Expected Performance of MnRoad Composite Pavements

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SHRP2
STRATEGIC HIGHWAY RESEARCH PROGRAM

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

Presentation

- Performance measures
- Initial performance results
- Prediction of future performance
  - HMA / RCA
  - EAC / RCA
  - EAC / LCC
- Summary

Performance Measures

- HMA surface on Recycled Aggregate Concrete (RCA): Initial & over Time
  - Smoothness, IRI
  - Texture depth
  - Noise
  - Friction
  - Rutting
  - Fatigue Cracking (transverse, longitudinal)
  - Joint Reflection Cracking (HMA)
    - No treatment
    - Saw & Sealed joints cut in HMA

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 (temperature & moisture)

Performance Measures

- EAC surface of Recycled Concrete Aggregate (RCA) & Low Cost Concrete (LCC): Initial & over Time
  - Smoothness, IRI
  - Texture depth
  - Noise
  - Friction
  - Fatigue Cracking (transverse, longitudinal)

Initial Results: Noise

Surface	Sound Intensity Level
HMA	???
Exposed Aggregate Concrete	101.7 dBA
Conventional Diamond Grind of EAC	100.4 dBA
Next Generation Concrete Surface (Special grinding) of EAC	98.8 dBA

Initial Smoothness: IRI

Surface	IRI, in/mile
HMA	???
Exposed Aggregate Concrete	???
Conv. Diamond Grind of EAC	???
Improved Diamond Grind of EAC	???

Results to be obtained from MnRoad soon.

Initial Texture, inches
ASTM E 965

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

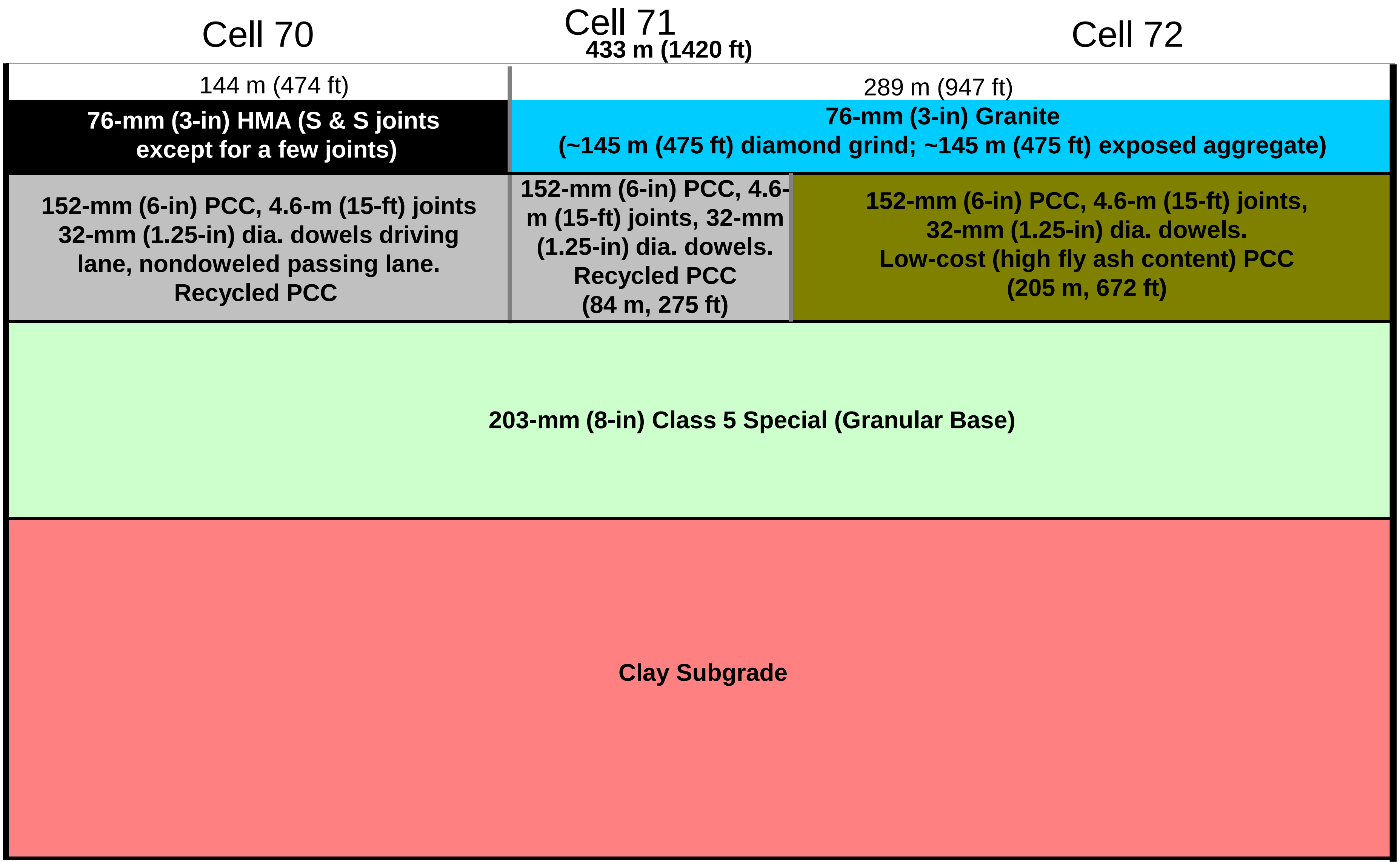
Initial Friction

Surface	Friction
HMA	0.656
Exposed Aggregate Concrete	0.615
Conv. Diamond Grind of EAC	0.720
Improved Diamond Grind of EAC	0.547

Prediction 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.

Experimental Plan for Construction at MnROAD



MEPDG Inputs

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

MEPDG Inputs

- Traffic: I-94 WIM data MP 200 WBL
  - AADT: 29,000
  - Percent Class 4 to 13 trucks: 12
  - Percent trucks outer lane: 78%
  - Axle load distribution: Used MEPDG defaults, need to obtain MnDOT WIM measured on I-94 at MP 200.

