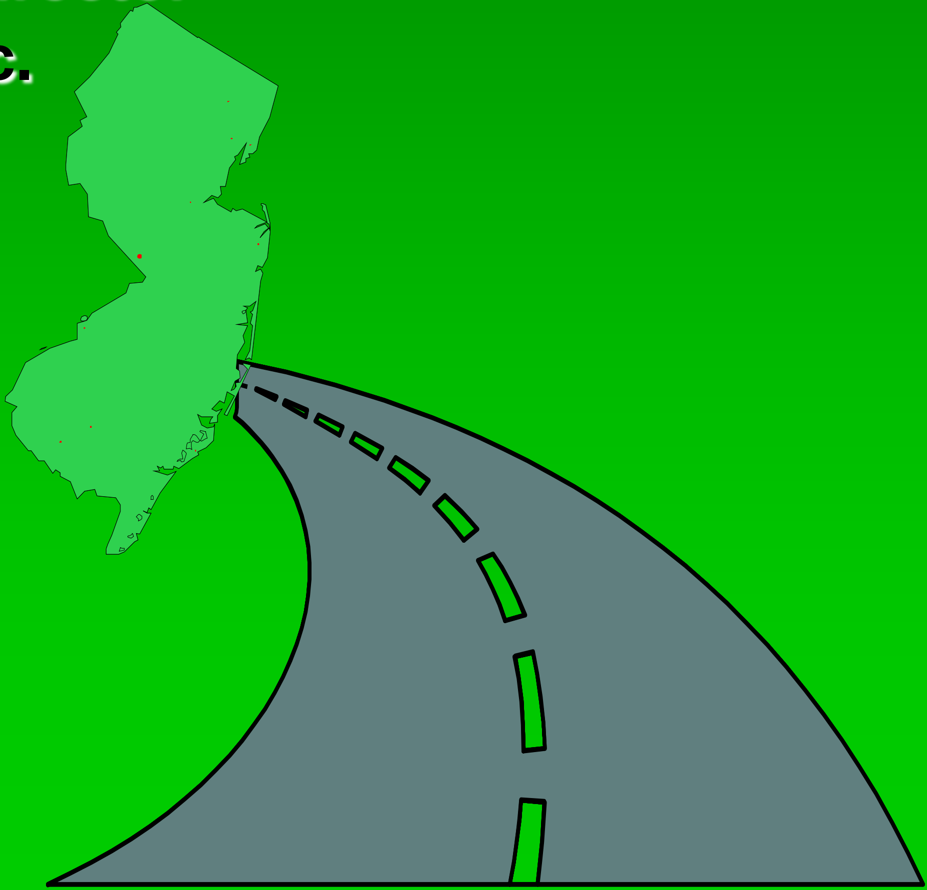
NJ I-295: A Perpetual Pavement Design and Construction Project

Presented by:

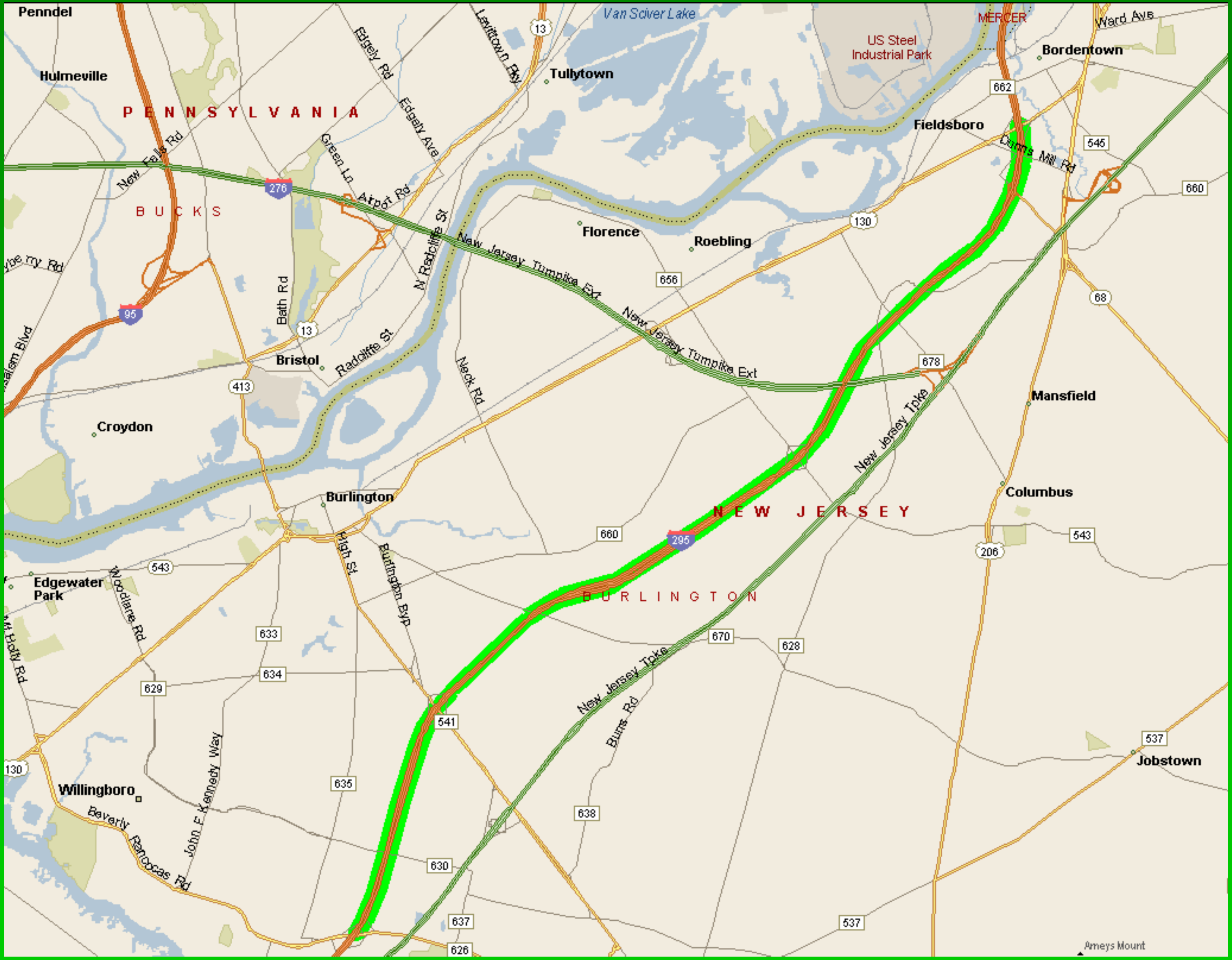
- **Robert Sauber, Executive Director**
- **NJ Asphalt Pavement Assoc.**

