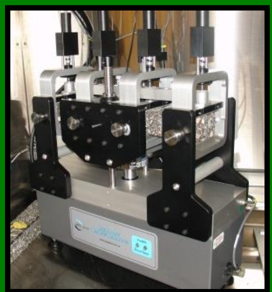
# University of Massachusetts

## Highway Sustainability Research Center

Innovative Research in Asphalt Pavements



# Crack Resistance with Thin Overlays

## Northeast Pavement Preservation Partnership

**Tuesday April 30th, 2013 ♦ 8:00AM**


**Professor Walaa S. Mogawer, P.E., F.ASCE**
Director - Highway Sustainability Research Center
Professor of Civil & Environmental Engineering
University of Massachusetts

# Outline

- Definitions
- Types of Cracking
- Laboratory Tests for Cracking Evaluation
- Texas Balanced Rutting & Cracking Mix Design Procedure for Overlays
- Cracking Evaluation of  Next Generation Overlays
- High Performance Thin Asphalt Overlays

# Definitions

## Thin Asphalt Overlay

- Pavement preservation strategy

- Thickness equal to 1 inch or less

# Definitions

## High Performance Thin Asphalt Overlay (HiPO)

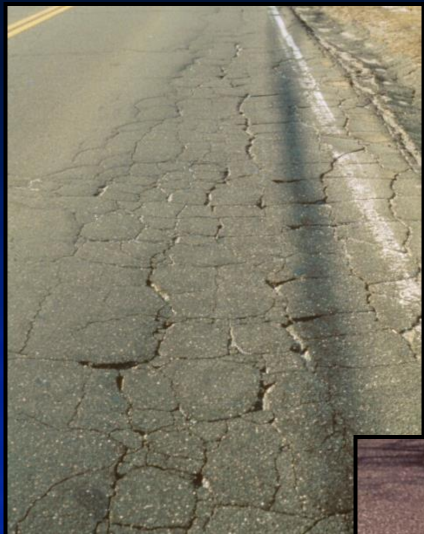
- Pavement preservation strategy

- Thickness equal to 1 inch or less

- Used in applications requiring higher levels of rutting and fatigue resistance

- Mixes typically utilize a polymer modified asphalt

# Types of Cracking



Alligator Cracking

Longitudinal Cracking

Reflective Cracking

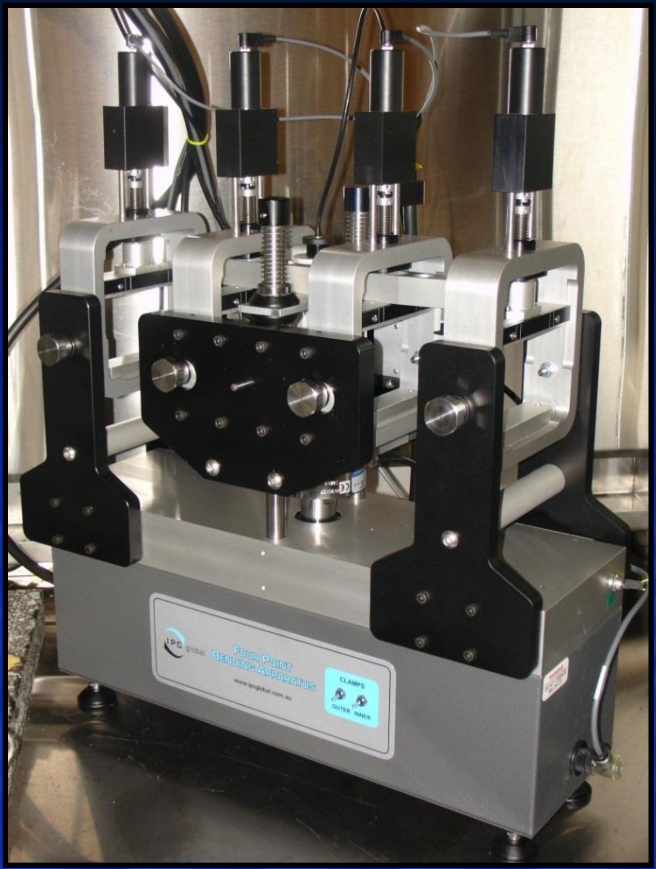
Transverse Cracking

Block Cracking

Edge Cracking

# Laboratory Tests for Cracking Evaluation

# Fatigue – Four Point Bending Beam



Testing in Accordance with AASHTO T321

- Beam specimens fabricated at a target air void level of 7.0 ± 1.0%
- Testing conducted in strain control mode
- Loading Frequency = 10Hz
- Sinusoidal Wave Form
- Failure Criteria = 50% reduction initial stiffness per AASHTO T321 method

| Temperature | Typical Strain Levels |
|---|---|
| Intermediate | 300µs, 500µs, 700µs & 900µs |