MEPDG Inputs
Vehicle Classification Data

Vehicle Class	Percent Vehicles
4	2.5
5	12.7
6	4.2
7	0.8
8	3.4
9	66.9
10	4.2
11	1.7
12	0.8
13	2.5
Total	100

Climate (5 Weather Stations)

21.9 miles MINNEAPOLIS, MN - CRYSTAL AIRPORT Lat. 45.04 Lon. -93.21 Ele. 872 Months: 101 (C)
25.0 miles ST CLOUD, MN - ST CLOUD REGIONAL AIRPORT Lat. 45.32 Lon. -94.03 Ele. 1024 Months: 116 (M1)
32.0 miles MINNEAPOLIS, MN - FLYING CLOUD AIRPORT Lat. 44.5 Lon. -93.28 Ele. 922 Months: 100 (C)
34.9 miles MINNEAPOLIS, MN - MINPLIS-ST PAUL INTL ARPT Lat. 44.53 Lon. -93.14 Ele. 874 Months: 116 (C)
39.2 miles ST PAUL, MN - ST PAUL DWTWN HOLMAN FD AP Lat. 44.56 Lon. -93.03 Ele. 711 Months: 116 (M6)

MEPDG Inputs

- HMA materials data
  - PG Grade: 64-34
  - Percent asphalt: 5.4 % by weight (assume 10.8% by volume)
  - Percent inplace air voids: 5.5 % measured
  - Density: 148 pcf
  - Gradation of HMA
    - Retained on ¾ in = 0%
    - Retained on 3/8 in = 20%
    - Retained on #4 = 40%
    - Passing #200 = 4.3%

MEPDG Inputs

- Concrete: EAC, RCA, LCA test data

Test	EAC	RCA	LCC
Flexural Strength, psi	854 psi	677	548
Modulus of Elasticity, psi	4.9 M psi	4.9 M psi	5.1 M psi
Coef. Expansion	5.6/F	5.8/F	5.4/F
Poisson’s Ratio	0.23	0.25	0.23

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

MEPDG Inputs

- **Unbound base course:**
  - 8-in thick
  - Class 5 granular base per MnDOT specifications.
  - Used default of 18,000 psi.

MEPDG Inputs

- **Subgrade:** FWD tested on top of slab & backcalculation of subgrade modulus (dynamic k-value, kd)
- Mean backcalculated k-value = 140 psi/in.
- Corresponding Input **Mr = 14,000 psi** at optimum density and water content gives k-value output of about 140 psi/in. This Mr is about the default for A-6 soil.

MEPDG Inputs

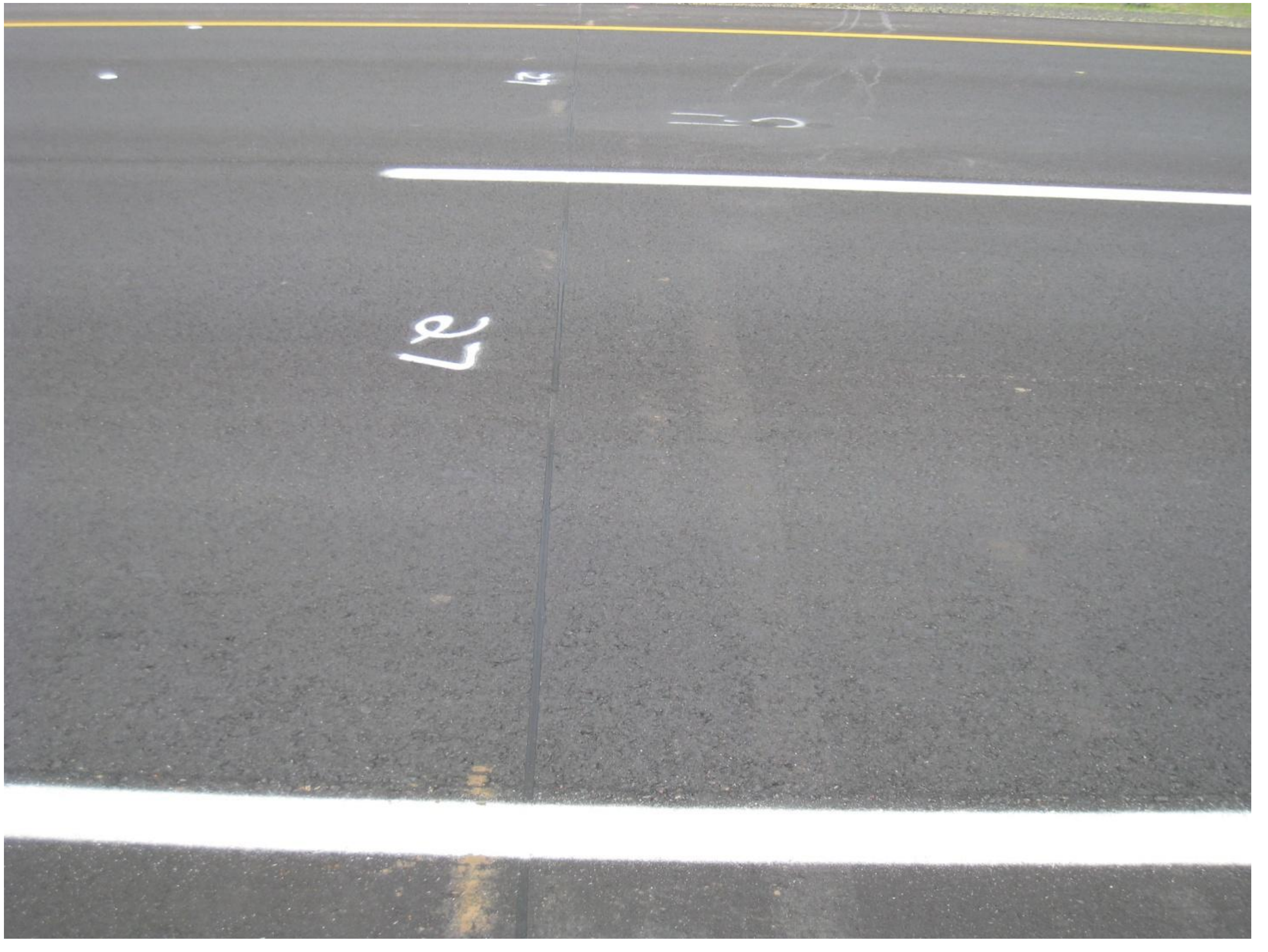
- **Design:**
  - Joint spacing: 15-ft
  - Joint sealing: None, single saw blade cut
  - Dowels:
    - Driving lane: 1.25-in diameter, 12-in spacing
    - Passing lane: No dowels