Presented to:

- **AMAP 12th Annual Meeting**
- **February 16, 2011**



Rt I-295 MP 45 – 57
Burlington County, NJ



The I-295 Problem

- Rt I-295 constructed 1972 to 1974
- Reached terminal serviceability a decade ago, NJ 101.5 attacks
- PCCP with ASR (alkali-silica reaction)
- Limited pavement program funding
- 90,000 ADT with 11% TT that must be maintained during construction

ASR at Transverse Joint

I-295 Project Specifics

- Rt. I-295 NB & SB MP 45 to 57.3
  - Three12’ travel lanes with 4’ inside and 12’ outside shoulders
  - Total paved width 52 ft each direction
- 21 structures within project limits resulting in 20 undercut locations to maintain underclearance
- Full closure limited to 59 days during summer months when traffic is “lower”

Rt I-295 NB right lane

Potential Solutions

- Patch and overlay, cost $26 million
  - Short service life, not cost effective
  - Ultimate fix will be more difficult
- Replace broken slabs
  - Slow and expensive, cost overrun risk
  - Not a long term solution, never ending
- Rubblization and HMA Overlay
  - Traffic control difficult: profile changes

Chosen Solution

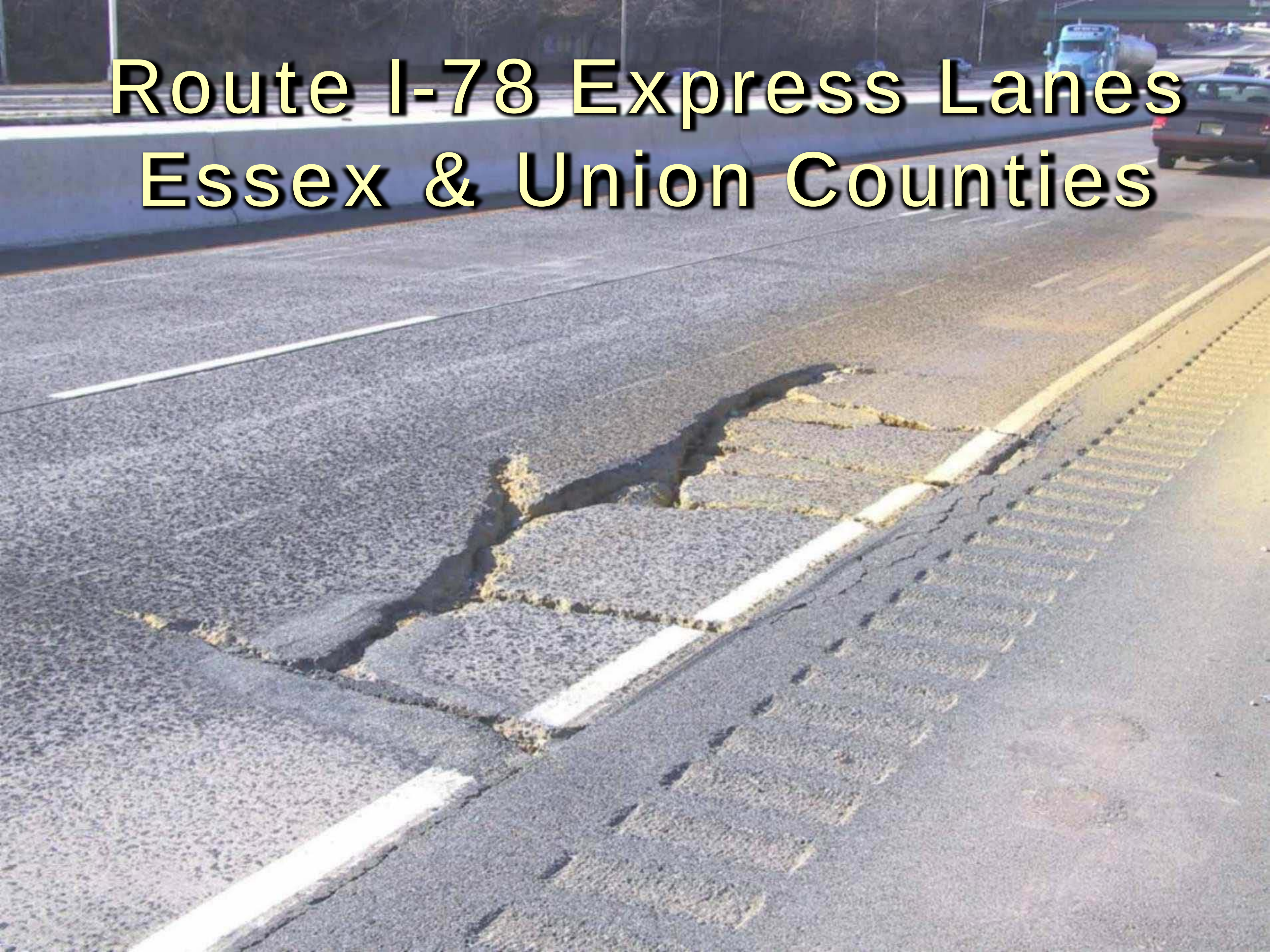
- Rubblization with directional closure to increase contractor productivity and safety, reduces project duration and cost
- Hyperbuild to reduce traffic exposure and obtain public support for directional closure
- Sustainability Elements
  - Rubblization recycles PCCP in place, limits excavation and material hauling
  - Engineered HMA base course will reduce thickness: save time, $ and the environment

Why Rubblization?