# Uniaxial Fatigue in the AMPT

Uniaxial Fatigue (Push-Pull)

AMPT

- Specimens fabricated at a target air void level of 7.0 ± 1.0%
- A proposed standard practice for continuum damage fatigue analysis was developed by the Asphalt Research Consortium (ARC)
- Number of cycles to failure ($N_f$) based on 50% reduction in |E*| criterion

| Specimen # | Temperature | Strain |
|---|---|---|
| 1 | 10°C | 200µs |
| 2 | 10°C | 260µs |
| 3 | 20°C | 200µs |
| 4 | 20°C | 260µs |

# Semi-Circular Bending (SCB) Test

SCB Test Setup

- Three notch depths utilized (25.4 mm, 31.8 mm & 38.0 mm)

- Test temperature = Intermediate

- Loading rate = 0.5mm/min

- Calculating the critical strain energy release rate, Jc

$$J_c = \left(\frac{U_1}{b_1} - \frac{U_2}{b_2}\right)\frac{1}{a_2 - a_1}$$

a = the notch depth
b = sample thickness
U = the strain energy to failure

# Reflective Cracking - Overlay Tester

- Test Temperature = Intermediate
- Test Termination at 1,200 cycles or 93% Load reduction
- Testing in accordance with Tex-248-F

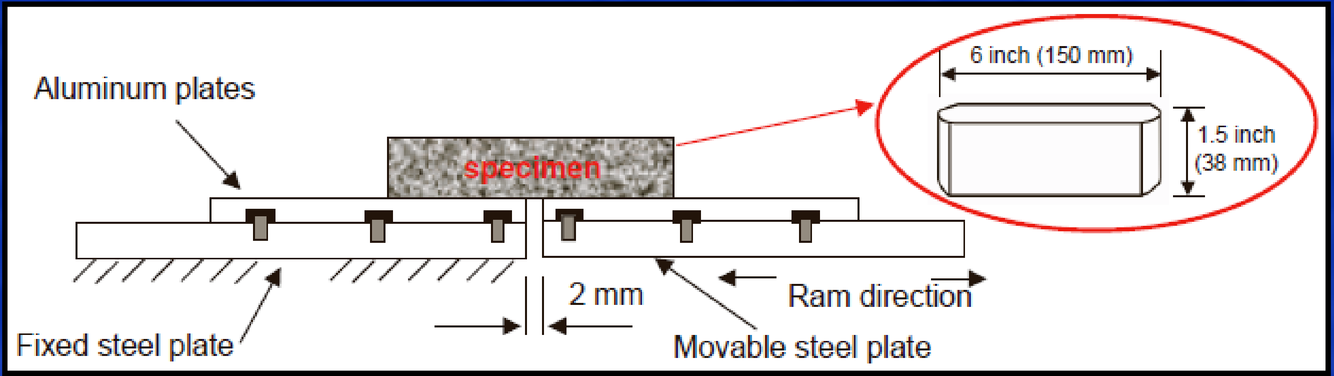
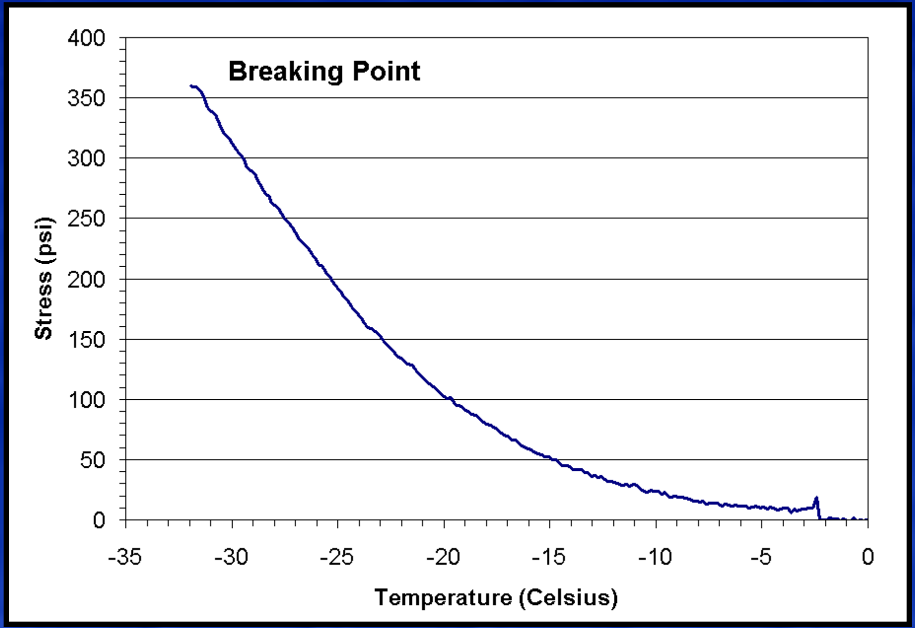



