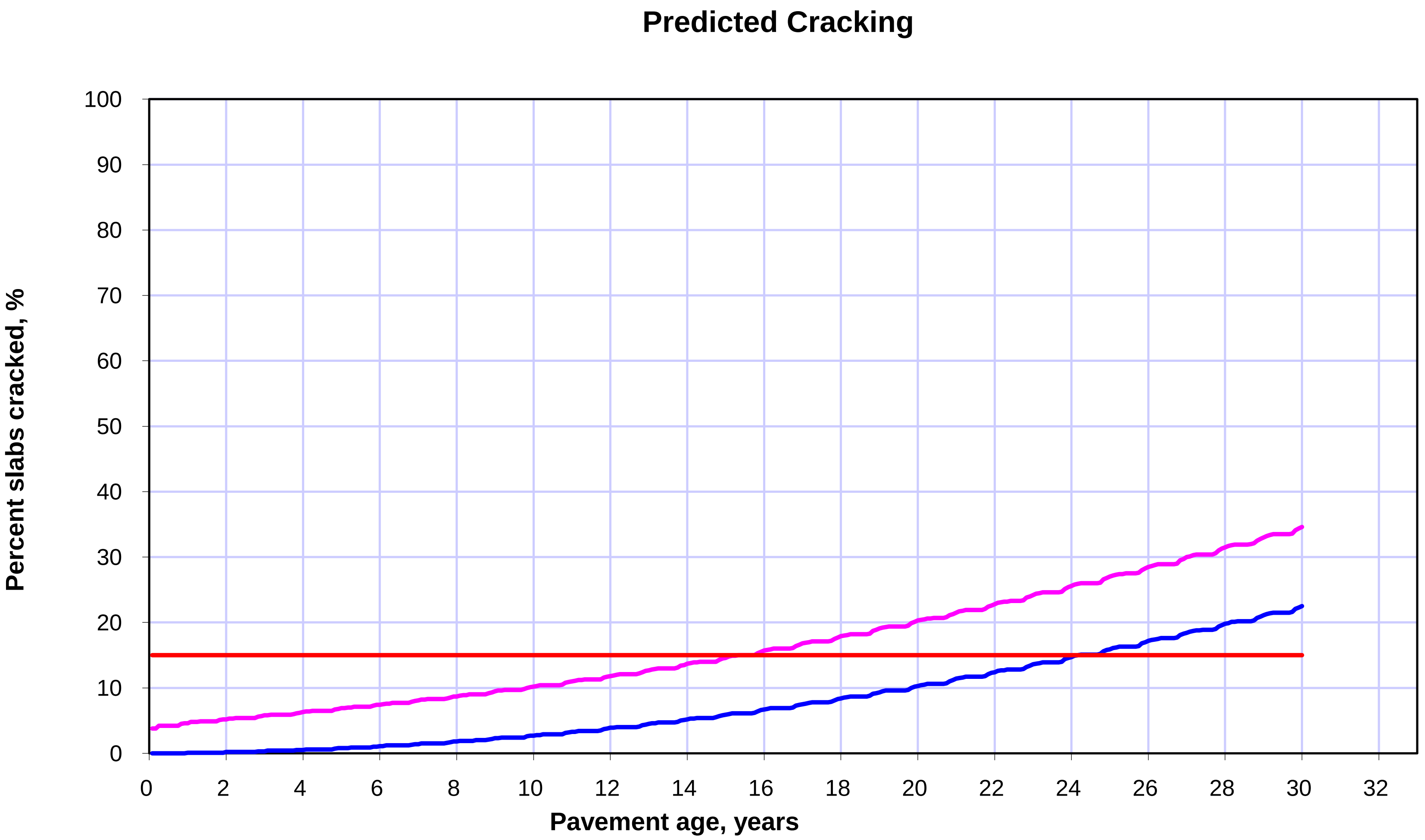
Rutting, 3-in HMA / 6-in RCA



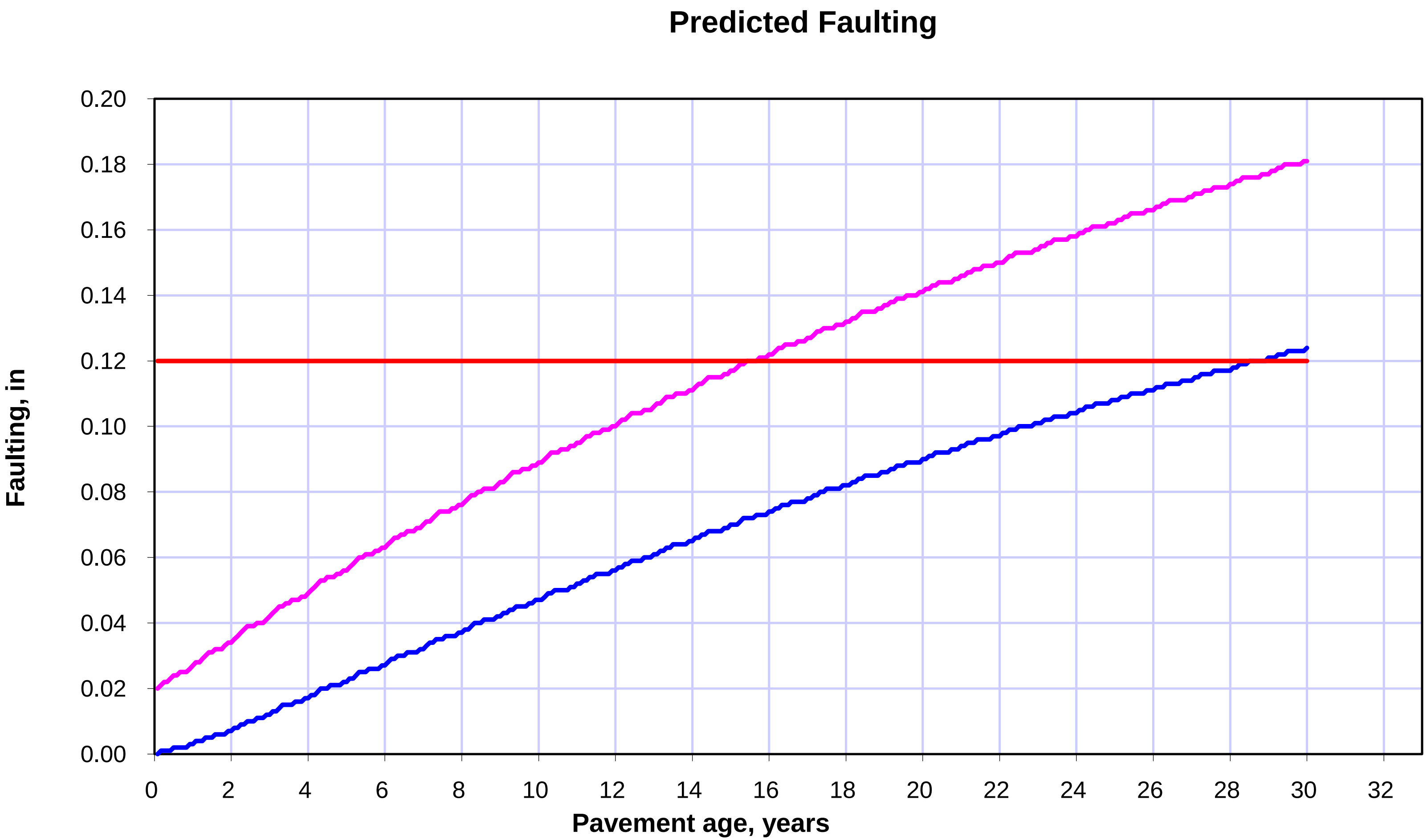
HMA / RCA Composite after 10 years and 6 million trucks

- Transverse Cracking < 5 % slabs
- Rutting < 0.10 in. mean
- IRI < 125 in/mile
- Two layer HMA over RCA composite pavement should be in good condition
  - Major question: will saw and seal of transverse joints hold up?