- Rubblization $1.46/sy vs. Removal $5.76/sy
  - Average of 3 lowest I-295 bids and typical
- Rubblization is cost effective when the amount of patching is approximately 10%
- Lower Risk to Owner and Contractor
  - Reduced subgrade exposure to moisture damage
- 4X faster than breaking, excavating, hauling and placing DGABC with traditional methods

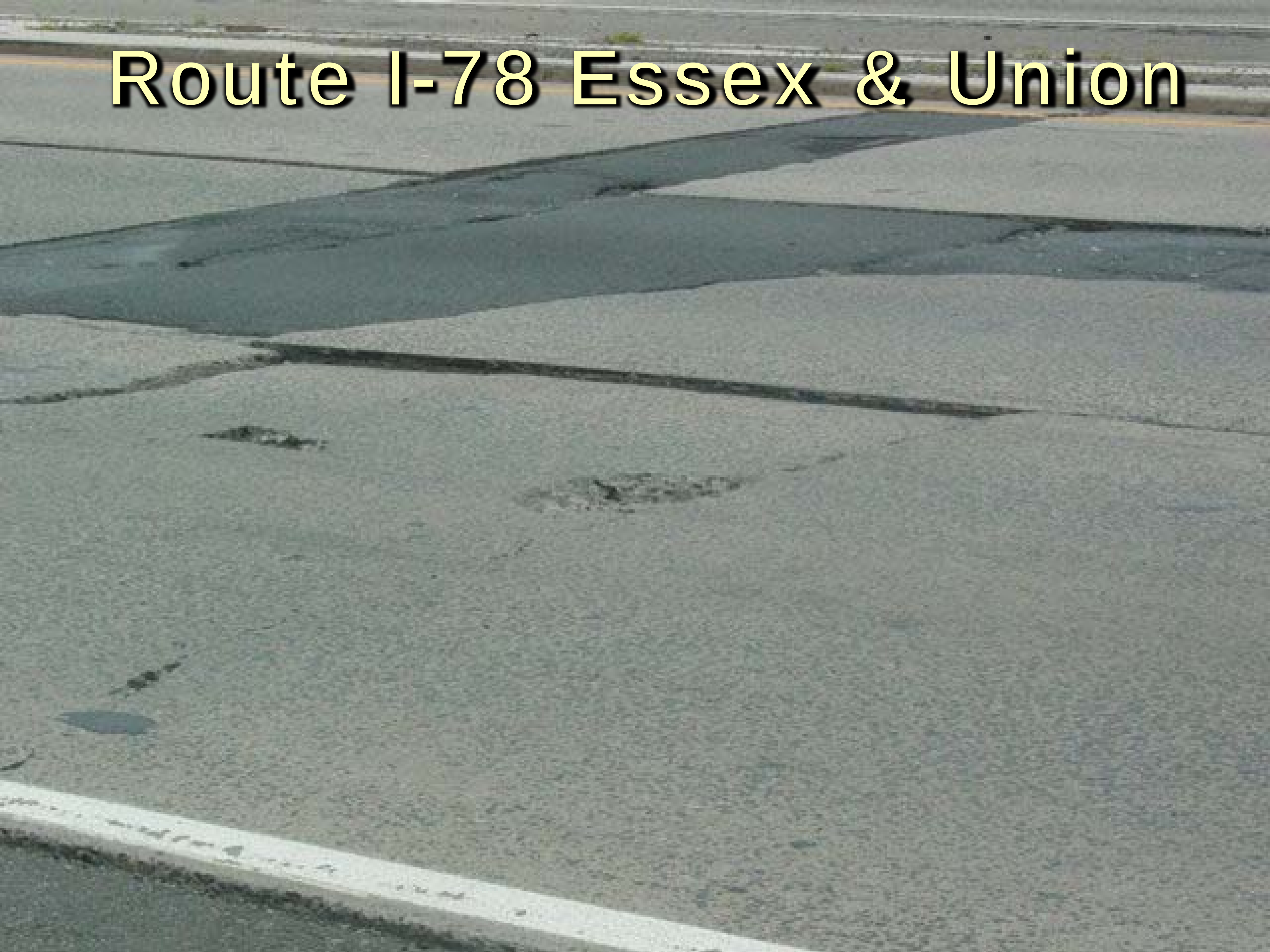

TULSA, OKLA
ESONANT
PAVEMENT
BREAKER

Route I-78 Express Lanes
Essex & Union Counties



Route I-78 Local Lanes
Essex & Union Counties

Route I-78 Essex & Union

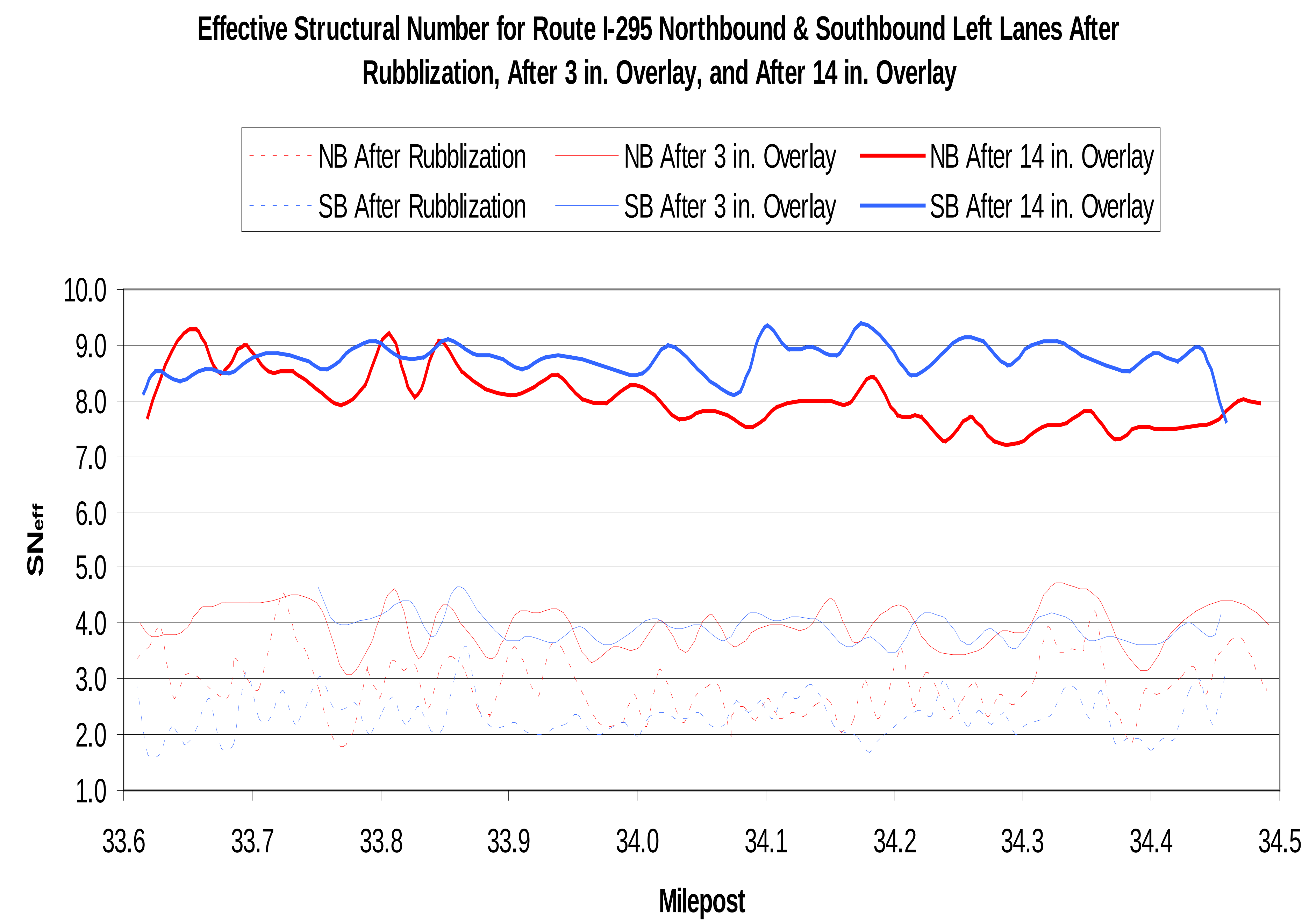


Cross section of rubblized I-78 PCCP


Portable Seismic Property
Analyzer (PSPA) for soils

Route I-78 PSPA Test Results

- Elastic modulus is evaluated from the average velocity of surface waves
- Seismic testing is a low strain modulus, reductions should be made to describe it as resilient modulus
- Modulus varied between 80 and 400 ksi
- Average modulus was 217 ksi


Effective Structural Number for Route I-295 Northbound & Southbound Left Lanes After Rubblization, After 3 in. Overlay, and After 14 in. Overlay
NB After Rubblization
NB After 3 in. Overlay
NB After 14 in. Overlay
SB After Rubblization
SB After 3 in. Overlay
SB After 14 in. Overlay
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
SNeff
33.6
33.7
33.8
33.9
34.0
34.1
34.2
34.3
34.4
34.5
Milepost

Rubblization Design Criteria

- AASHTO M-E Design Guide for Highways 150 ksi for PCCP 8 to 12 inches thick