**Diagram from: Zhou et al. "Overlay Tester: Simple Performance Test for Fatigue Cracking" Transportation Research Record: Journal of the Transportation Research Board, No. 2001, Transportation Research Board of the National Academies, Washington, D.C., 2007, pp. 1–8.**

# Mixture Low Temperature Cracking - TSRST

- Cooling Rate of -10ºC/hour
- Testing in accordance with AASHTO TP10-93



# Other Laboratory Tests

- Low Temperature Creep Compliance (IDT) - AASHTO T322 Combined with LTSTRESS Analysis
- Asphalt Concrete Cracking Device (ACCD)
- Asphalt Binder Cracking Device (ABCD) - AASHTO TP92
- Linear Amplitude Sweep (LAS) Test

# Texas Balanced Rutting & Cracking Mix Design Procedure for Overlays

# Balanced Mix Design Procedure for Overlays

1. Determine OAC:
   - Evaluate volumetric properties of compacted specimens
   - Determine OAC at target density
   - Check VMA requirements

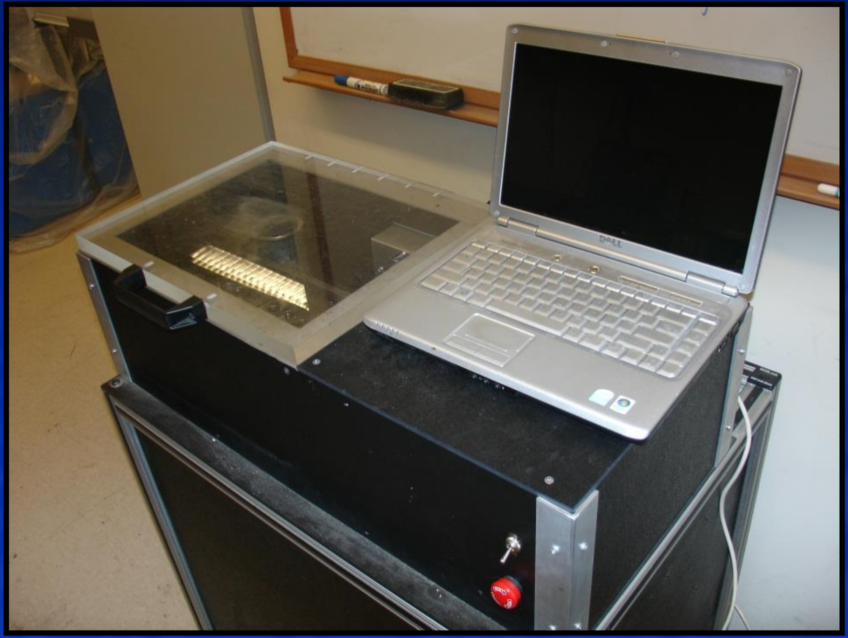
# Balanced Mix Design Procedure for Overlays

2. Evaluate mix properties:
   - Compact two HWTD and two OT specimens at OAC, OAC+0.5%, and OAC+1.0% at 93±1.0% density
   - Run HWTD to evaluate rutting resistance
   - Run OT to evaluate cracking resistance

