

Summit on Increasing RAP Usage

Performance of Recycled HMA Mixes

Randy West, Director
National Center for Asphalt Technology



Outline

- Laboratory Research
- State Reports
- National Reports
- NCAT Test Track
- Summary

Laboratory Research

- RAP in HMA is one of the most researched topics in the field of pavement materials.
- Most of that research is based on laboratory testing.
- That is a good place to start, but relating lab test results to field performance is like a preseason football poll.

State Reports

Washington State

- WA-RD-98.1, 1986
- Title: *Hot Mix Recycling Evaluation in Washington*
- Authors: Peters, et al.
- Scope: 16 projects, RAP contents from 8 to 79% (half $\geq 70\%$), projects ranged from 1.5 to 10 years old

Washington State

- Findings:
 - WSDOT's initial two projects...are still performing very well.
 - The early data indicates equally promising results for the 14 other projects.
 - Because of the impressive pavement performance exhibited by the recycled pavements, ...benefits such as conservation of natural resources, ...and its cost advantage... hot-mix recycling has become an attractive addition to the WSDOT paving program.

Louisiana

- LTRC Report No. 216, April 1995
- Title: *Evaluation of Recycled Projects for Performance*
- Author: “Skip” Paul
- Scope: 10 projects, RAP content: 20 to 50%, data covered a six to nine years, evaluated pavement condition ratings, serviceability, structural analysis, and mix and binder properties

Louisiana

- Findings
 - pavements containing RAP performed similarly to conventional mixtures for a period of six to nine years of service life
 - pavements with RAP exhibited slightly more distress with respect to longitudinal cracking
 - the substitution of up to 15 % [RAP in wearing courses] can provide acceptable performing pavements as long as the 12,000 poise viscosity limitation is maintained.

Connecticut

- Report No.: FHWA-CTRD-647-4-87-1
- Title: *Performance Evaluation of Hot Mixed Recycled Pavement – Route 4, Burlington*
- Authors: Ganung and Larsen
- Scope: conventional and 30% RAP, performance compared at 6 years of service

Connecticut

- Findings:
 - No rutting was detected
 - Roughness was low
 - Extracted asphalt viscosities were higher for recycled versus control, possibly explaining for the greater cracking on the recycled
 - This condition was reversed on the overlaid sections

Georgia

- TRR 1507, 1995
- Title: *Performance of Recycled Hot-Mix Asphalt Mixtures in Georgia*
- Authors: Kandhal, et al.
- Scope: Detailed comparison of 5 pairs of recycled versus control projects, followed by comparison of a larger set of control and recycled HMA projects. RAP contents range from 10 to 25%

Georgia

- Findings:
 - For the 5 paired comparisons, there was no rutting, raveling, or fatigue cracking in either the recycled or conventional sections.
 - Comparison of recycled vs. conventional mixes on 15 projects indicated the RAP mixes performed equal to or better than the virgin mixes.

Massachusetts

- Title: *Hot Mix Recycling in Massachusetts*
- Scope: Rehabilitation project on I-295, 35% RAP in binder layer, OGFC surface. The new binder in the RAP mix was adjusted to a softer grade.
- Findings
 - The pavement showed no distress after 11 years
 - The RAP pavement performed better than the original conventional pavement

California

- Title: *Comparative Analysis of Long-Term Field Performance of Recycled Asphalt in California Environmental Zones*, TRB 2008
- Authors: Zaghoul and Holland
- Scope: 60 RAP sections (up to 15% RAP) in 3 climatic zones in CA, evaluations at 5 to 9 years of service, rated by Structural Service Life, Distress Service Life, and Roughness Service Life

California

- Findings: Performance of RAP pavements differs for the three climatic zones
 - North Coast climatic zone – Excellent to good performance of pavements with RAP
 - Mountain climatic zone – structural performance was marginal, but distress performance was poor
 - Desert climatic zone – Structural performance was good but distress performance was poor

Granite Construction

- Title: *Recycled Hot Mix Asphalt Performance in Various Climatic Regions*
- Authors: Robinette and Epps
- Scope and Approach:
 - Evaluated 114 conventional and recycled projects (10-35% RAP) on low-volume roads in 3 climatic regions: Low Desert, High Desert, & Coastal
 - Pavement ages from 1 to 10 years
 - Visual condition surveys
 - Predicted service lives

Robinette and Epps

- Findings:
 - Analyses of visual pavement condition surveys indicate that recycled HMA pavements have a longer expected life for two of the three cases [climatic regions]

National Studies

FHWA

- FHWA-SA-95-060, 1996
- Pavement Recycling Executive Summary and Report
- Author: Sullivan
- Scope: Review of HMA Recycling Practices and Performance in 17 states