- Asphalt Institute Airfield Project 2007
  - Slabs 6 to 8 in. thick: Moduli from 100 to 135 ksi
  - Slabs 8 to 14 in. thick: Moduli from 135 to 235 ksi
  - Slabs >14 in. thick: Moduli from 235 to 400 ksi

Initial Pavement Design

- Initial design performed using 1993 AASHTO Pavement Design Guide
  - 12” thick HMA over rubblized PCCP, 4 lifts
  - Rubblized PCCP and subgrade modulus determined using PSPA and FWD data from previous rubblizion projects
  - The 59 day closure required extremely high HMA production and placement; up to15,000 tons/day

Initial Pavement Design

- For 12” thickness, 2400 linear feet (+ width of bridge) of PCCP excavation at each structure, 100’ transition per inch thick
- From past experience, box outs problematic because they are usually at low points
- Most excavated areas required a 2 ft undercut (clay subgrade)
- Acid producing clay (pH 3.5) limited in-situ lime treatment

Typical Box Out

Acid Producing Clay

Rt. 295 NB Haul Road

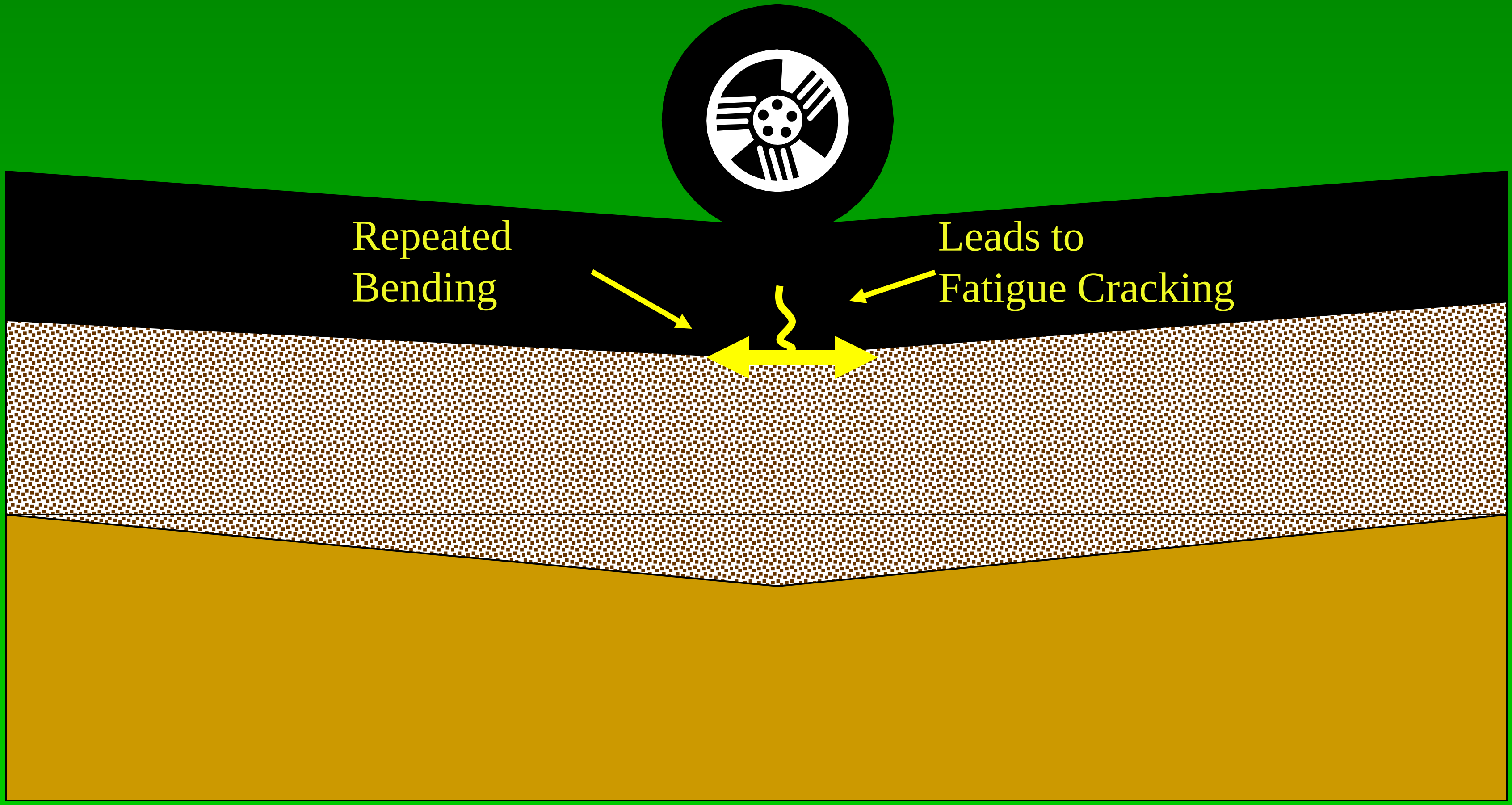
M-E Design Approach

- Time and money could be saved by reducing HMA thickness from 12” to 8”
- Evaluated pavement response in MEPDG (typical NJ HMA materials) and revealed bottom-up cracking to be an issue at 8” thickness, also a rutting potential
- NJDOT decided on perpetual pavement design with “rich” bottom layer but need to develop a specification to insure that properties met design requirement