3. Select a balanced asphalt content based on HWTD and OT requirements

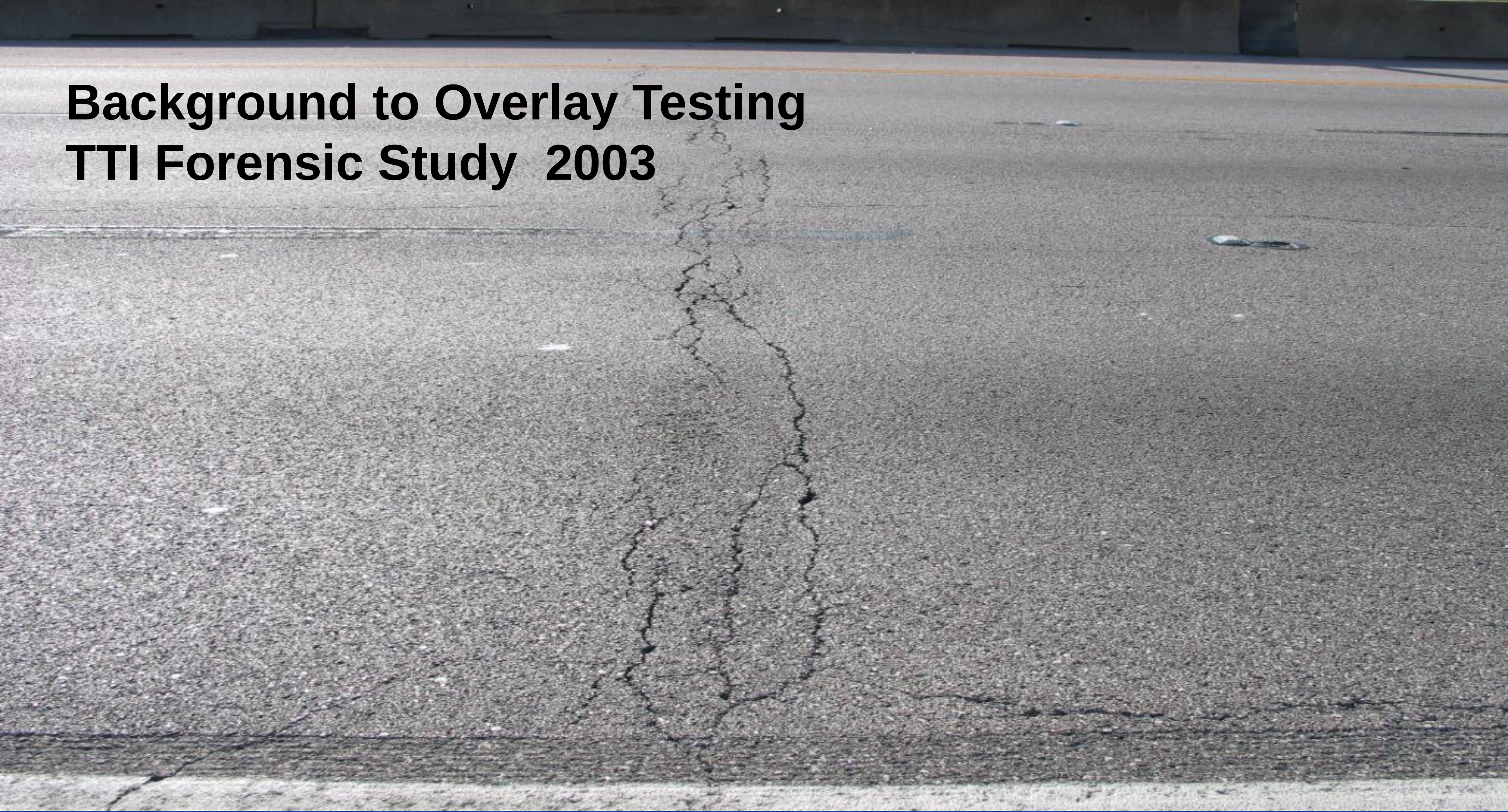
# Balanced Mix Design Procedure for Overlays


**Hamburg Wheel Tracking Device**



**Overlay Tester**

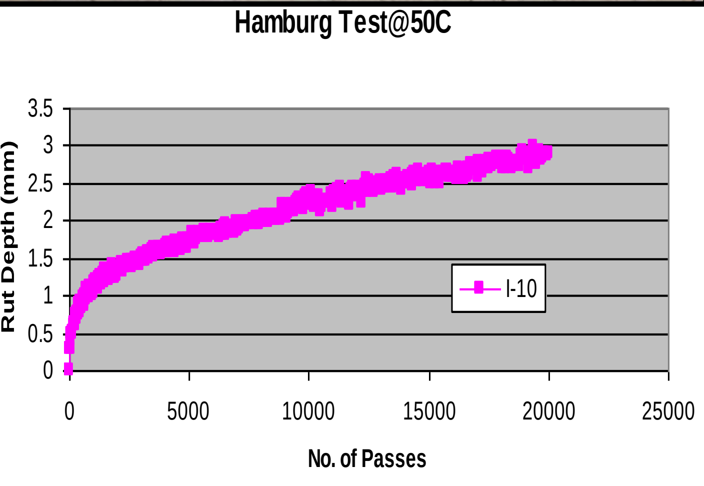
# Background to Overlay Testing
# TTI Forensic Study 2003