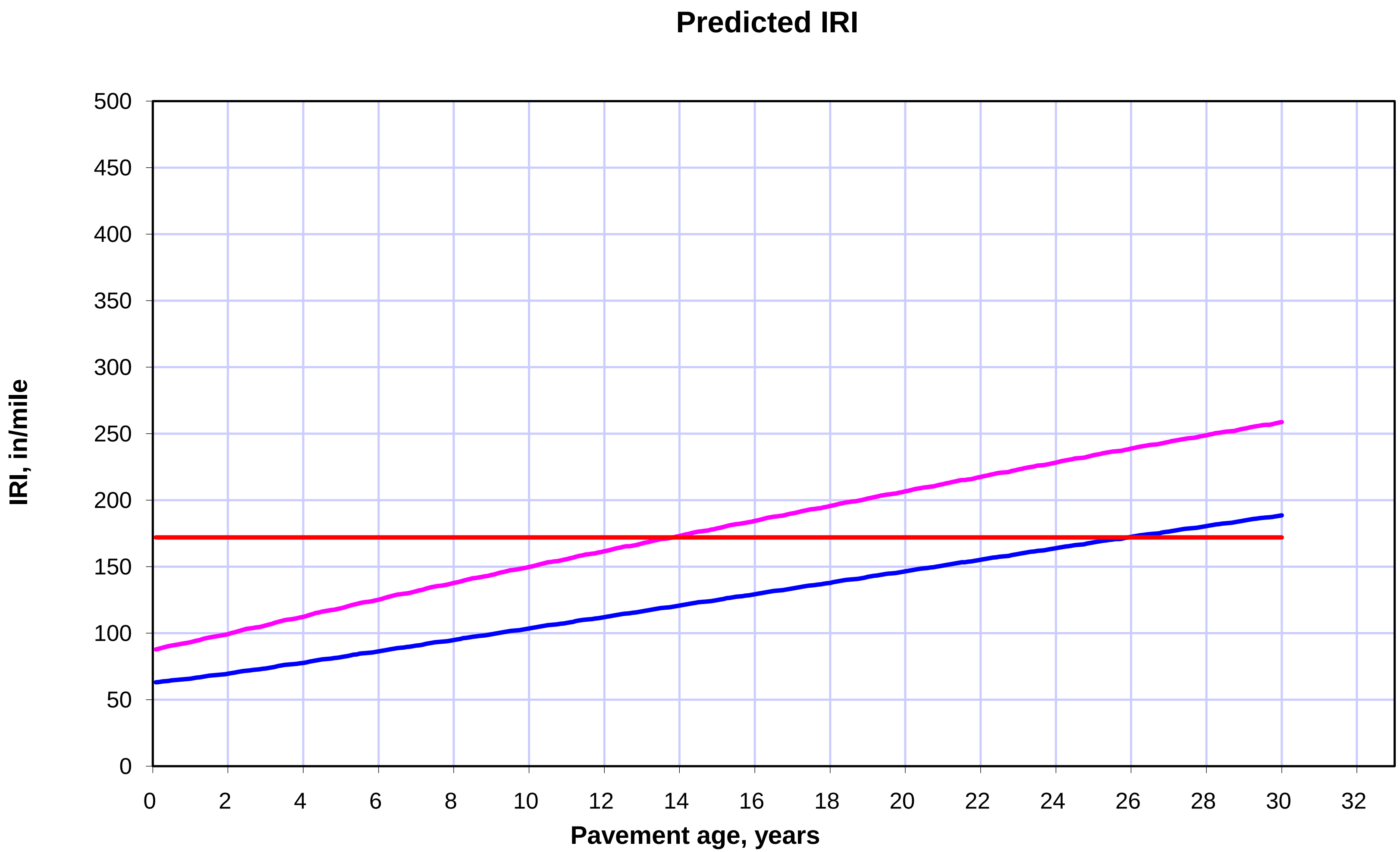
Slab Cracking, 3-in EAC / 6-in RCA



Joint Faulting, 3-in EAC / 6-in RCA



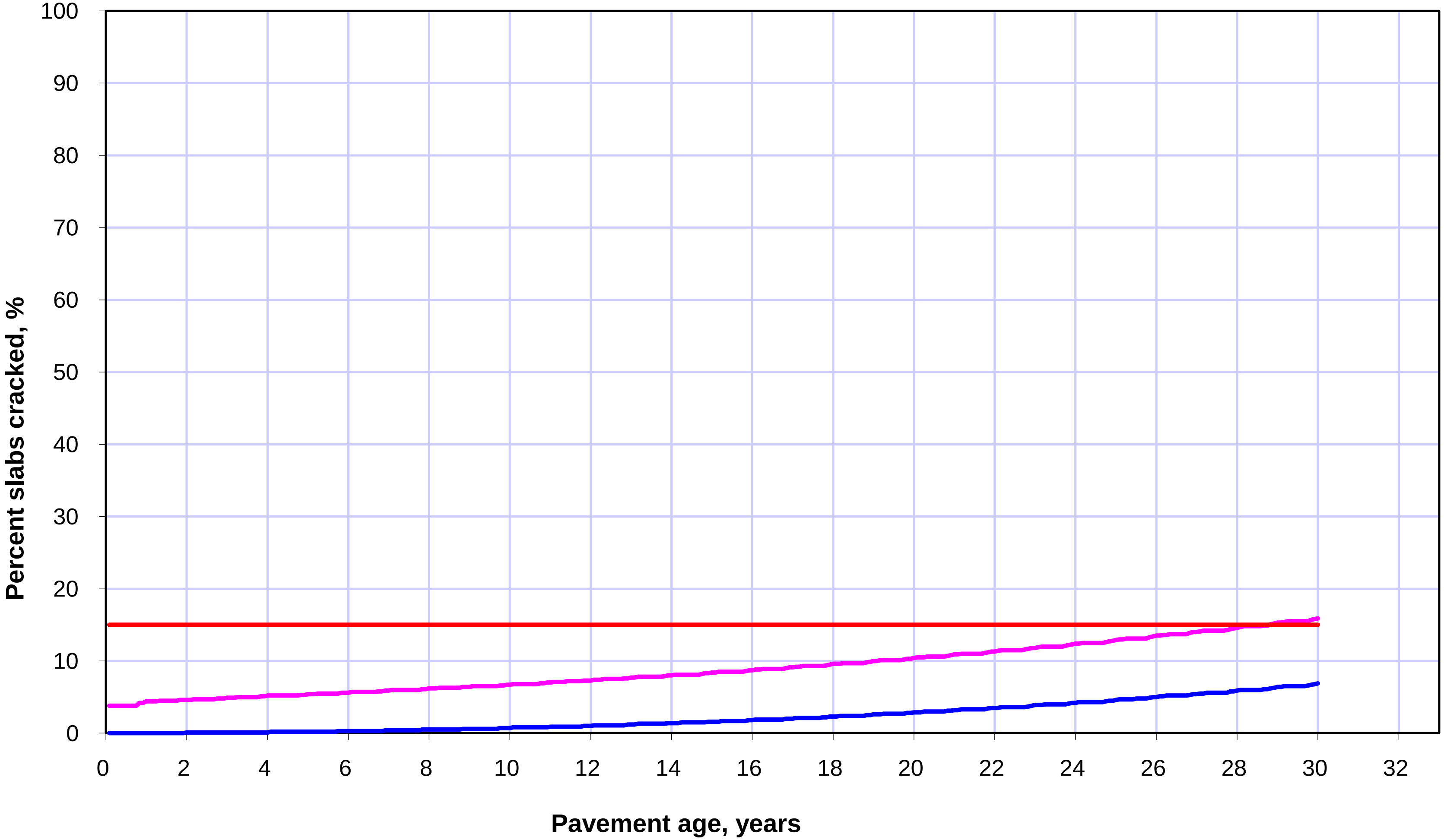
IRI, 3-in EAC / 6-in RCA



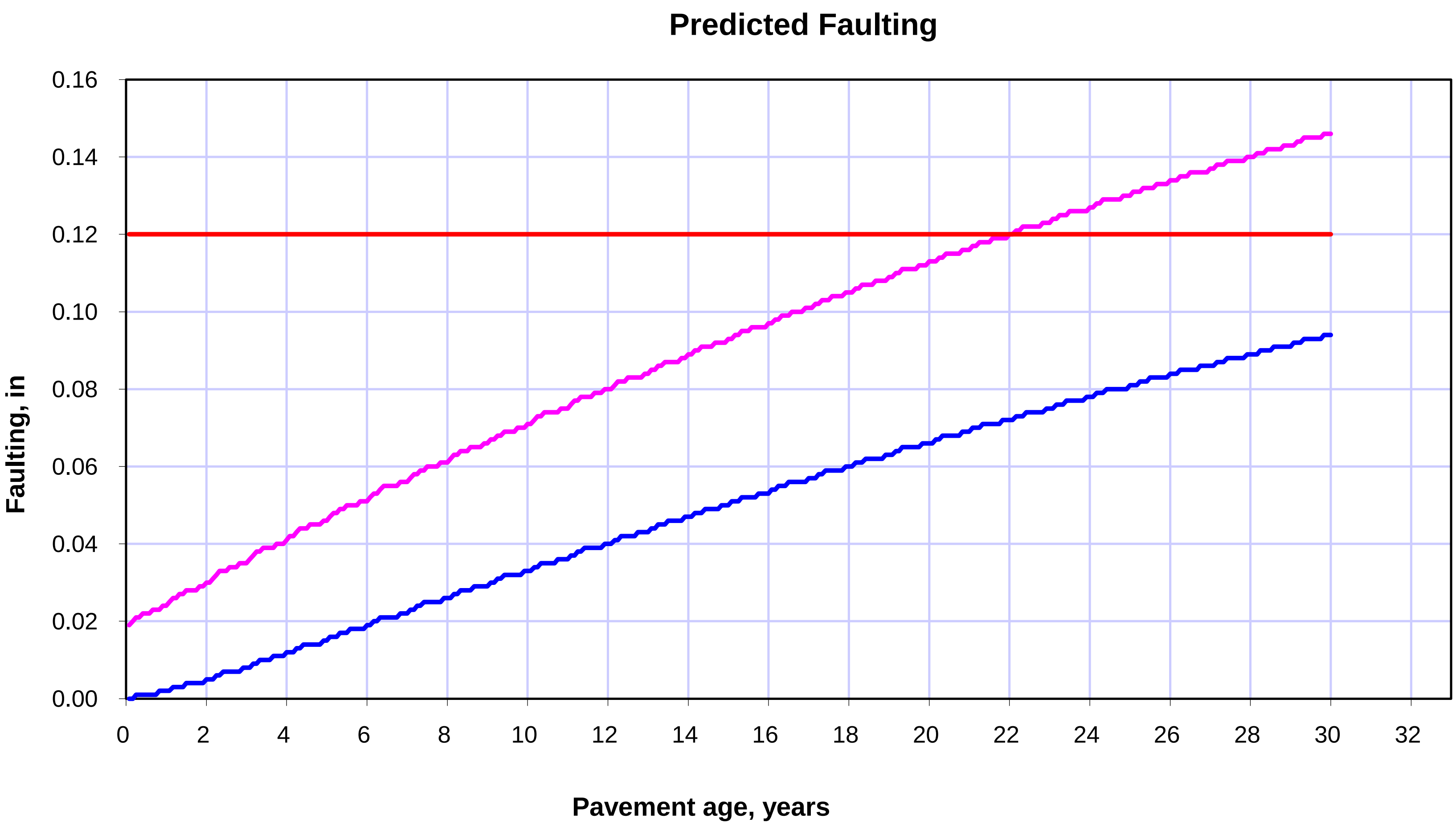
EAC / RCA Composite after 10 years and 6 million trucks

- Transverse Cracking < 5 % slabs
- Joint faulting < 0.10 in. mean
- IRI < 125 in/mile
- Two layer composite concrete pavement should be in good condition