HMA/RCA Predictions

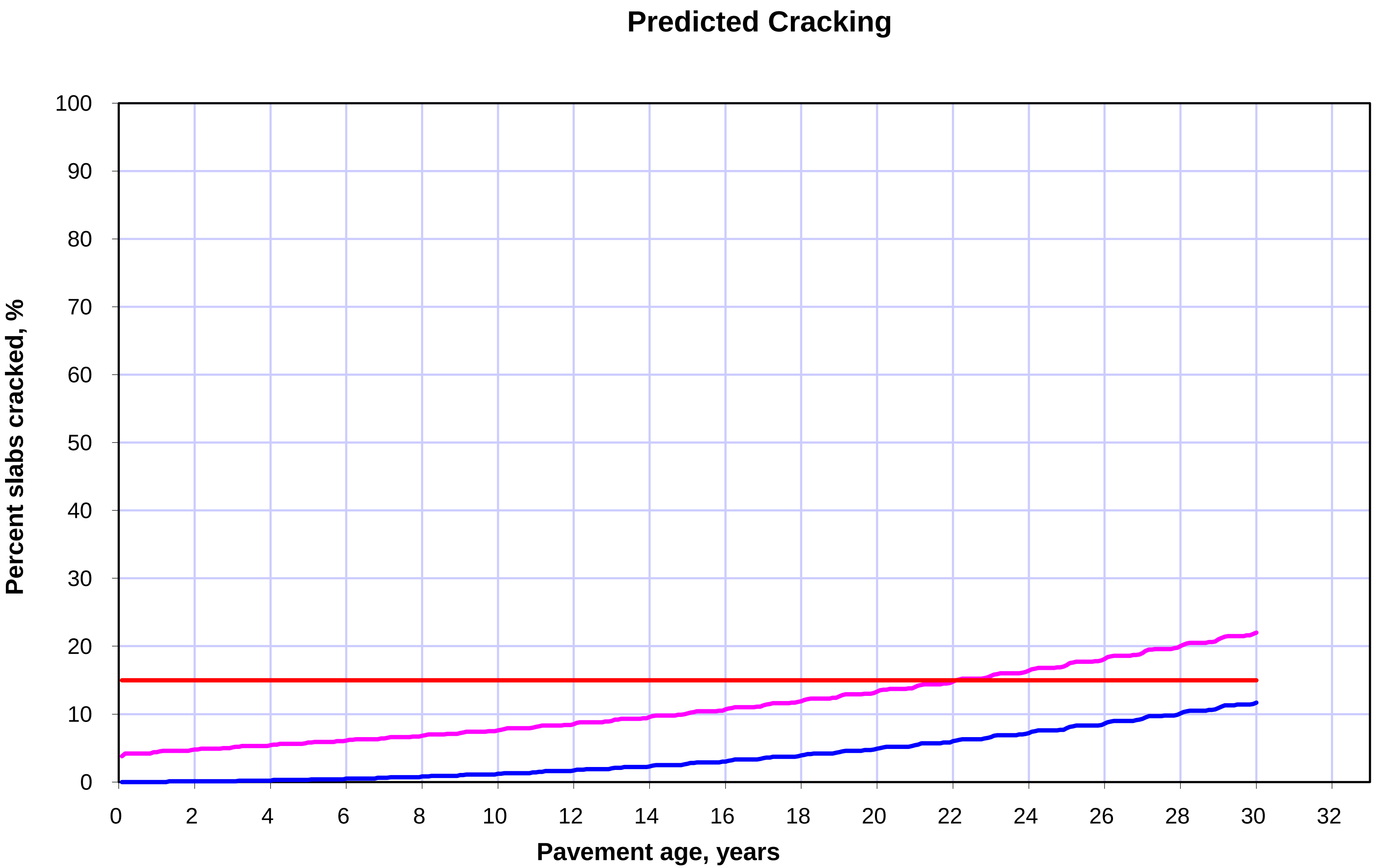
- MEPDG outputs:
  - Slab fatigue transverse cracking
  - Rutting of HMA
  - IRI
- Other potential distress
  - Transverse saw and seal joints