**Reflection Cracking on IH 10 in Houston**

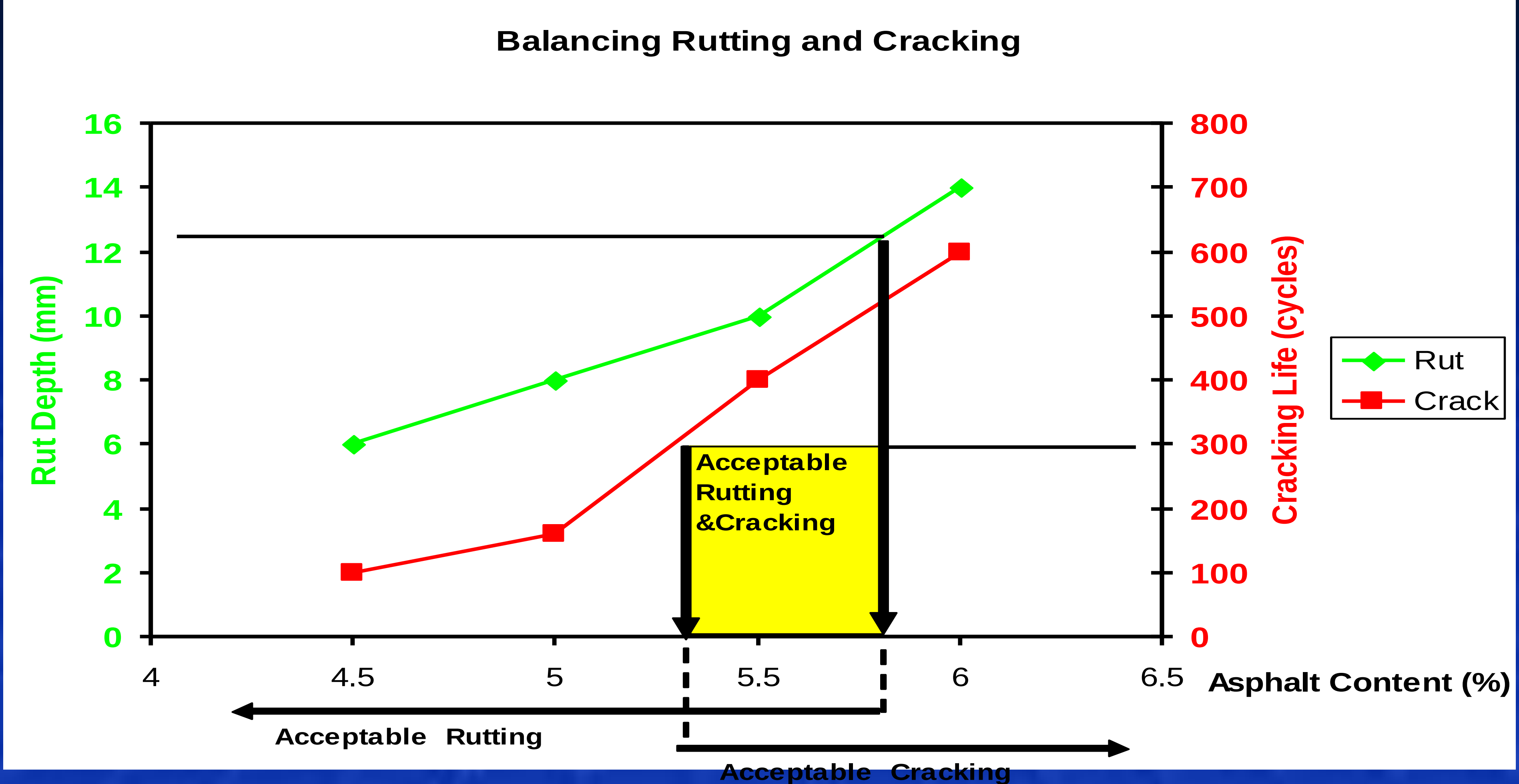
Had to be replaced after 3 years

# IH-10 Type C (PG76-22), 4.4%AC




| Properties | Result | Target |
|---|---|---|
| Cracking<br>(overlay tester cycles to failure) | **2** | >300 |
| Rutting<br>(Hamburg cycles to 12.5mm rut) | **2.9 mm at 20K** | >20K |

# Balanced Mix Design Procedure for Overlays



# Cracking Evaluation of Next Generation Overlays

**Verification of Thin Lift Overlays Incorporating High Amounts of Recycled Materials RAP, RAS, & GTR**

# Cracking Verification for Thin Overlays

- Testing conducted by HSRC since 2009

- Mixtures tested include:

  High Reclaimed Asphalt Pavement (RAP) Content Mixtures

  Mixtures Incorporating Recycled Asphalt Shingles (RAS)

  Mixtures Incorporating High RAP and Asphalt Rubber Containing GTR

  Mixtures Incorporating Rejuvenators and High RAP and/or RAS

  Mixtures Incorporating Warm Mix Asphalt Additives and High RAP and/or RAS

# Cracking Verification for Thin Overlays

- Use Overlay Test data in conjunction with Hamburg Wheel Tracking Device (HWTD) test data
  - Generally, mixtures performing well in the Overlay Tester exhibit poor performance in the HWTD
  - Identify if not enough asphalt is being obtained from recycled materials (under asphalted mixtures)
  - Identify if rejuvenator softens highly recycled mixtures
  - Identify conditions where WMA additives improve cracking resistance