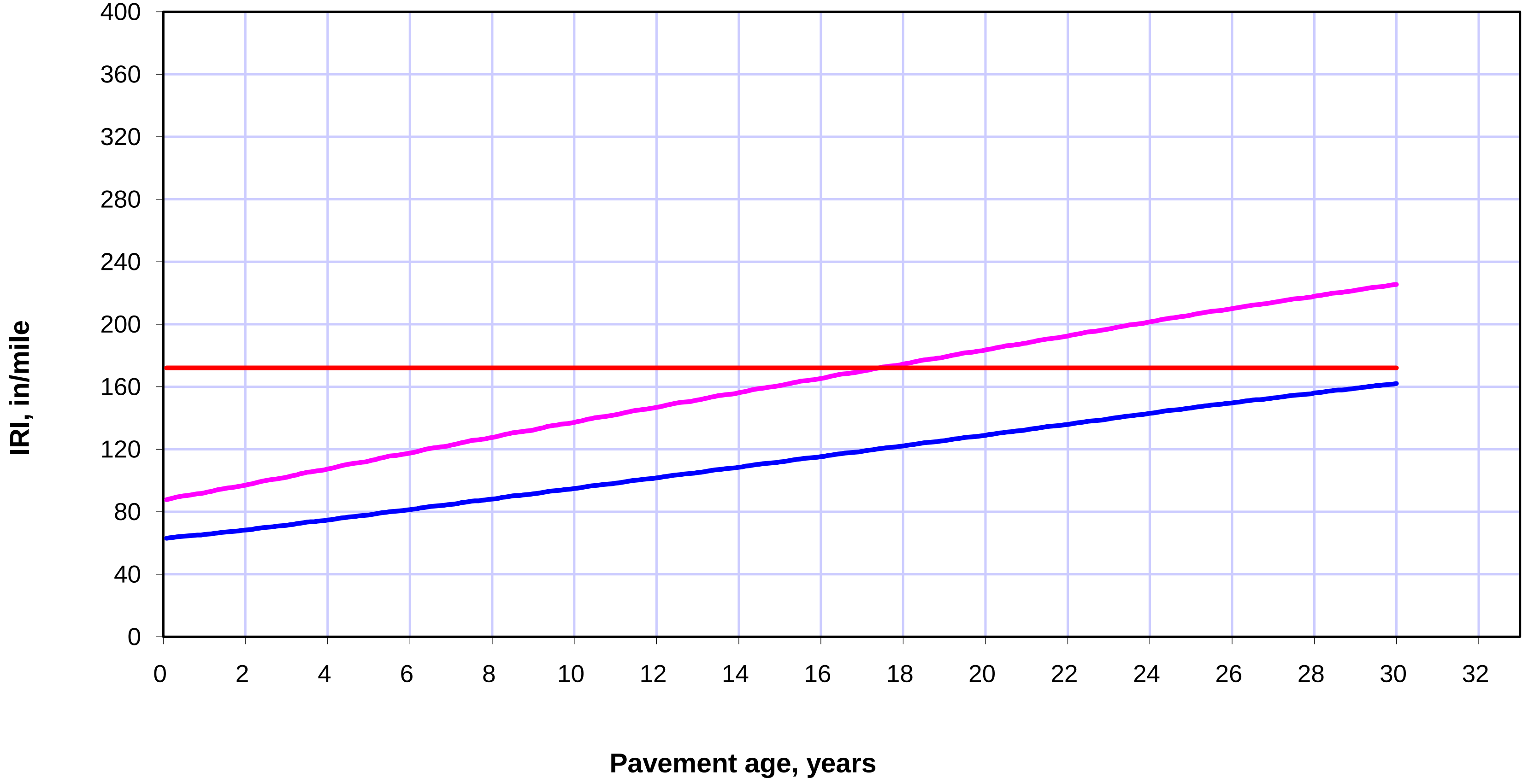
Cracking, EAC / LCC Predictions



Faulting, EAC / LCC Predictions

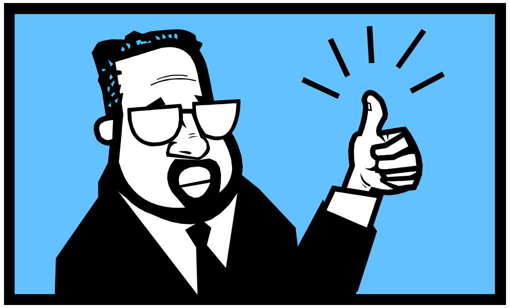


IRI, EAC / LCC Prediction



EAC / LCC Composite after 10 years and 6 million trucks

- Transverse Cracking < 5 % slabs
- Joint faulting < 0.10 in. mean
- IRI < 125 in/mile
- Two layer composite concrete pavement with "cheap" concrete lower layer should be in good condition



Summary

- Construction quality of each section appears to be good
- Material properties as expected
- Initial performance measures reasonable
- Future performance predictions show longer than expected life for HMA/RCA and EAC/RCA and less for EAC/LCC
- Actual monitoring over time will provide proof of concept

Case Study

By C.S. McCrossan

Paving Division

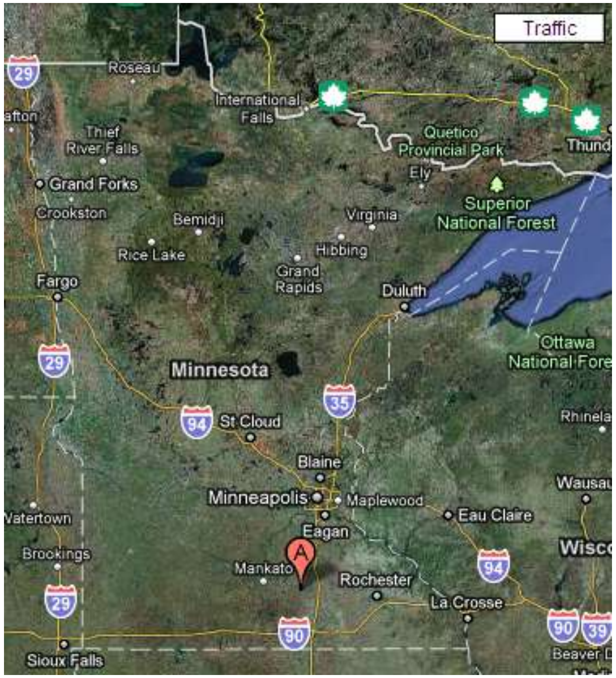
Conventional vs.
Composite Paving

Objective

- Find a project located in an area that has poor availability of Class A aggregates.
  - Take paving costs from project bid as Conventional Paving and compare to expected costs of Composite Paving.
- Under these circumstances is Composite Paving an economical alternative?