3-in HMA / 6-in RCA Section

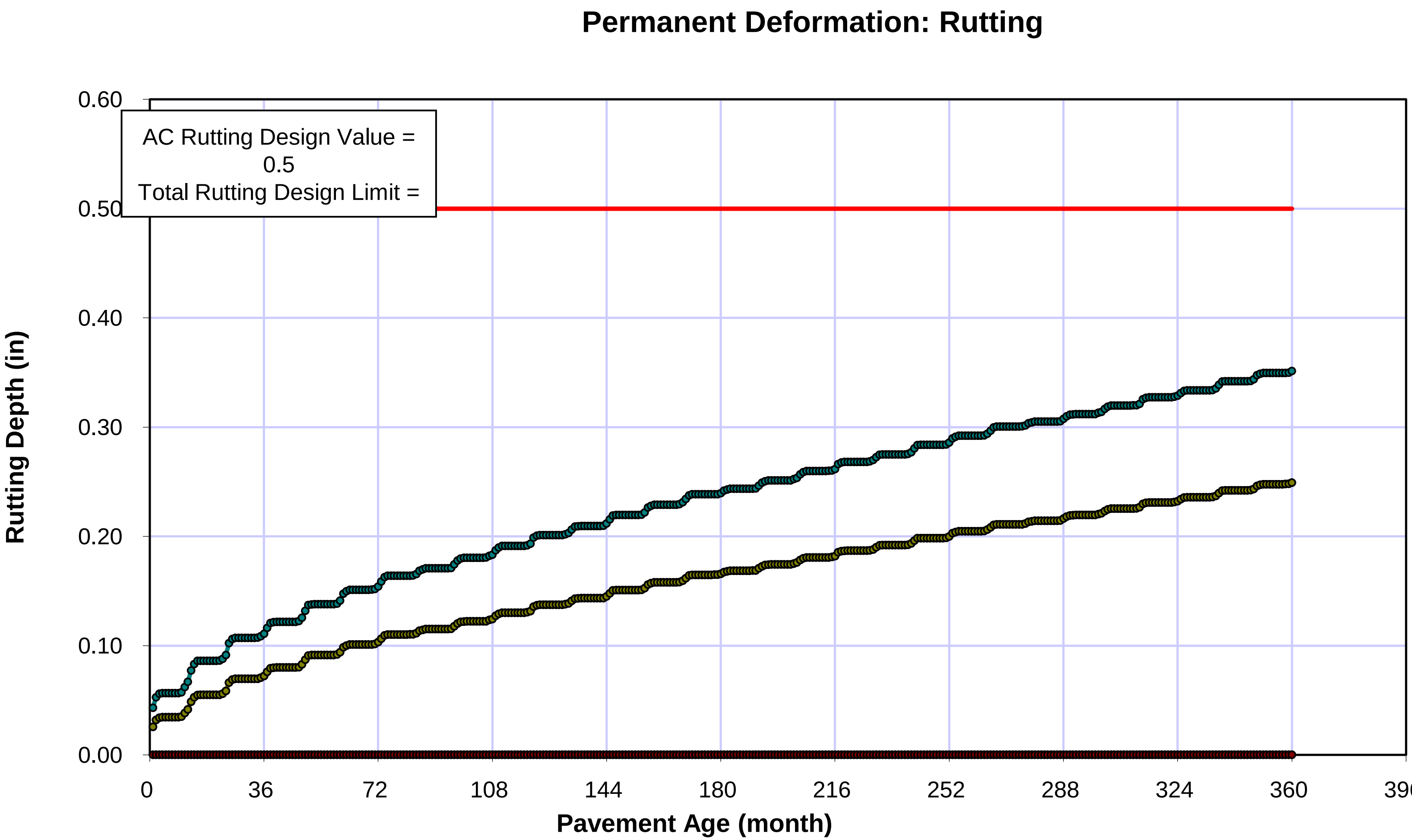
Saw & Seal Transverse Joints



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



Rutting, 3-in HMA / 6-in RCA



MEPDG Prediction HMA / RCA

Age / Trucks	% Slab Cracking	Rutting, in	Smoothness IRI, in /mile
0	0	0	63
5 years 3 million	0.3	0.09	94
10 years 6 million	1.2	0.13	100
15 years 10 million	2.7	0.17	107

Reflection cracking of transverse joints: controlled by saw and seal.

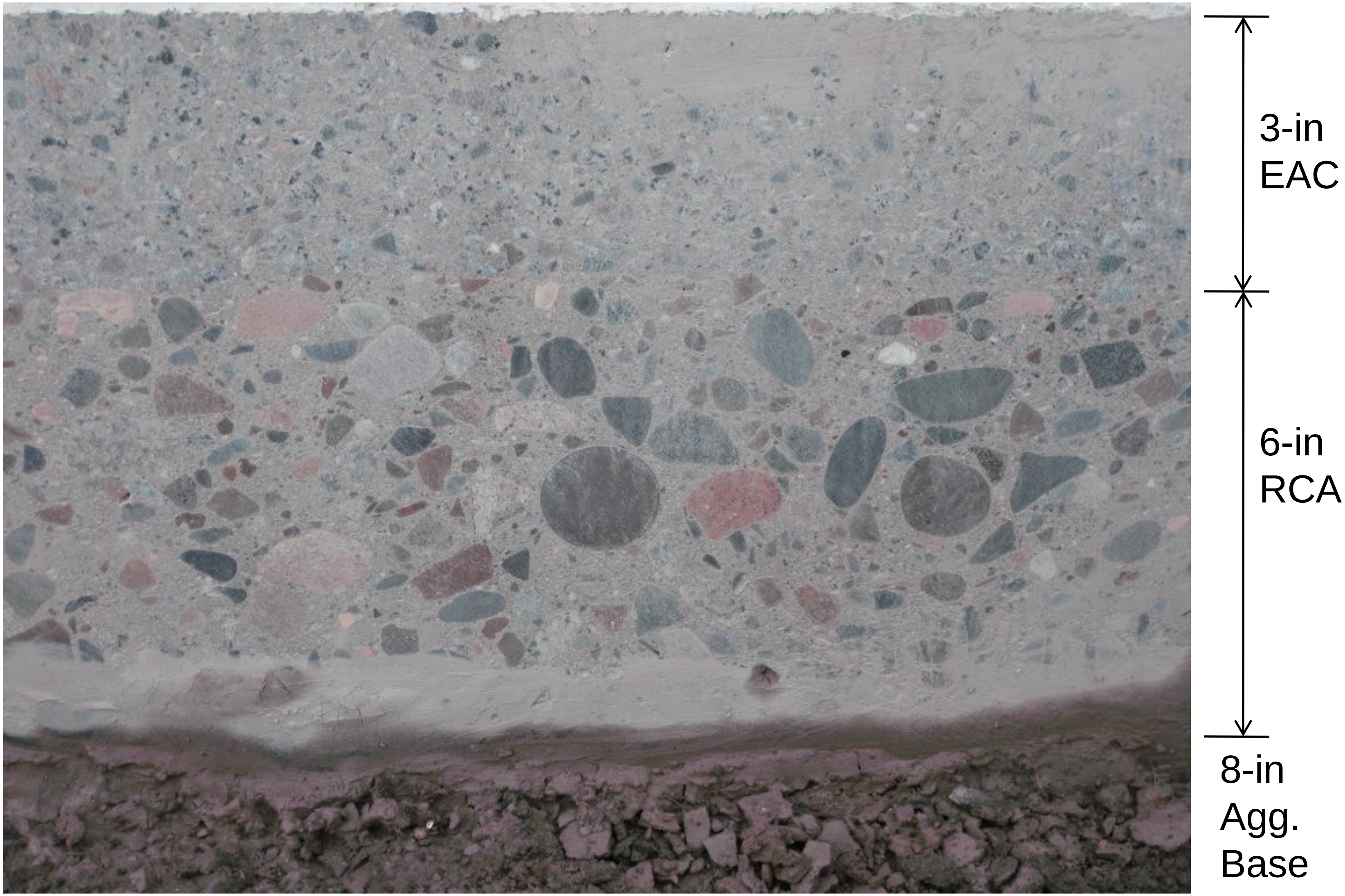
HMA / RCA Composite after 10 years and 6 million trucks

- 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 after 10 years and 6 million trucks in driving lane.
  - Major question: will saw and seal of transverse joints hold up?