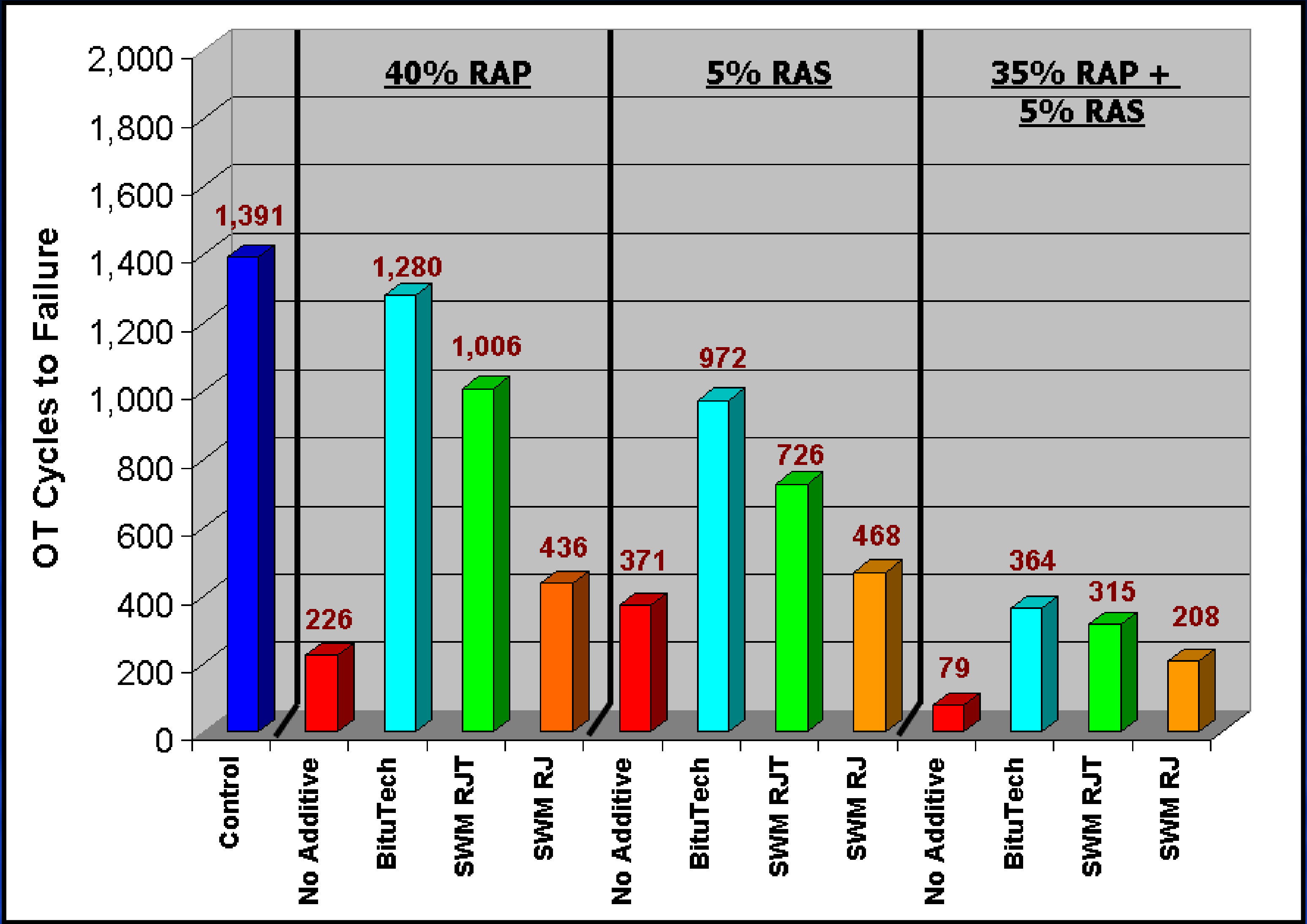
# Highly Recycled + WMA

| Mixture | Average OT Cycles to Failure | HWTD Stripping Inflection Point |
|---|---|---|
| 9.5 mm Control (PG58-28) | 1,004 | 16,800 |
| 9.5mm + 40% RAP | 3 | NONE |
| 9.5mm + 5% RAS | 308 | NONE |
| 9.5mm + 35% RAP + 5% RAS | 22 | NONE |
| | | |
| 9.5mm Control + 1% WMA | 936 | 6,200 |
| 9.5mm + 40% RAP + 1% WMA | 143 | NONE |
| 9.5mm + 5% RAS + 1% WMA | 297 | 9,800 |
| 9.5 mm + 35% RAP + 5% RAS + 1% WMA | 63 | NONE |