FHWA-SA-95-060 Conclusions

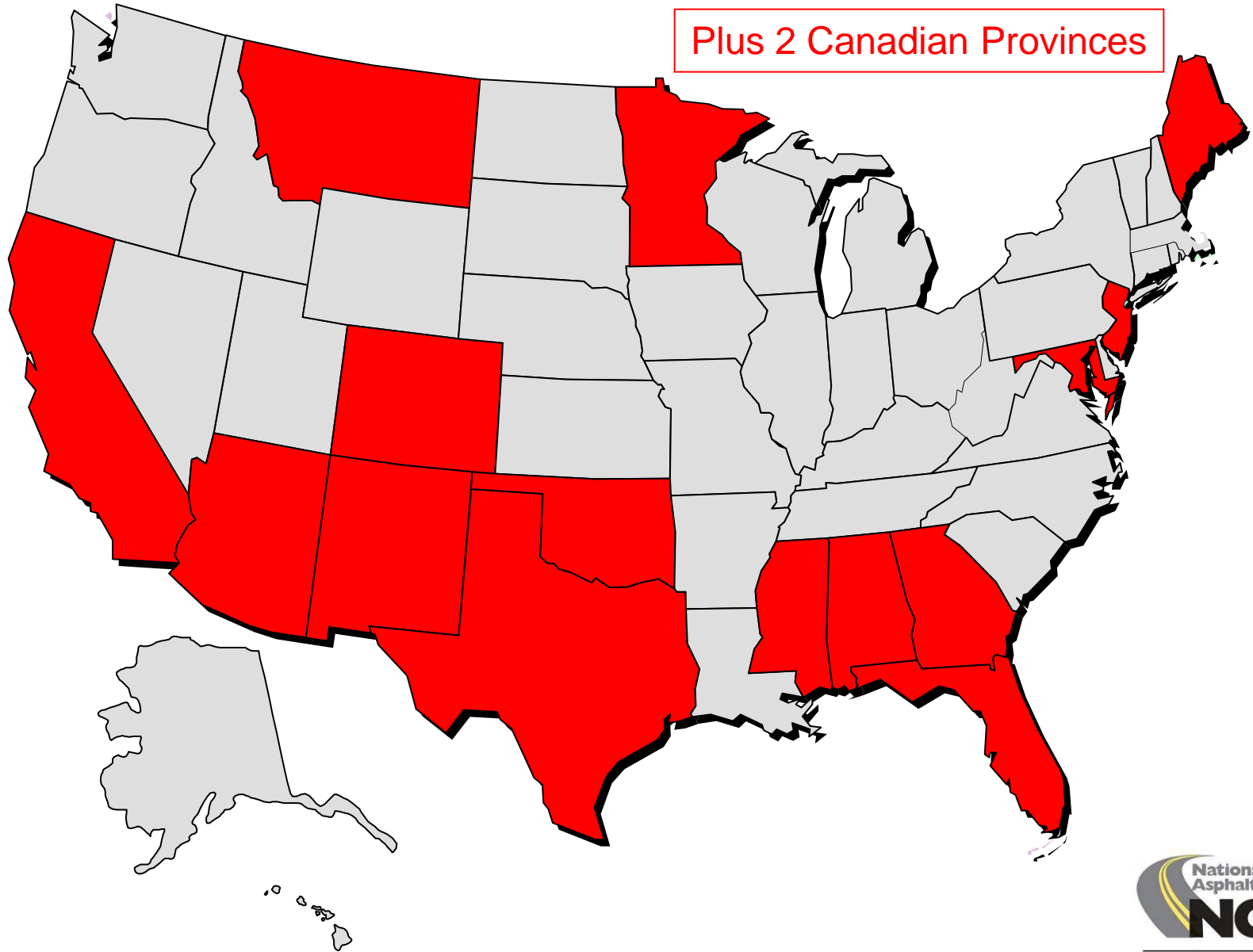
- “Long-term pavement performance (17 years)... show that recycled HMA that is designed and controlled during production will perform comparably to conventional HMA and can improve material properties of the existing pavement layer.
- Similar to poor performing conventional HMA, poor recycled HMA performance can be related to poor mix design procedures or use of control and acceptance procedures that do little to ensure the quality of the recycled HMA.
- Recycled HMA, which is designed and produced in a quality assurance program that verifies mix design assumptions to reasonable limits, can be expected to perform comparably to conventional HMA.”

LTPP Study: RAP vs. Virgin Mixtures

- Report: FHWA-RD-98, June 1998
- Title: *Performance Trends of Rehabilitated Asphalt Concrete Pavements in the LTPP Experiments: Initial Observations*
- Researcher: *Brent Rauhut Engineering*
- Scope: SPS-5 and GPS-6 sections
 - factors: overlay thickness, milling, and RAP
 - RAP sections contained 30% RAP from project millings

LTPP Study: RAP vs. Virgin Mixtures

Plus 2 Canadian Provinces



LTPP Study: *Findings*

- Rutting - "...there is no important difference in resistance of rutting between virgin and recycled mixes."
- Fatigue - "The recycled mixtures have a higher percentage of sections with fatigue cracking compared to the virgin mixtures, but exhibit on the average smaller areas of cracking."
- Thermal Cracking - "In general, it is believed that mixtures with RAP are stiffer (or more brittle) and more susceptible to thermal fracture. The initial performance observations seem to contradict the debatable hypothesis."

Texas – Follow Up on SPS-5

- In TRB Circular E-C078, October 2005
- Title: *Lessons Learned from the Long-Term Pavement Performance Program and Several Recycled Sections in Texas*
- Authors: Chen and Daleiden
- Scope: Five TXDOT SPS-5 projects with 30% RAP and virgin HMA sections and one nearby Hot-In-Place recycled pavement

Texas Follow Up on SPS-5


- Findings:
 - After more than 10 years of service, the RAP sections perform as well as the virgin asphalt concrete (AC) sections.
 - All SPS-5 sections are able to resist reflective cracking when a mixture of 30% RAP and a softer binder is used, the result is a high penetration number (30 to 45), with a flexible mixture able to resist cracking.
 - In contrast, cracks came through the HIP recycled sections in just a few weeks for US-175 and US-84. Low penetration numbers in the range of 20 to 21 were found.



Experience with RAP on the NCAT Test Track



Use of RAP in the First Two Cycles of the NCAT Test Track

- 
- 2000 FDOT S6 & S7
 - 15% RAP
 - PG 67-22
 - 20 million ESALs, 5 years
 - <4 mm rutting
 - No cracking
 - No raveling

Use of RAP in the First Two Cycles of the NCAT Test Track

- 2006 TNDOT S6, MSDOT S2
 - 15% RAP
 - PG 76-22
 - 9 million ESALs
 - No rutting
 - No raveling
 - No cracking