Case Study

- Project
  - U.S. Highway 14 Concrete Paving
- Location
  - Near Waseca, MN
- General Stats
  - 90,000 Cubic Yards of Concrete
    - 80,000 CY Mainline, 310,000 SY
    - 10,000 CY Crossroads and Ramps
  - 19.5 Miles paving
  - 22 total days paving scheduled
  - Closest Class A aggregate source was New Ulm Quartzite (2 hour round haul)



Comparison

- Conventional
  - 1 Boom Truck
  - 1 Paver
  - 1 Belt Placer
  - 1 Cure/Texture
  - 1 Skidsteer
  - 1 Pickup
  - 1 Service Truck
  - 1 Water Truck
  - 13 Crew Members
- Composite
  - 1 Boom Truck
  - 2 Pavers
  - 2 Belt Placers
  - 2 Cure/Texture
  - 1 Skidsteer
  - 1 Pickup
  - 1 Service Truck
  - 1 Water Truck
  - 1 Steel Bristle Broom
  - 18 Crew Members

Conventional Paving

Batch Plant

Two Batch Plants would be necessary to batch the different mix designs simultaneously

COMPOSITE PAVING

- 2 Pavers
- 2 Belt Placers
- 2 Cure/Texture Machines
- 18 Crew Members

COMPOSITE PAVING

The lower lift comprised of recycled concrete as the source of coarse aggregate.

The upper lift used the high quality, Class A aggregates.

Conventional vs. Composite

Pave, Tie, Green Saw	
Sq. Yds.	310,000
$ per Sq. Yd.	$2.98
Total Cost	$923,800.00
Structural Concrete	
Cubic Yards	80,000
$ per CY	$71.54
Total Cost	$5,723,200.00
Conventional Cost	$6,647,000.00

Pave, Tie, Green Saw	
Sq. Yds.	310,000
$ per Sq. Yd.	$3.70
Total Cost	$1,147,000.00
Structural Concrete	
Cubic Yards	80,000
$ per CY	$69.31
Total Cost	$5,544,800.00
Composite Cost	$6,691,800.00

0.7% Difference in Construction Costs

Aggregates

Conventional Aggregates	
Type	**Tons**
¾" Class A	34,270
1 ½" Class A	37,213
Total Tons	**71,483**
Class A	
Material $/Ton	$12.78
Trucking (2 Hour)	$7.46
Total $ Per Ton	**$20.24**

Composite Aggregates	
Type	**Tons**
¾" Class A	11,310
1 ½" Class A	12,280
Recycled Agg.	47,893
Total Tons	**71,483**
Recycled	
Material $/Ton	$7.00
Trucking (2 Hour)	$1.45
Total $ Per Ton	**$8.45**

Conclusion

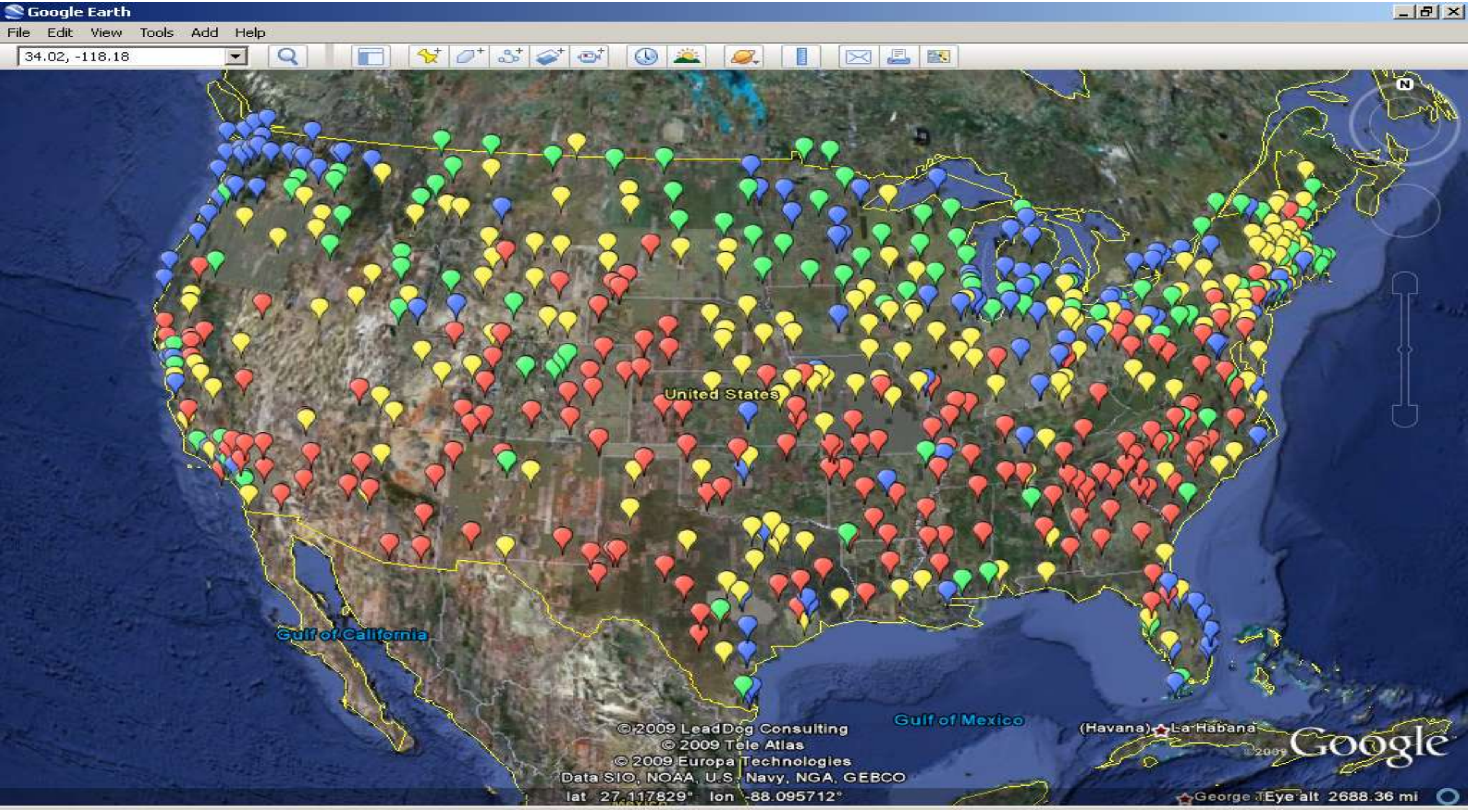
- Implementation of a Composite Paving process would be a viable and competitive alternative to Conventional Paving, if:
  - Class A aggregates aren’t readily available
    - Long haul times drive the price of the aggregate too high
  - Recycled Concrete could be produced on or near the site
    - Haul times would have to be cut to minimal levels
    - Would have to produce Recycle at about 50% the cost of Class A
  - You were capable of producing and paving at an equal rate to conventional paving