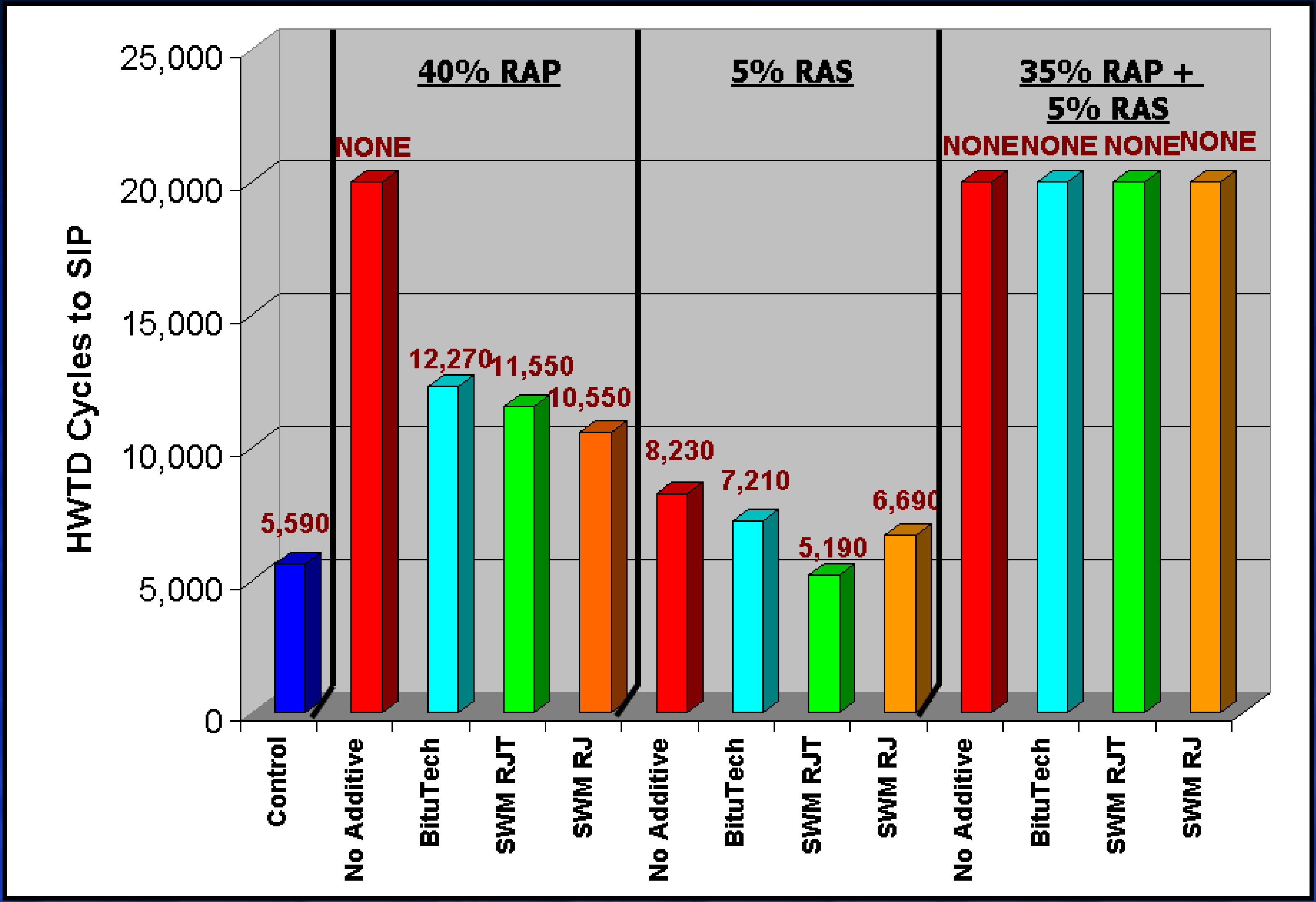
# Highly Recycled + AR + WMA

| Mixture | Average OT Cycles to Failure | HWTD Stripping Inflection Point |
|---|---|---|
| ARGG Control | 351 | NONE |
| ARGG + 25% RAP | 43 | NONE |
| ARGG + 40% RAP | 54 | NONE |
| | | |
| ARGG Control + 1% WMA | 275 | NONE |
| ARGG 25% RAP + 1% WMA | 64 | NONE |
| ARGG 40% RAP + 1% WMA | 21 | NONE |

# Highly Recycled + Rejuvenator



# Highly Recycled + Rejuvenator



# OT for Performance Verification

- Overlay Tester data helps identify when highly recycled mixture is being softened (high cycles to failure) which leads to better cracking resistance.