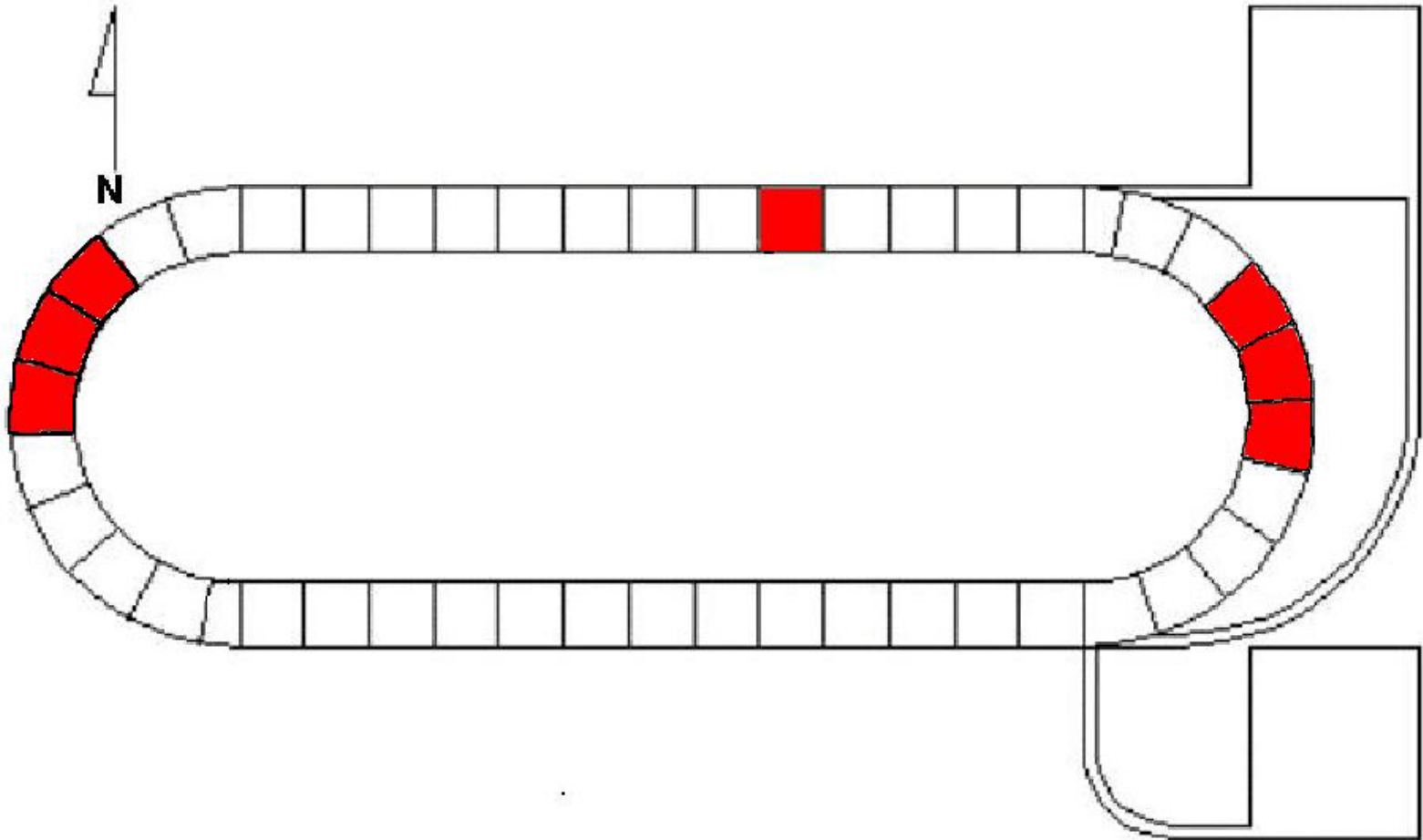


NCAT TEST TRACK

RAP Experiment



RAP Test Sections



NCAT Test Track RAP Sections

1. virgin control mix with PG 67-22
2. 20% RAP with PG 67-22 virgin binder
3. 20% RAP with PG 76-22 virgin binder
4. 45% RAP with PG 52-28 virgin binder
5. 45% RAP with PG 67-22 virgin binder
6. 45% RAP with PG 76-22 virgin binder
7. 45% RAP with PG 76-22 + Sasobit

Objectives:

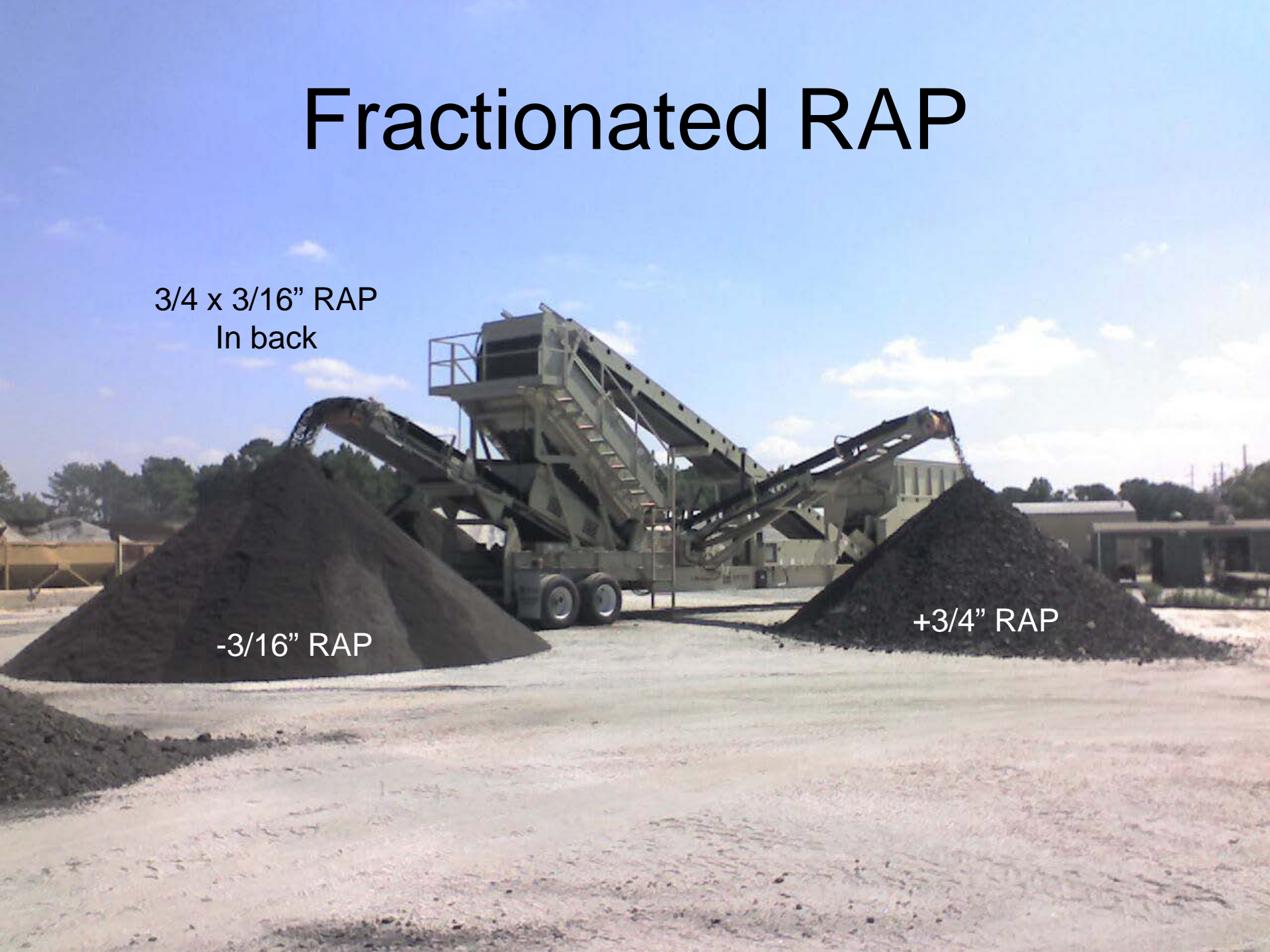
- Determine the appropriate grade of virgin binder needed for High RAP mixes.
- Assess constructability of high RAP mixes
 - Mix design issues
 - Plant issues
 - Paving and compaction
- Accelerated Traffic Performance
 - Compare rutting over time
 - Compare cracking and durability