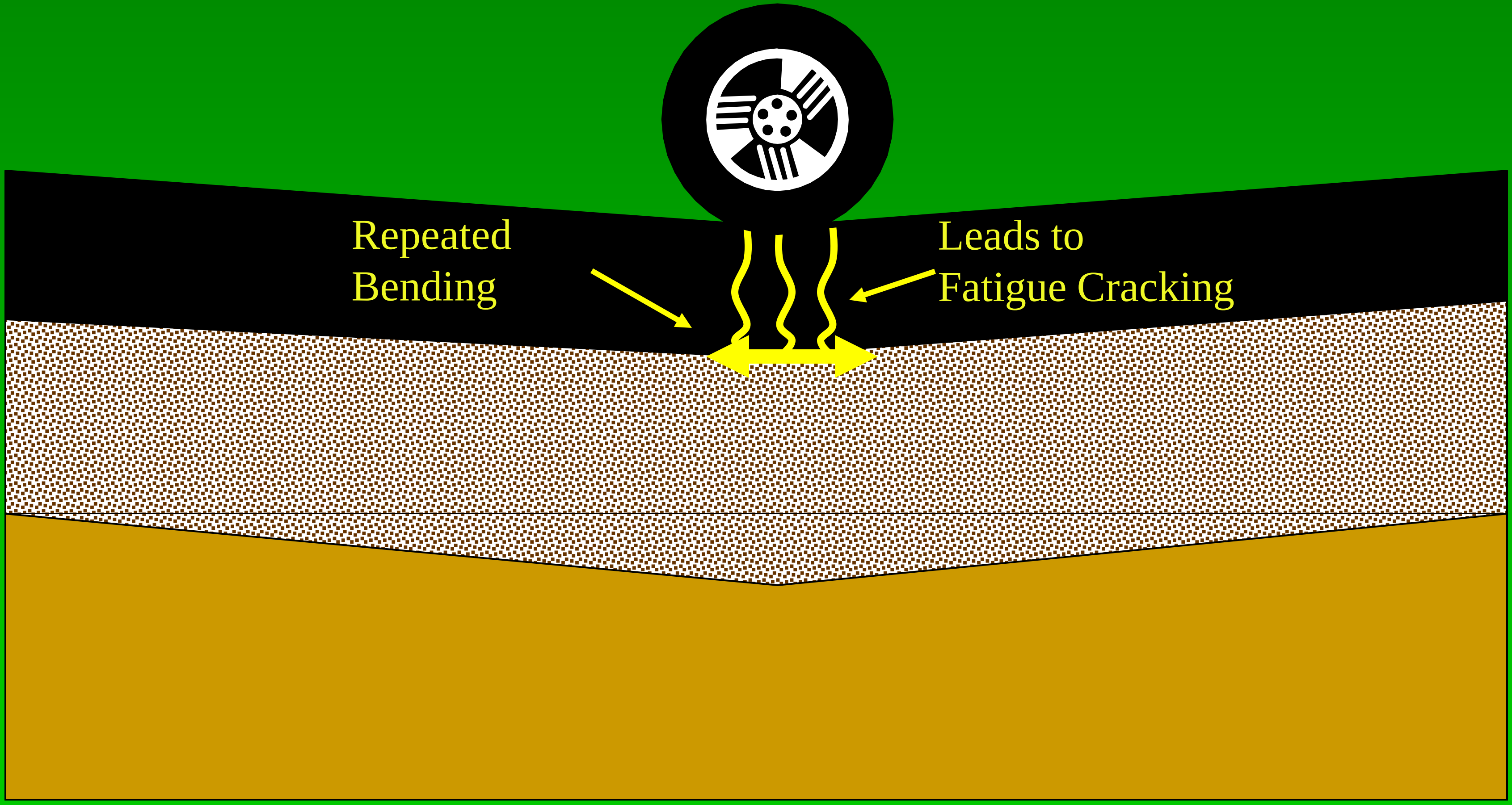
Ad Hoc Team Assembled

- NJDOT reached out to industry and academia to develop a solution
- Rutgers University- Tom Bennert
- NuStar Energy- Frank Fee
- NJAPA- Wayne Byard
- Also consulted with experts from NAPA, Kraton Polymer and a few others to develop a level of confidence