- HWTD data indicates when highly recycled mixture is being stiffened (more HWTD passes to failure).

- Proper thin lift mixture design balances the performance of mixture in both tests, yielding mixture with good cracking and rutting characteristics.

# High Performance Thin Asphalt Overlays

# Pilot Specifications for High Performance Thin Overlays

**A pilot regional specification for HiPO mixtures entitled "Superpave 9.5 mm Highly Polymer-Modified Thin Overlay Specifications" was developed based on input and recommendations from members of state transportation agencies of various regional pavement preservation partnerships, industry, and academia.**

**Pilot specification on AASHTO TSP2 web site:**

**http://www.tsp2.org/pavement/other-information/research-pavement/**

# High Performance Pilot Specifications

**The goal of the specification was to provide a guide that could be utilized to develop better performing preservation/ rehabilitation overlay mixtures that addresses reflective cracking, low temperature cracking, fatigue cracking, and rutting issues encountered with conventional overlays that shorten there service life.**

# Pilot Specification

| HiPO Thin Lift Mixtures with & without RAP | | |
|---|---|---|
| **Property** | **Device/Test** | **Criteria** |
| Thermal Cracking Temperature of Mixture | Thermal Stress Restrained Specimen Test (TSRST) - AASHTO TP10-93 | ± 6°C from the low temperature performance grade of the binder |
| Cracking | Overlay Test - TXDOT Tex-248-F | Average overlay test cycles to failure ≥300 |
| Fatigue Life | Flexural Beam - AASHTO T321 | ≥100,000 Cycles |
| Rutting | Asphalt Pavement Analyzer (APA) AASHTO T340 | Average rut depth for six specimens is ≤ 4 mm at 8,000 loading cycles |
| **Added Requirement for HiPO Thin Lift Mixtures with RAP** | | |
| Cracking | Overlay Test - TXDOT Tex-248-F | Average overlay test cycles to failure within ±10% of the overlay test cycles to failure of control specimens without RAP |

# Vermont US Route 7 - Danby, VT

- **AADT = 4,500 vehicles**
- **Existing pavement surface was 14 years old with isolated areas of permanent deformation, some transverse cracking and some shrinkage cracking.**
- **Surface preparations included spot shimming of permanent deformation areas, crack sealing, patching of cracks wider than 1 inch and patching of all potholes.**
- **After one year in service there is no apparent distress in either test section or in the control as of mid to late spring 2012.**

# Minnesota Trunk Highway (TH) 100 - Minneapolis, MN

- 1,370 tons of HiPO mixture placed in the summer of 2011.
- AADT = 64,000 vehicles
- Existing roadway exhibited bad transverse cracks and potholes.
- Surface preparation was milling to a depth of 1.5 to 2 inch.
- After one winter in service, some transverse cracks have reflected through the HiPO overlay. Rutting was not noted.

# New Hampshire Route 202 - Rochester, NH

- 1,500 tons of the HiPO mixture incorporating 25% RAP placed.

- AADT = 4,600 vehicles

- Existing pavement was in poor condition and no milling was done prior to the placement of the HiPO.

- After one year in service, the HiPO mixture has minimal cracking returned.

# Mixture Fracture Performance Data

| Type | Reflective | Thermal | Fatigue | Fatigue | Mixture Meets All Cracking Criteria in Pilot Spec.? |
|---|---|---|---|---|---|
| Test Information | Average Overlay Test (OT) Cycles to Failure | TSRST Avg. Low Cracking Temperature | Beam Fatigue $N_f$ to 50% Reduction in Stiffness | Semi-Circular Bending (SCB) Test | |
| Pilot Specification Criteria | Average overlay test cycles to failure ≥300 | ± 6°C from the low temperature performance grade of the binder | ≥100,000 Cycles[2] | Not in Spec.<br><br>Critical Value of J-integral $(J_c)$ kJ/m$^2$ | |
| MN Control | 133 | -32.2°C | 26,004 | 0.40 | NO Reflective & Fatigue |
| MN HiPO | 434 | -31.8°C | 336,019 | 0.40 | YES |
| NH HiPO | 2,000 [1] | -33.1°C | 348,266 | NT | YES |
| VT HiPO No RAP | 2,000 [1] | -30.1°C | 794,790 | 0.45 | YES |
| VT HiPO With RAP | 1,144 | -27.8°C | 383,065 | 0.36 | NO Reflective & Thermal |

MN = Minnesota NH = New Hampshire VT = Vermont NT = Not tested due to lack of materials.
(1) Mixture did not meet test failure criteria at the conclusion of 2,000 cycles in OT.
(2) 750 μstrain for PG76-34 HiMA & 500 μstrain for PG82-28 HiMA

# Thank You!