Thermally Insulated Concrete Pavements Pooled Fund Study

- MN, CA, WA, FHWA Sponsored Study
- U’s of Minnesota, California, Washington
- 36 Months
- $439,000

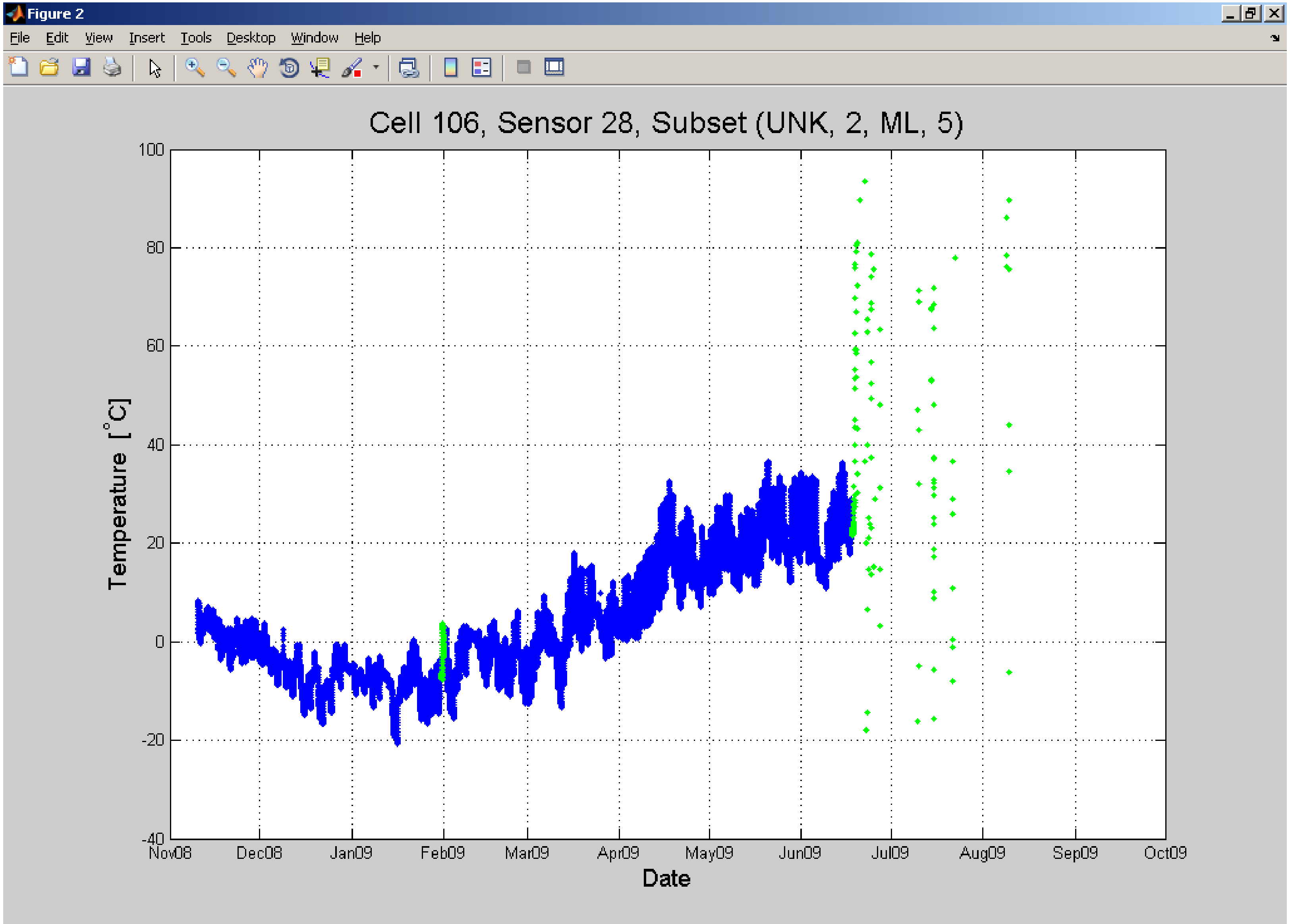
- Task 1 – Literature Review
- Task 2 – Life Cycle Analysis
- Task 3 – EICM Validation
- Task 4 – Evaluate Pavement Response Models
- Task 5 – Develop Design Guidelines
- Task 6 – Develop Construction Guidelines
- Task 7 – State of the Practice Synthesis
- Tasks 8 & 9 – Final Report