Bottom-up Cracking



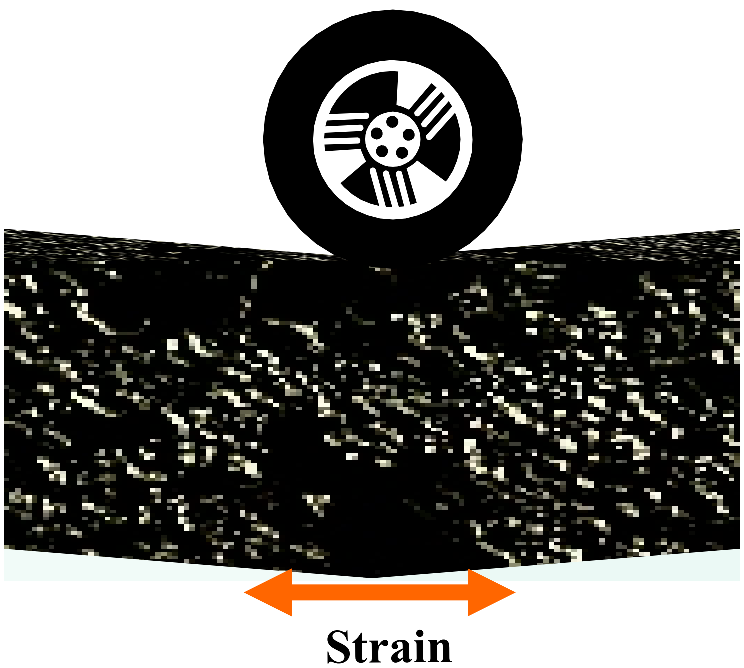
Bottom-up Cracking

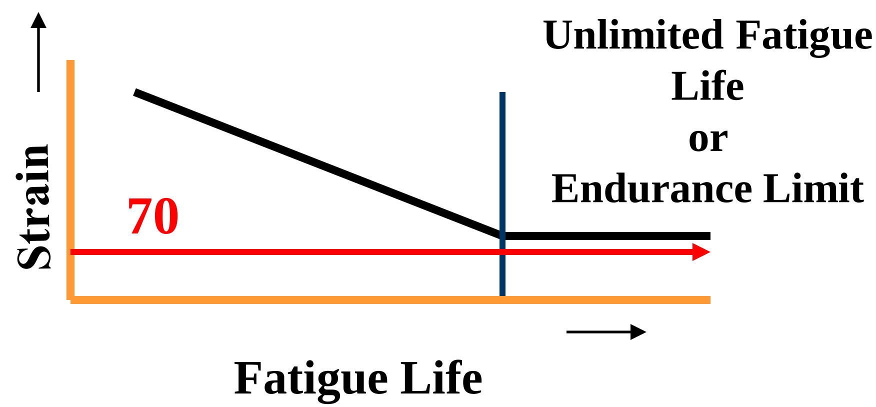


Fatigue Theory for Perpetual Pavements

High Strain = Short Life

Low Strain = Unlimited Life





Goal of Perpetual Pavement Design

- Design the structure such that there are no deep structural distresses
  - Bottom up fatigue cracking
    - Limit tensile strain at bottom of asphalt layer
  - Structural rutting
    - Limit compressive strain at top of subgrade
- All distresses can be quickly remedied from surface
- Result in a structure with ‘Perpetual’ or ‘Long Life’

I295 – Designing for Perpetual Pavement

- Need to determine tensile strain at bottom of HMA
  - Use Elastic Layer Theory
  - Use "optimal" structure and thickness
  - Need to make sure HMA can withstand resultant tensile strain
- Need rut resistant HMA
  - New pavement section over rubblized PCC – very stiff so likelihood of structural rutting minimal – more concerned with surface rutting

Change Design Methodology

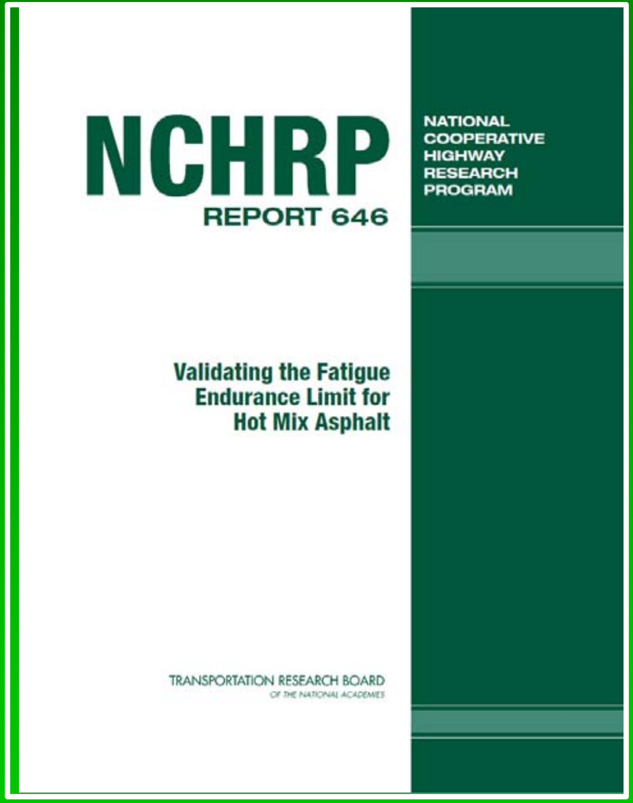
- Evaluated maximum tensile strain with 8” HMA over rubblized PCC
  - Used JULEA software – same in MEPDG
  - Resulted in 82 micro-strains (rounded up to 100 microstrains to be conservative)
- Final design pavement cross-section
  - 2” SMA Surface
  - 3” 19M76 Intermediate Course
  - 3” of NJDOT Bottom Rich Base Course
    - Designed specifically for this project
    - Utilized Endurance Limit concept

Rt I-295 Pavement for Full Reconstruction

- 2" SMA 12.5 Surface Course
- 3" HMA 19M76 Intermediate Course
- 10" HMA 25M64 Base Course
- 8" Dense Graded Aggregate Base Course

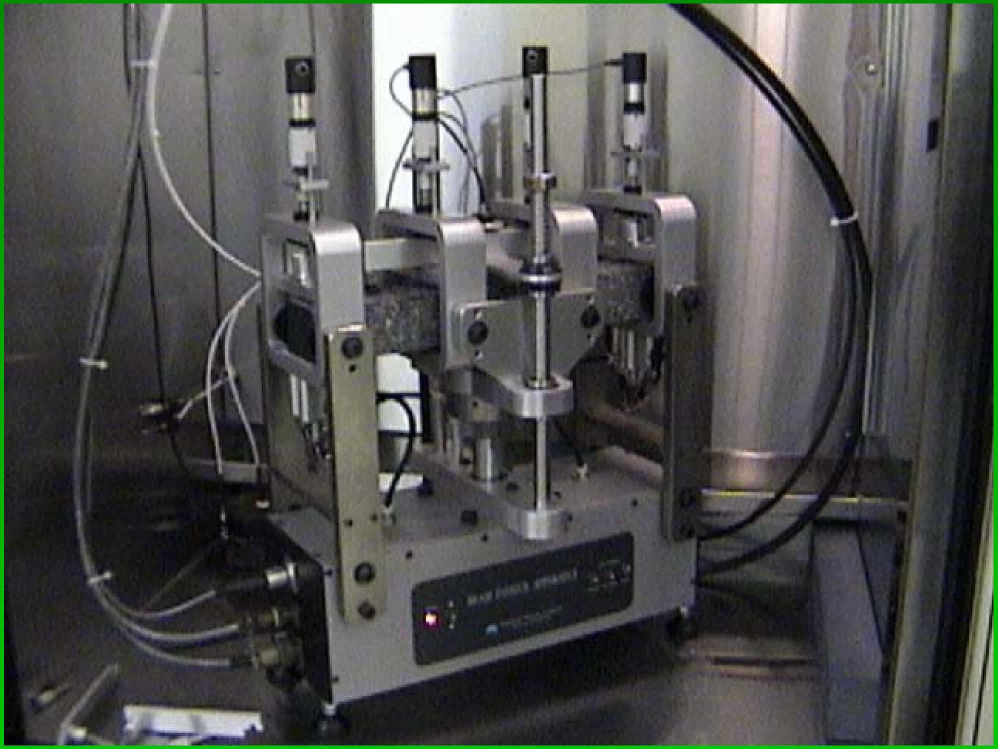
Endurance Limit

- Used methodology in NCHRP Report 646
- Conduct flexural beam fatigue at 400 and 800ms
  - 3 samples each
- Use 95% confidence interval with a selected # of repetitions