EAC / RCA Predictions

- MEPDG outputs:
  - Slab fatigue transverse cracking
  - Transverse joint faulting
  - IRI

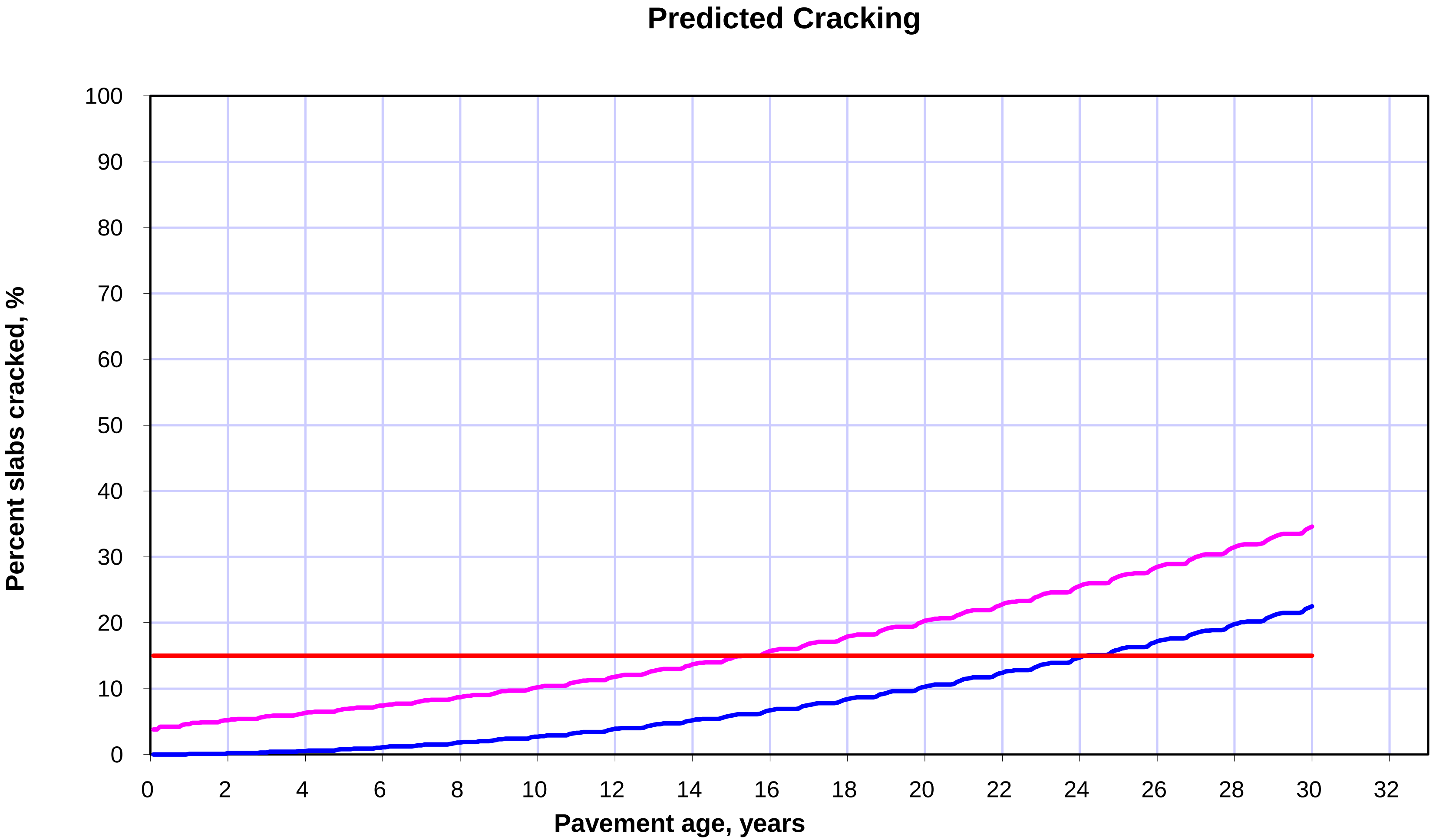
3-in EAC / 6-in RCA



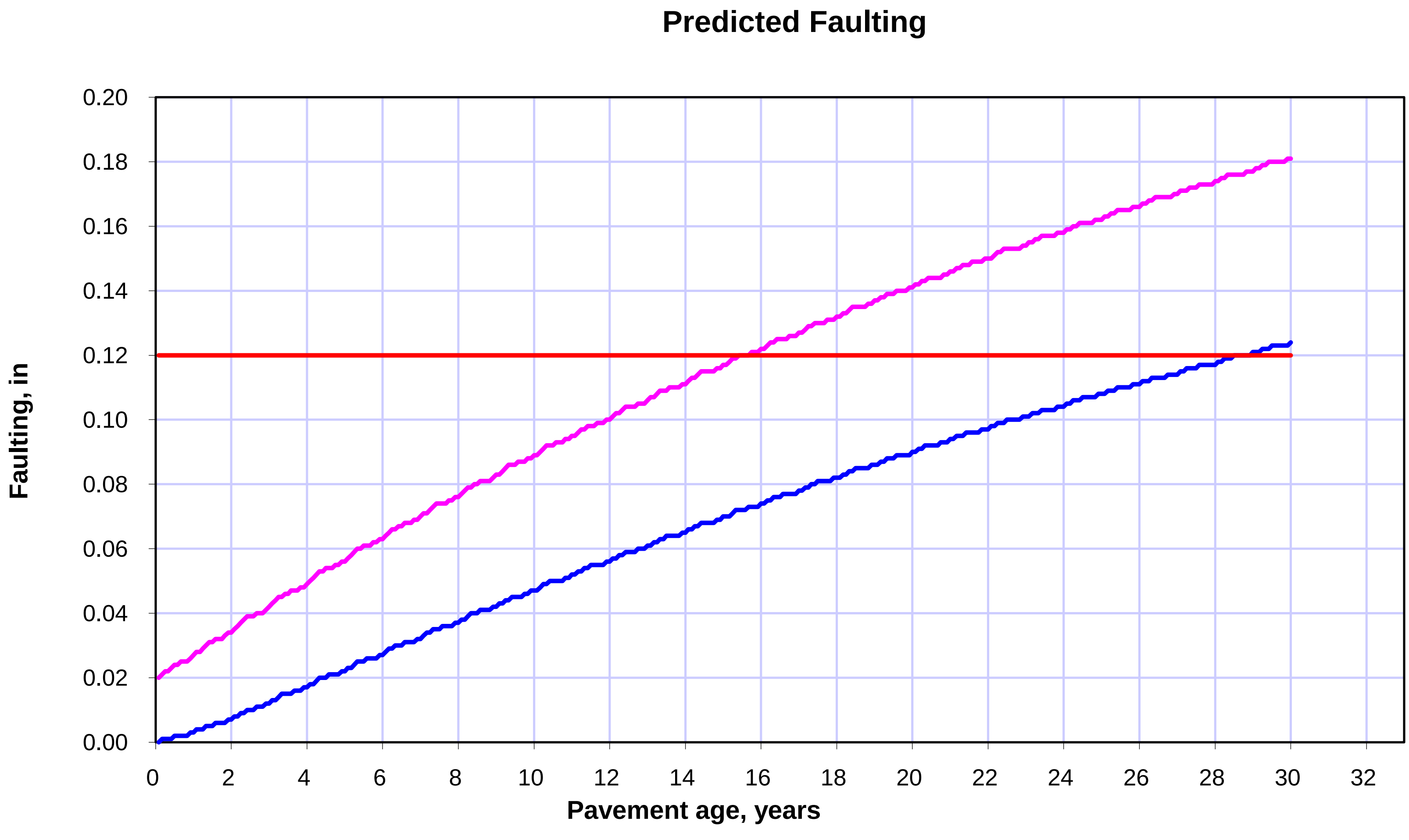
3-in EAC / 6-in RCA

3-in EAC / 6-in LCC

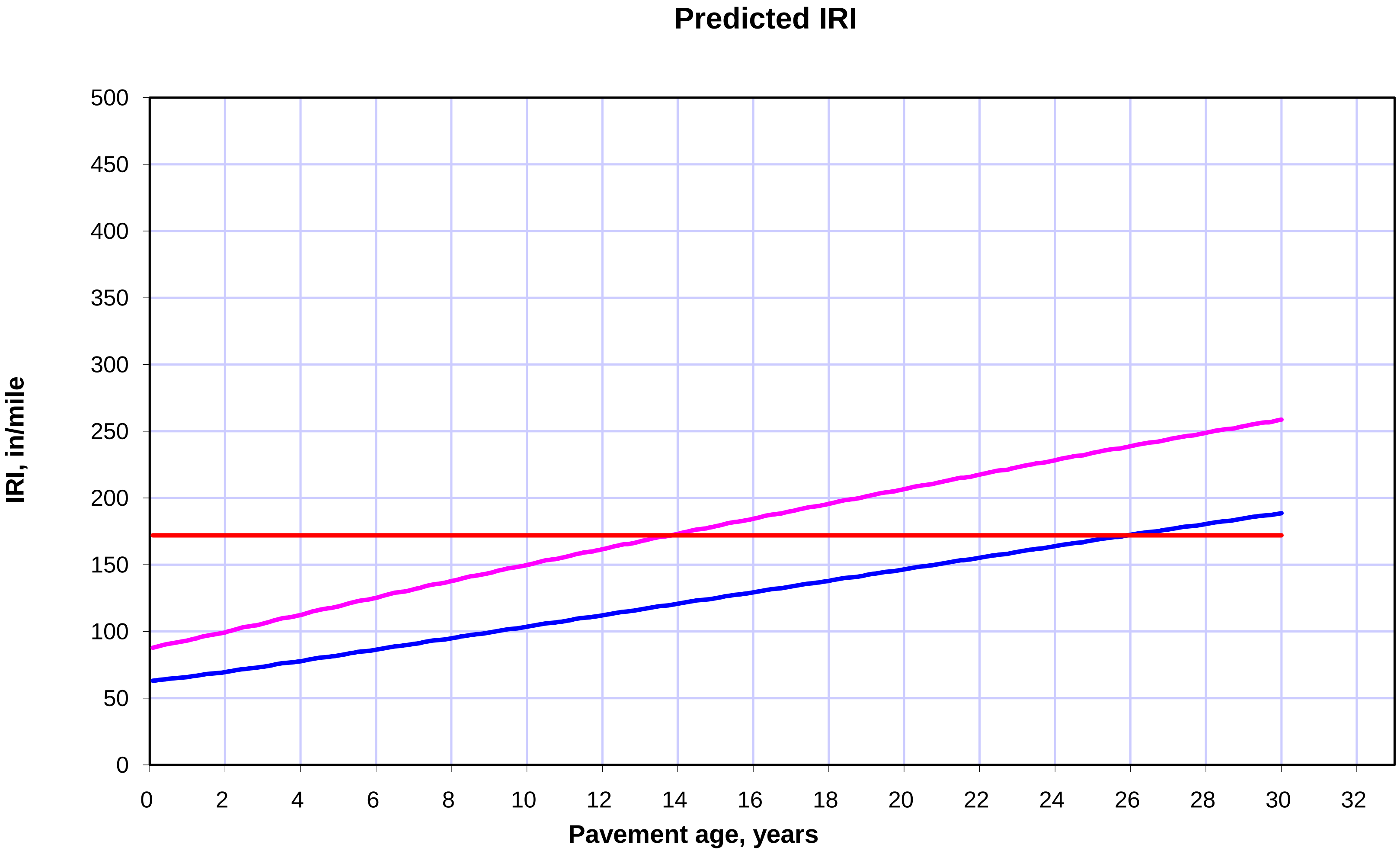
Slab Cracking, 3-in EAC / 6-in RCA



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



IRI, 3-in EAC / 6-in RCA



MEPDG Prediction EAC / RCA

Age / Trucks	% Slab Cracking	Joint Faulting, in	Smoothness IRI, in /mile
0	0	0	63
5 years 3 million	0.8	0.02	82
10 years 6 million	2.7	0.05	103
15 years 10 million	5.9	0.07	125