Issues with Weather Station Data

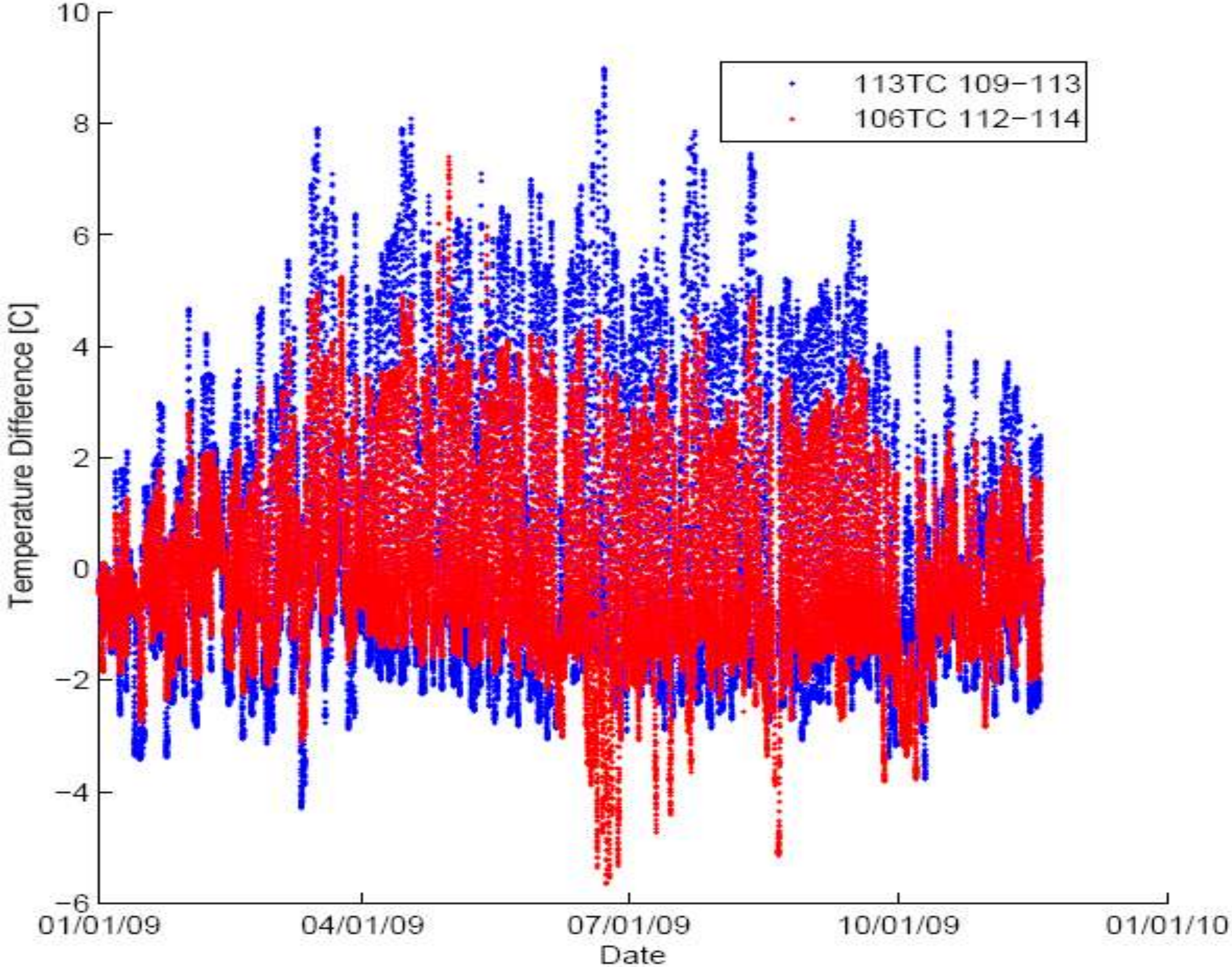


Blue < 16% Green 16-25% Yellow 26-40% Red > 40%

Thermocouple Flags



Thermal Gradients



Next Steps

- Continue Data Collection at MnROAD and other sites
  - Pavement performance monitoring
  - Surface characteristics
  - Instrumentation
- MEPDG and EICM Modeling and Calibration
- Write Design Procedures and Construction Guidelines
- Life Cycle Analysis (Costs, Performance)
- Training Materials to Aid in Implementation

Thank You!