HMA Flexural Fatigue Test

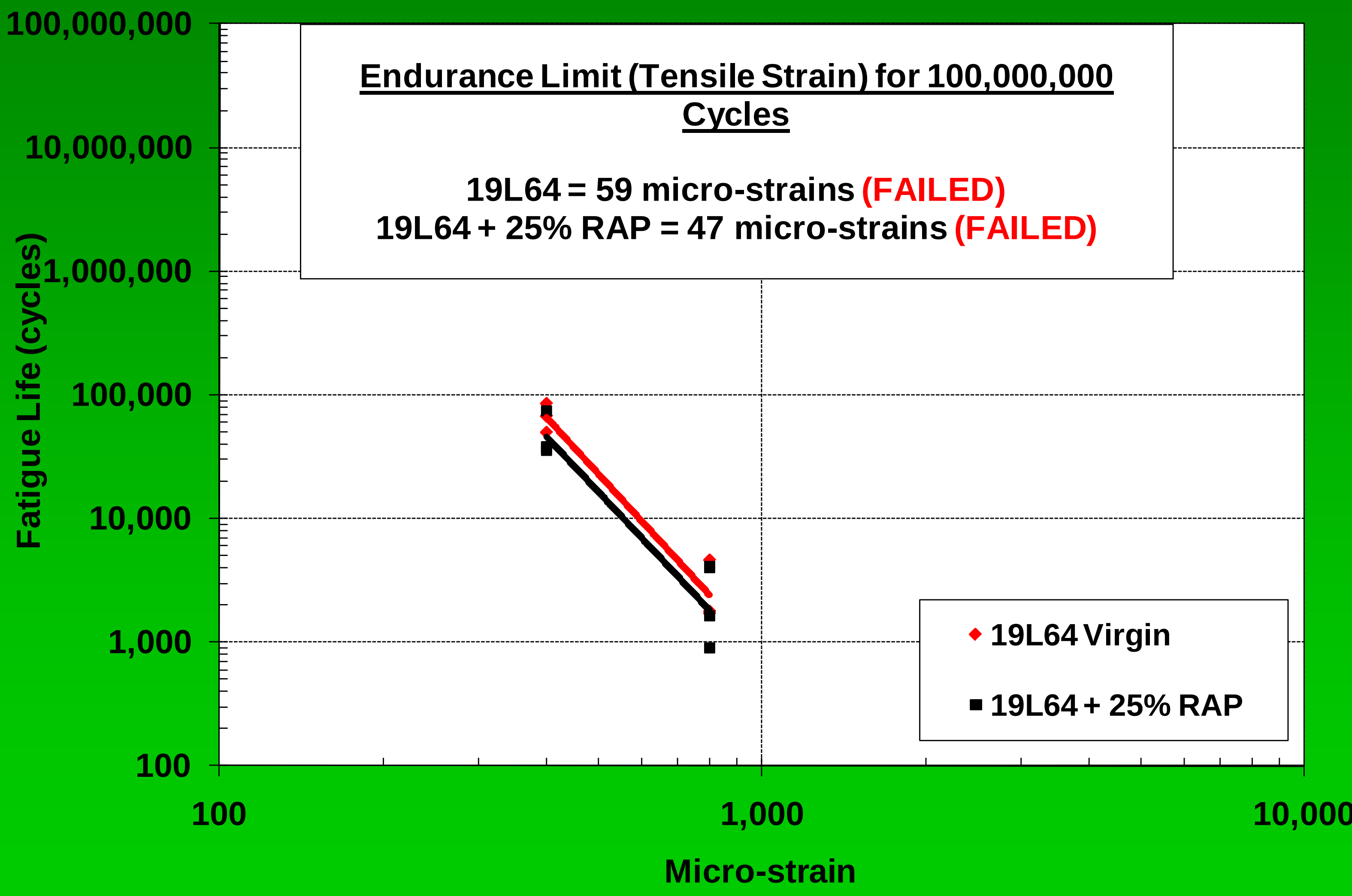
- Flexural Beam Fatigue AASHTO T-321
- Tests mix's ability to withstand repeated bending
- Data = number of loading cycles to failure (Fatigue Life)
- Run at typical strain (deformation) to simulate anticipated pavement deflections