Fractionated RAP

3/4 x 3/16" RAP
In back

-3/16" RAP

+3/4" RAP



Recycled Mix Production



Coarse (3/4 – 3/16") RAP Bin



Fine (-3/16") RAP Bin

Mix QC Summaries

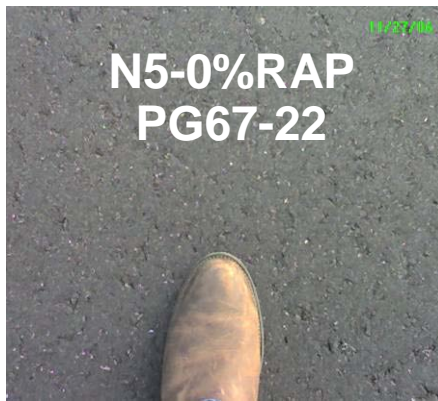
Mix	Virgin Control	20% RAP	45% RAP
NMAS	12.5	12.5	12.5
Pb	5.8%	5.6 – 5.8%	4.9 – 5.1%
Va	2.9%	1.9 – 2.1%	1.7 – 3.6%
VMA	15.9%	14.2 – 14.5%	12.5 – 13.9%
In-Place Density	95%	92 – 94%	94 – 96%

Test Section Construction



RAP Sections

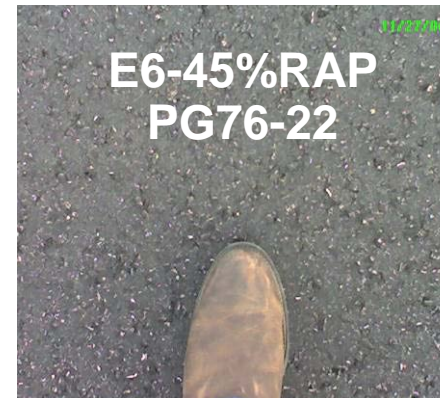
No RAP



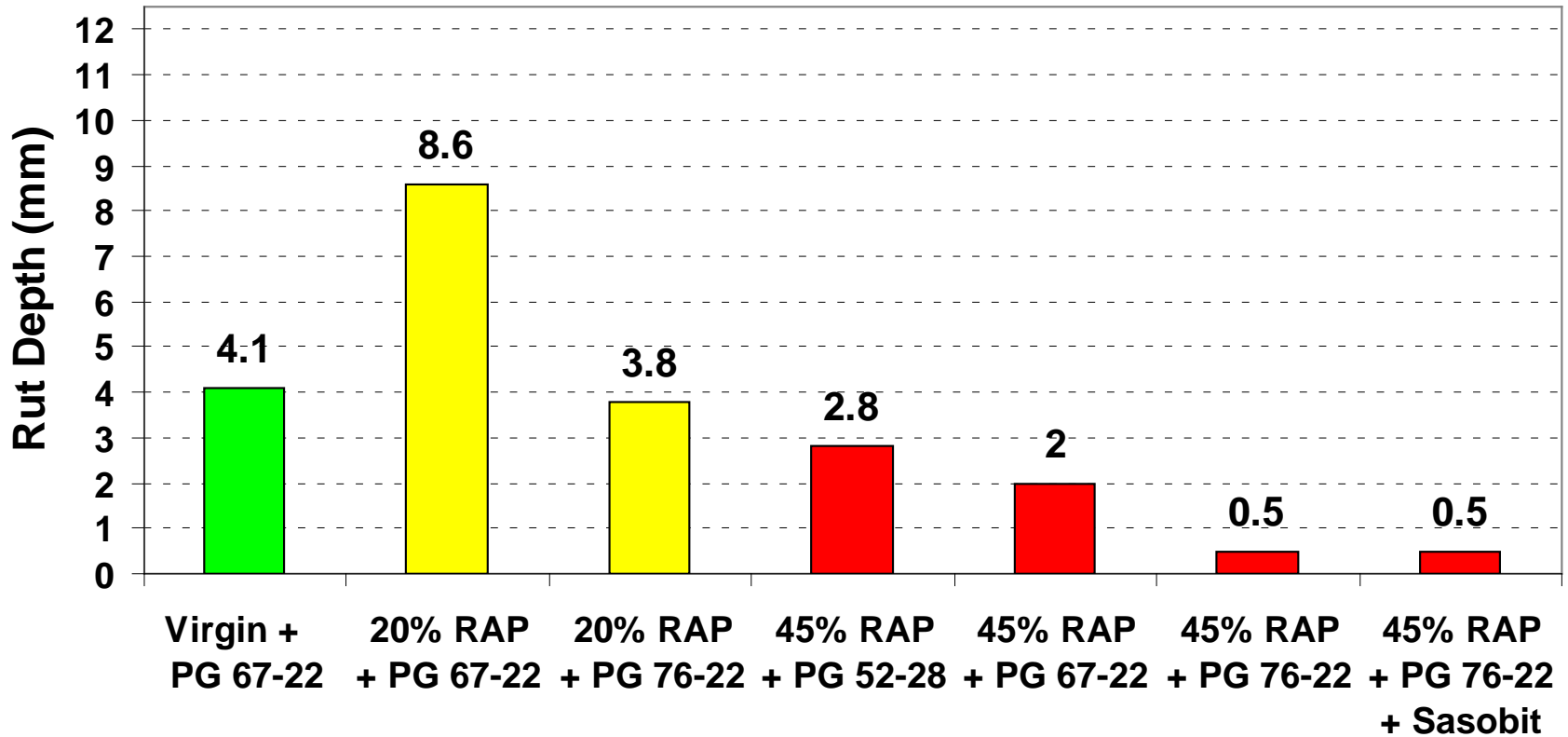
Moderate RAP



High RAP



Rutting Performance @ 9.0M ESALs



Virgin and RAP Mixtures

E7 45% RAP PG76-22+Sasobit

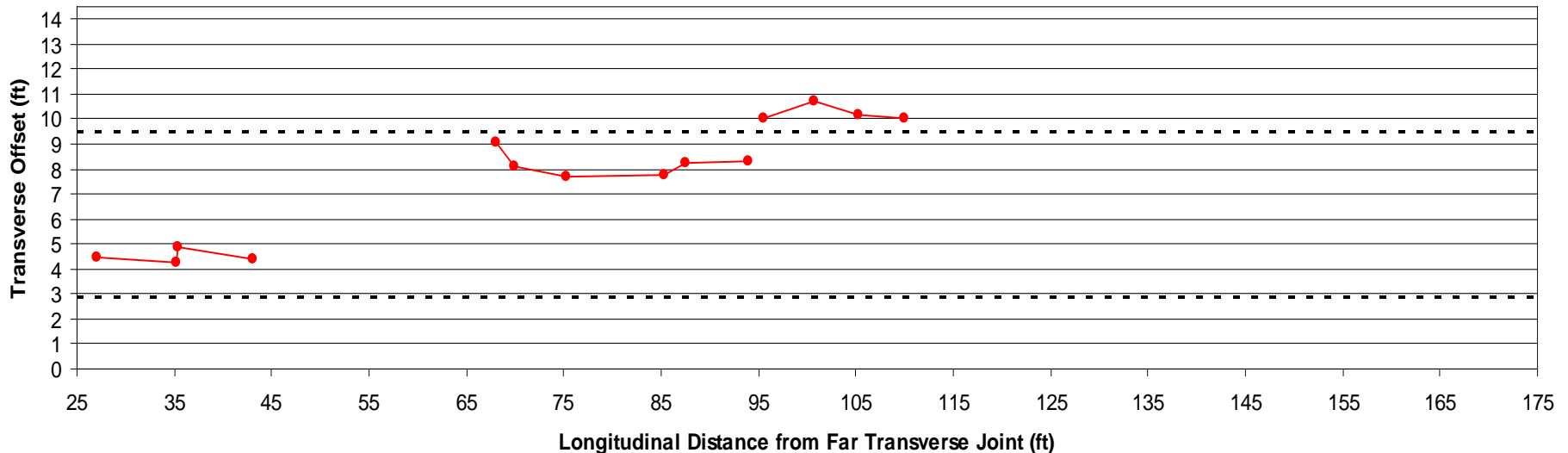


Cracking first noted in E7 in January 2008

Recycled Mix Field Performance