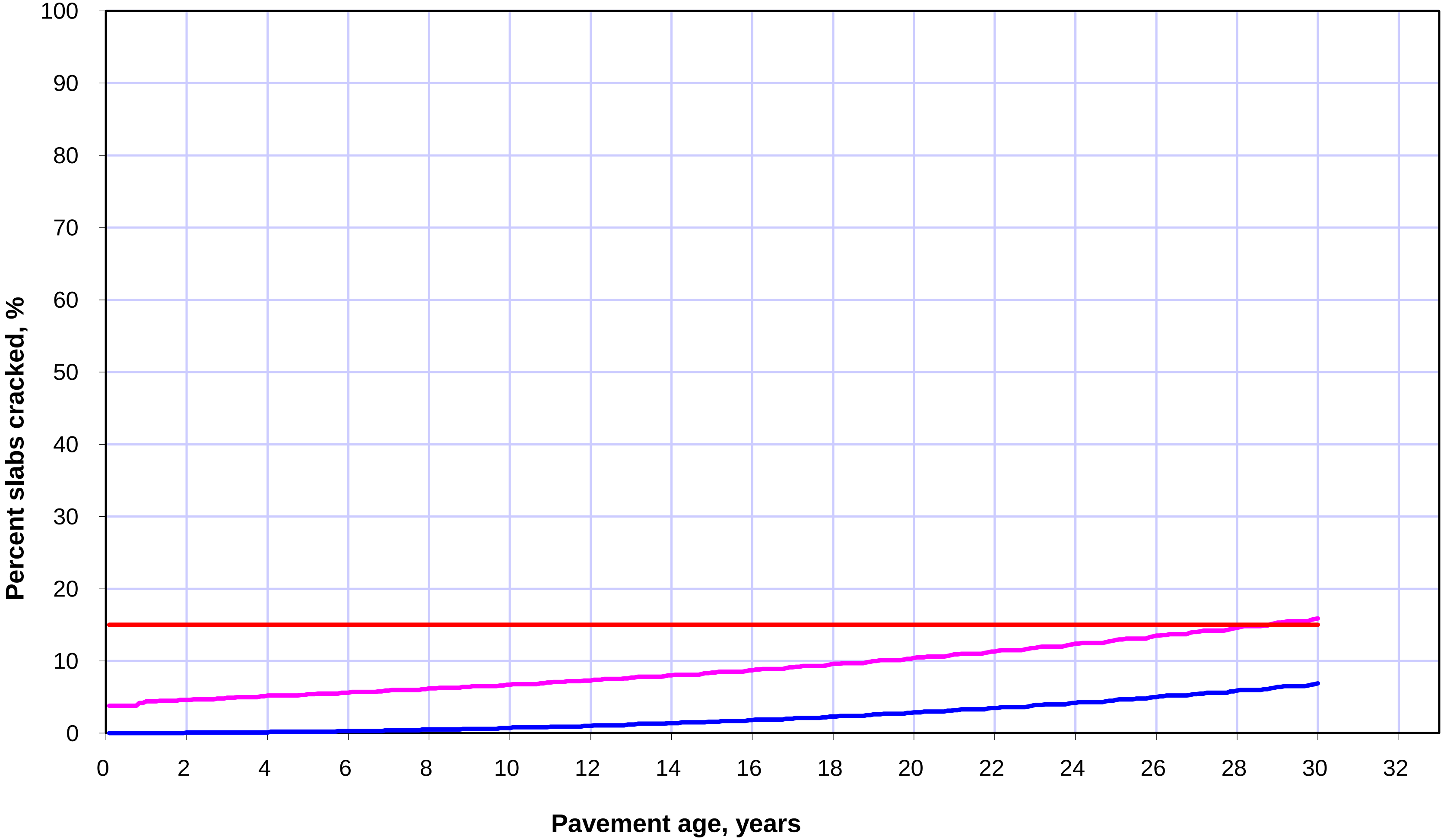
EAC / RCA Composite after 10 years and 6 million trucks

- Transverse Cracking < 5 % slabs.
- Joint faulting < 0.10 in. mean.
- IRI < 125 in/mile.
- Two layer composite concrete pavement should be in good condition after 10 years and 6 million trucks in driving lane.

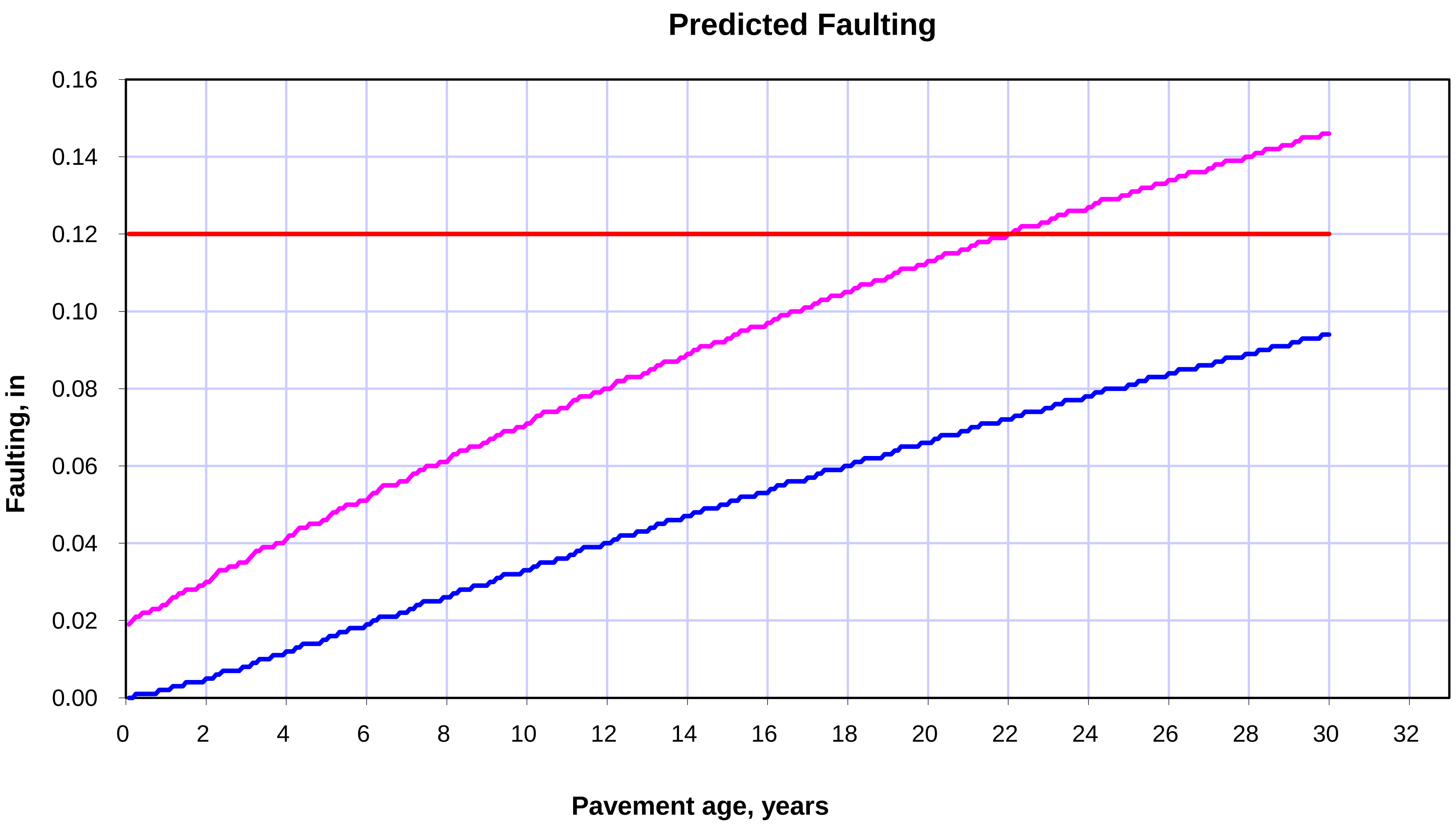
EAC / LCC Predictions

- MEPDG outputs:
  - Slab fatigue transverse cracking
  - Transverse joint faulting
  - IRI