E7, 45% RAP w/ PG76-22+Sasobit

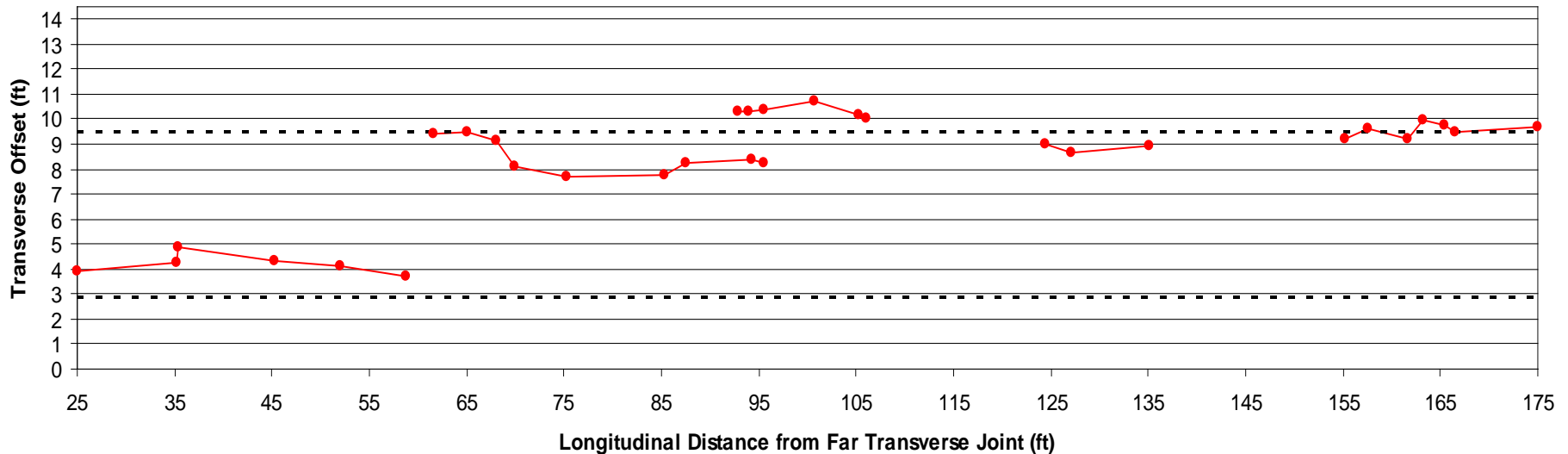
1/28/08 @ 5.5M ESALs



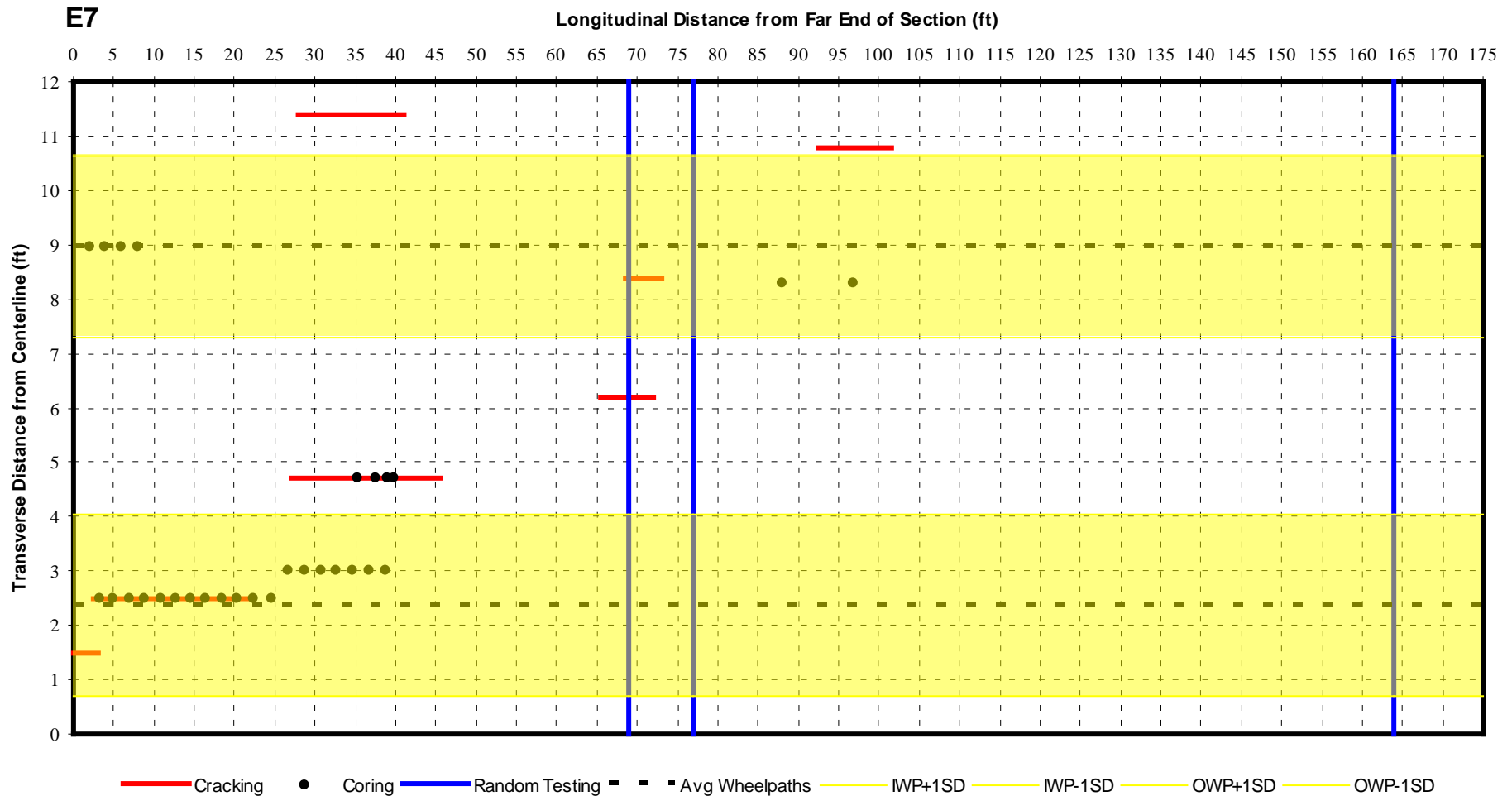
Recycled Mix Field Performance

E7, 45% RAP w/ PG76-22+Sasobit

7/21/08 @ 8.0M ESALs



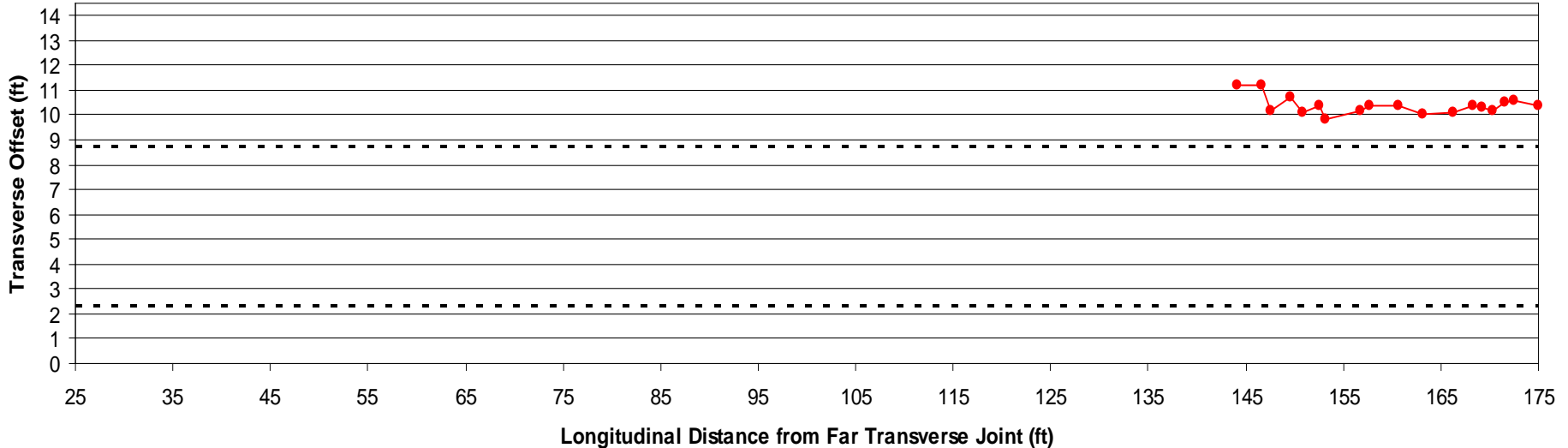
Cracking in E7 during 2003 Cycle



Recycled Mix Field Performance

W3, 20%RAP w/ PG76-22

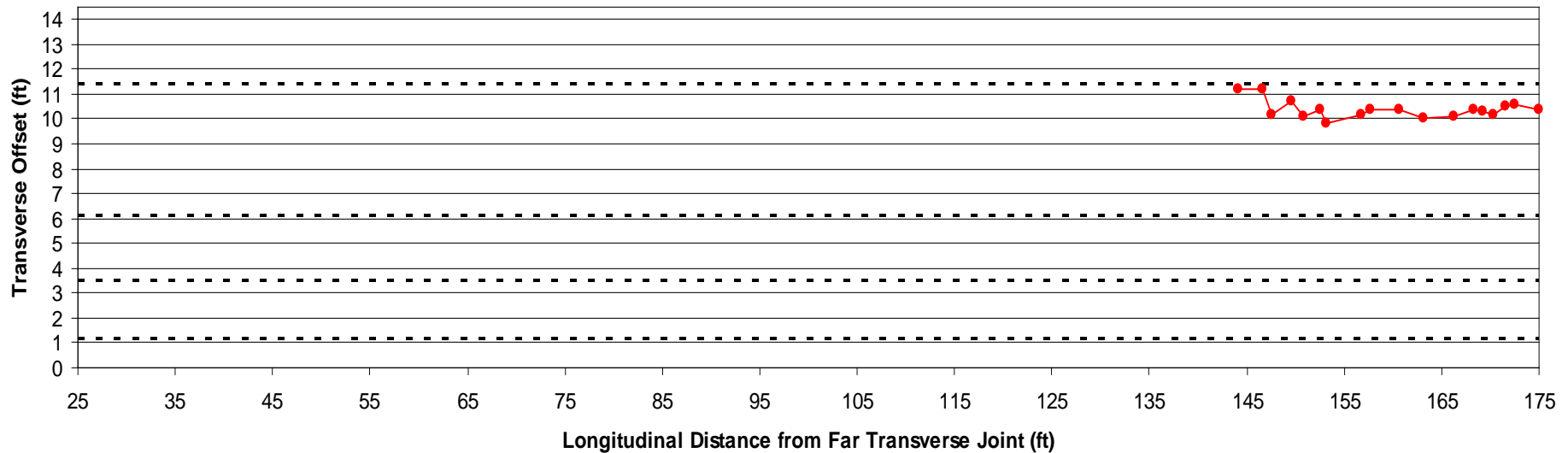
4/7/08 @ 6.5M ESALs



Recycled Mix Field Performance

W3, 20%RAP w/ PG76-22

7/21/08 @ 8.0M ESALs



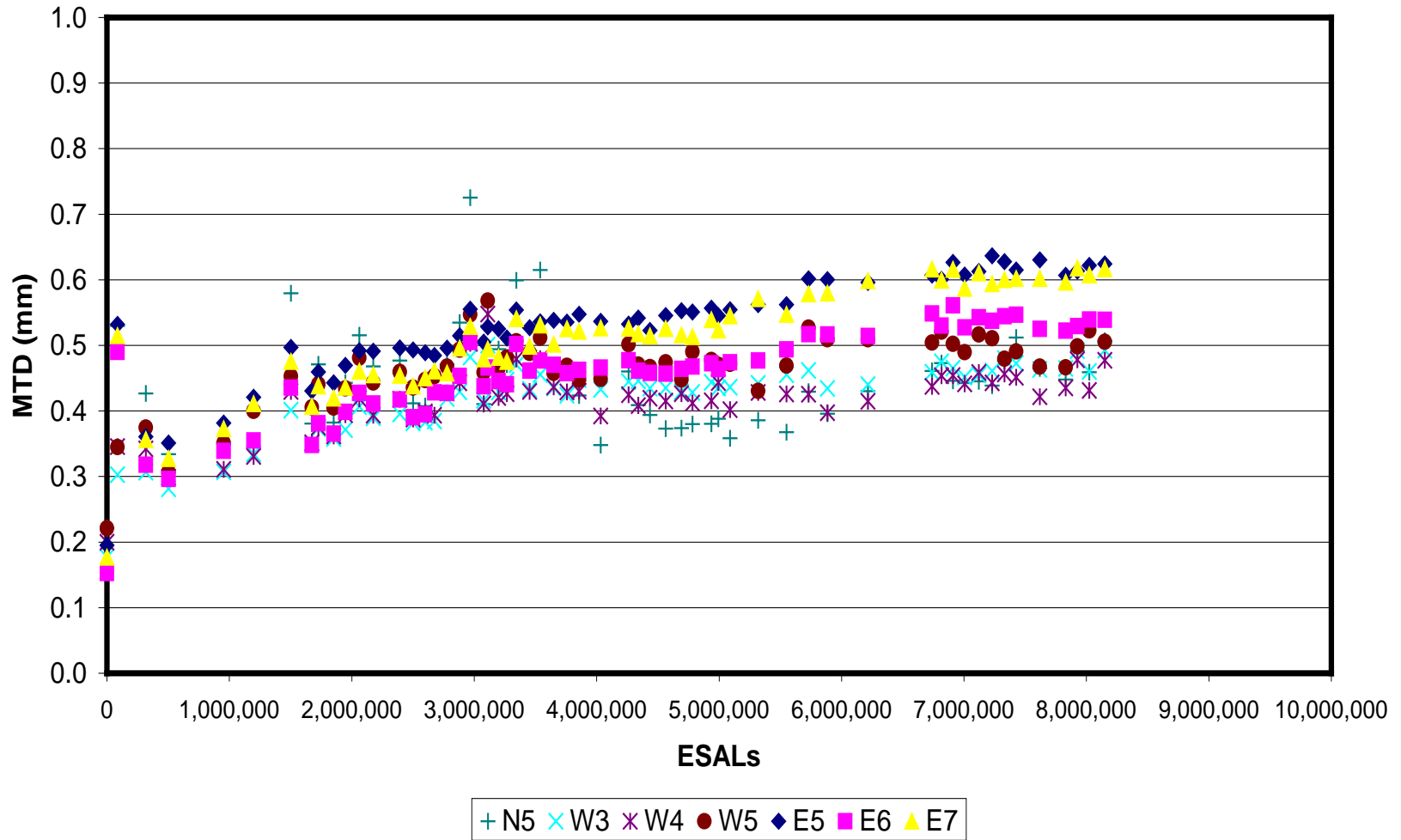
Cracking Observations

- No cracking has been detected except in E7 (45% RAP w/ PG76-22+S) and W3 (20% RAP w/ PG76-22)
- The cracks in E7 and W3 are low severity
- Cracking in E7 is likely due to reflection cracks from previous cycle