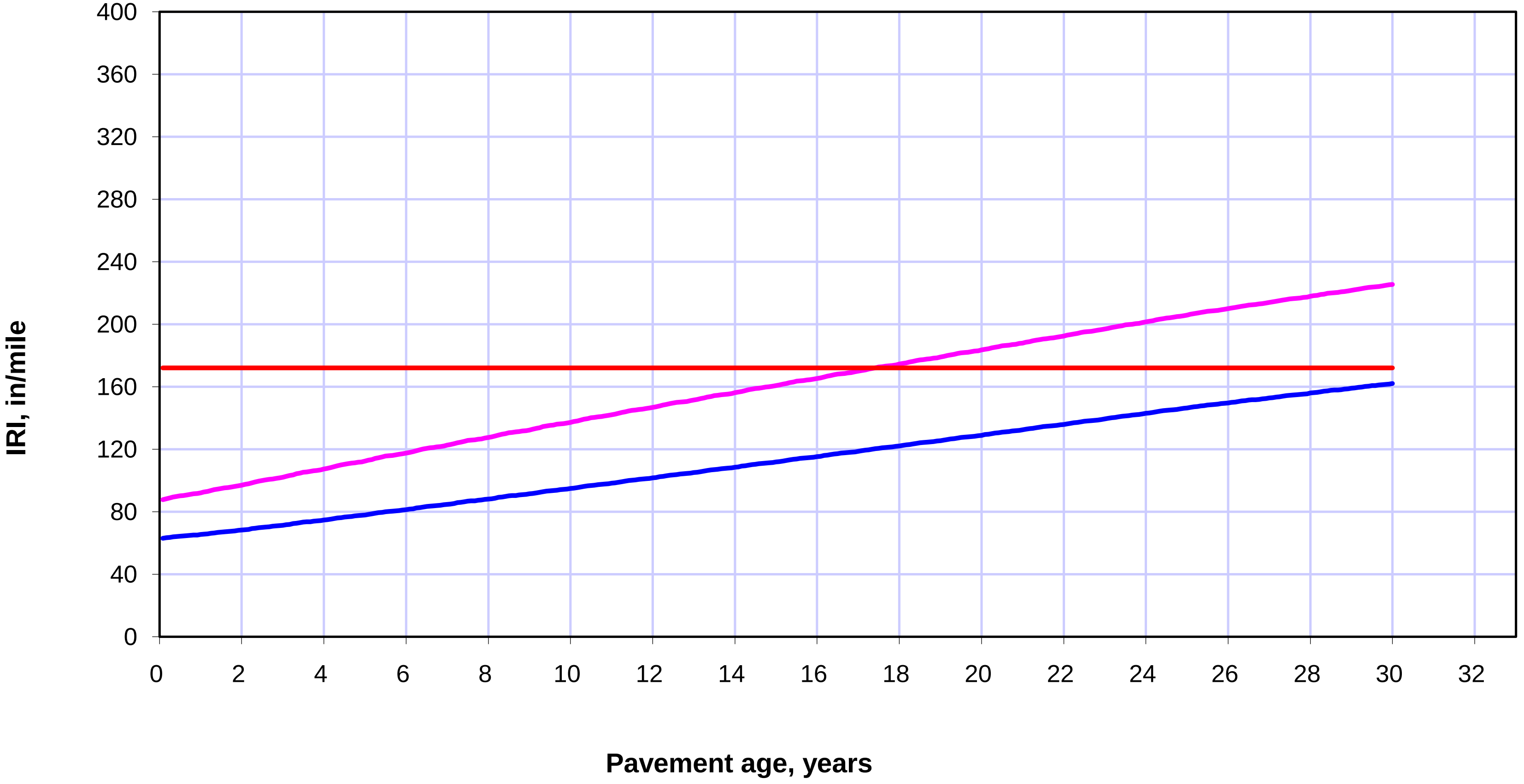
Cracking, EAC / LCC Predictions



Faulting, EAC / LCC Predictions



IRI, EAC / LCC Prediction



Comparison RCA & LCC

Property	Recycled Aggregate Concrete, RCA	Low Cost Concrete, LCC
Cement, pounds	360	240
Flyash, pounds	240	360
Compressive Strength, psi	4300	5062
Flexural Strength, psi	665	650
Modulus Elasticity, psi	4.8 million	5.1 million
Coefficient of Thermal Expansion, per degree F	5.8	5.4

MEPDG Prediction EAC / LCC

Age / Trucks	% Slab Cracking	Joint Faulting, in	Smoothness IRI, in /mile
0	0	0	63
5 years 3 million	0.2	0.02	78
10 years 6 million	0.7	0.03	95
15 years 10 million	1.6	0.05	112

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 after 10 years and 6 million trucks in driving lane.

What If?

30-year Design: 23 million Trucks

- 3-in HMA / 8-in RCA
  - No structural fatigue cracking
  - HMA would need replacement at 8 to 15 years depending on:
    - Saw and seal transverse joints: will these hold up?
    - Rutting of HMA

What If?

30-year Design: 23 million Trucks

- 3-in EAC / 8-in RCA
  - No structural fatigue cracking
  - Some joint faulting and roughness.
  - EAC should perform with no problems: good friction, no significant wear.
  - Diamond grinding should perform with no problems: good friction, low noise.

30-year Design: 23 million Trucks

- 3-in EAC / 8-in LCC
  - No structural fatigue cracking
  - Some joint faulting and roughness.
  - EAC should perform with no problems: good friction, no significant wear.
  - Diamond grinding should perform with no problems: good friction, low noise.

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.