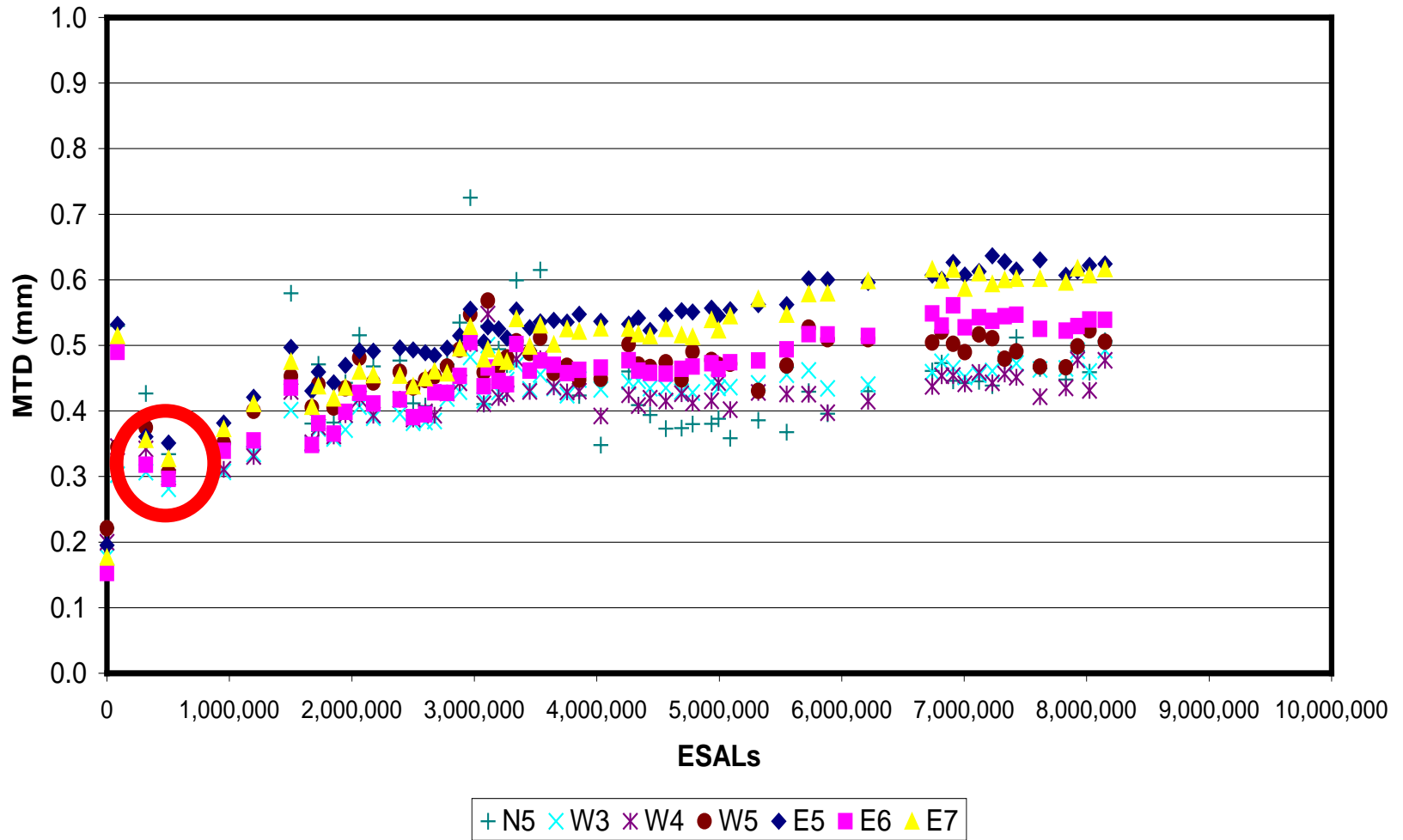
Texture Comparisons with Time/Traffic



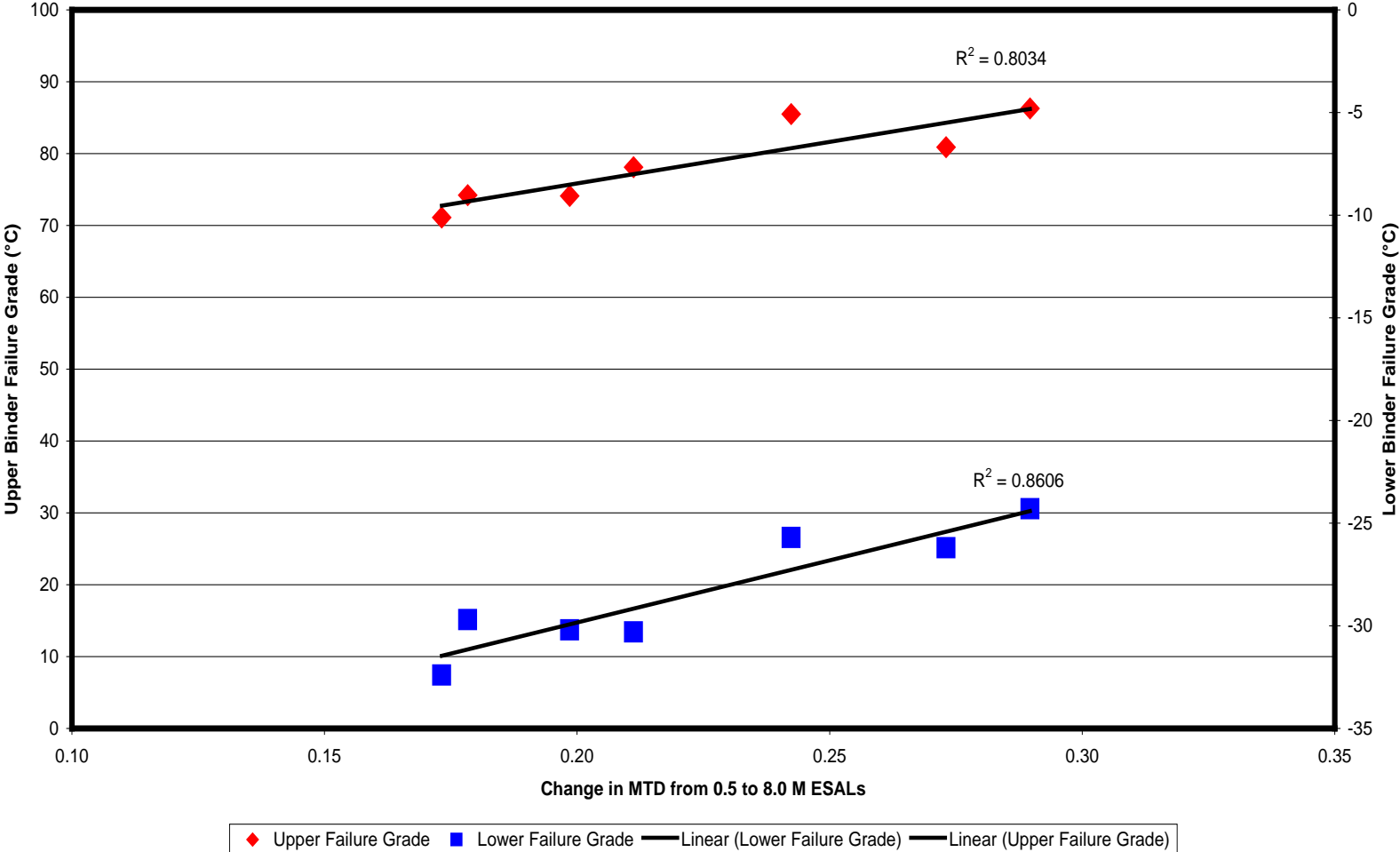
RAP Study Sections



RAP Study Sections



Change in MTD and Binder Grade



Preliminary Observations

- Constructability of all RAP sections was very good. No problems encountered with compaction. The Sasobit did not appear to help compactability.
- Volumetric QC results (low V_a , high VFA) were marginal for some sections.

Preliminary Observations

- Rutting performance on the track has been good.
- Low severity cracking near edge of wheelpaths in section E7 (45% RAP w/ PG76-22+S) is progressing in extent. This cracking is likely reflection cracking from the previous cycle.
- Single longitudinal wheel path crack in W3 (20% RAP w/ PG76-22) is progressing at much slower rate.

Preliminary Observations

- Changes in pavement macro-textures appear to be related to binder failure grade. The texture changes of the RAP sections are within typical ranges.

Recycled HMA Performance Summary

- Few reports are available to evaluate long-term performance of moderate and high RAP mixes
- RAP mixes perform very well with regard to rutting
- Comparisons of field cracking performance range from no difference to slightly more cracking with RAP mixes
- Detailed documentation of older projects would be helpful