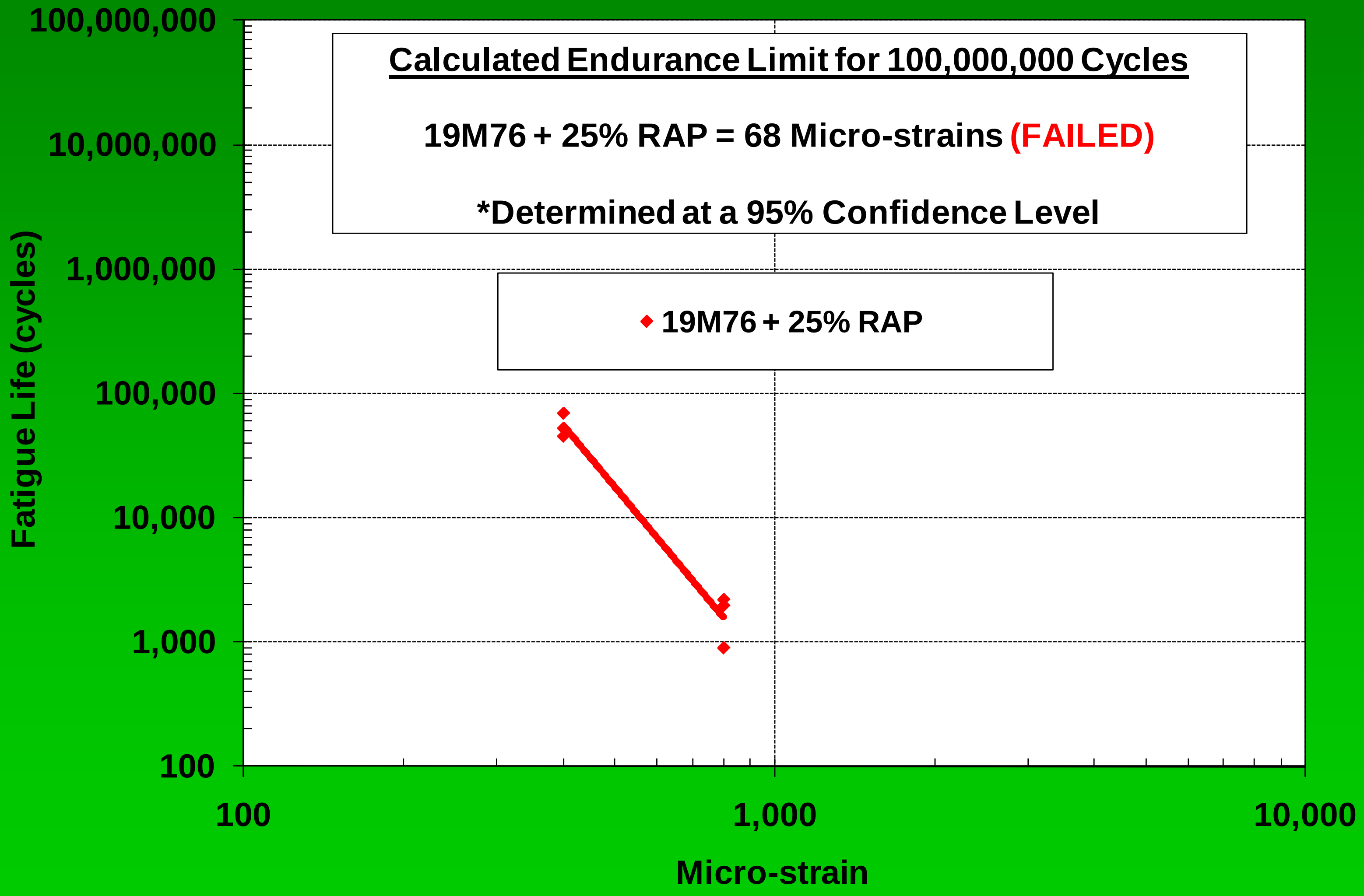
What Mix to Use?

- With performance evaluation in place, Rutgers University began testing plant produced mixes in Fall 2009
- Different base course mixes were evaluated – none were successful
  - Must achieve an Endurance Limit greater than 100 micro-strains at 100,000,000 cycles (NCHRP 9-38 had used 50,000,000 cycles)
- Required design of new mixture
  - Bottom Rich Base Course - BRBC

Endurance Limit – 19L64



Endurance Limit – 19M76



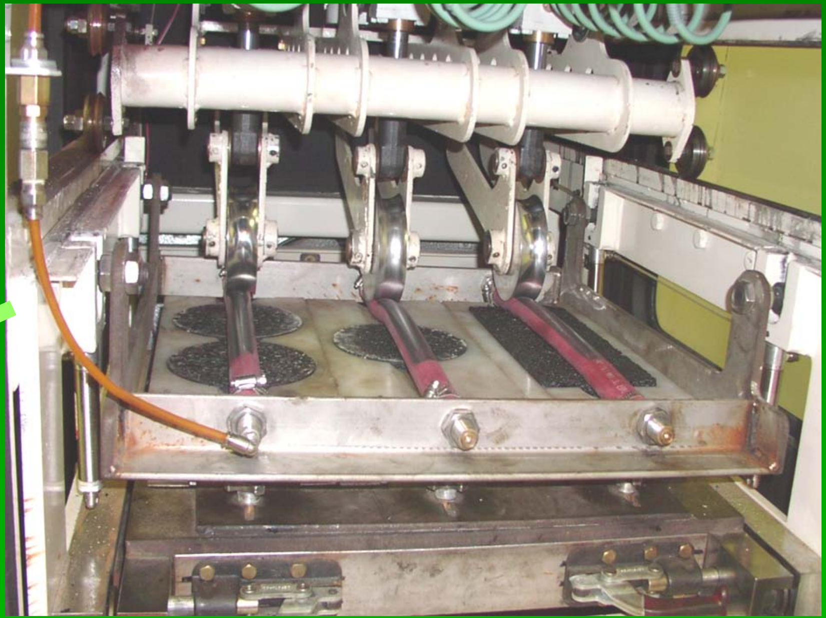
BRBC Specification

Table 902.07.03-1 BRBC Grading of Total Aggregate		
Sieve Size	**Percent Passing by Mass**	
	minimum	**maximum**
1”	100	--
¾”	90	100
½”	--	90
#8	23	49
#200	2.0	8.0
Minimum Percent Asphalt Binder by Mass of Total Mix	5.0	

Table 902.07.03-2 Volumetric Requirements for Design and Control of BRBC					
	Required Density (% of Max Sp. Gr.)	**Voids Filled with Asphalt**	**Voids in Mineral Aggregate**	**Dust to Binder Ratio**	**Draindown AASHTO T 305**
	@ N_{des} (50 gyrations)	**(VFA)**	**(VMA)**		
Design Requirements	96.5	70 - 80	≥ 13.5 %	0.6 – 1.2	≤ 0.1 %
Control Requirements	95.5 – 97.5	70 - 80	≥ 13.5 %	0.6 – 1.3	≤ 0.1 %

Table 902.07.03-3 Performance Testing Requirements for BRBC	
Test	**Requirement**
Asphalt Pavement Analyzer (AASHTO TP 63)	< 5 mm@ 8,000 loading cycles
Flexural Fatigue Life of HMA (AASHTO T 321)	> 100,000,000 cycles@ 100 microstrains

Asphalt Pavement Analyzer



- **AASHTO TP 63**
- **100 lb wheel load; 100 psi hose pressure**
- **Tested at 64ºC for 8,000 loading cycles**

BRBC Specification

- No RAP, it reduced fatigue life
- No natural sand, it reduced VMA
- Binder
  - PG76-28 by addenda (NJDOT Spec)
  - RTFO Elastic Recovery > 60% @ 25^{o}C (AASHTO T301)
- Performance Specification
  - APA and Flexural Beam
    - Testing for mix design verification and control (1st Lot and every 5th Lot after)

Required BRBC Protocol

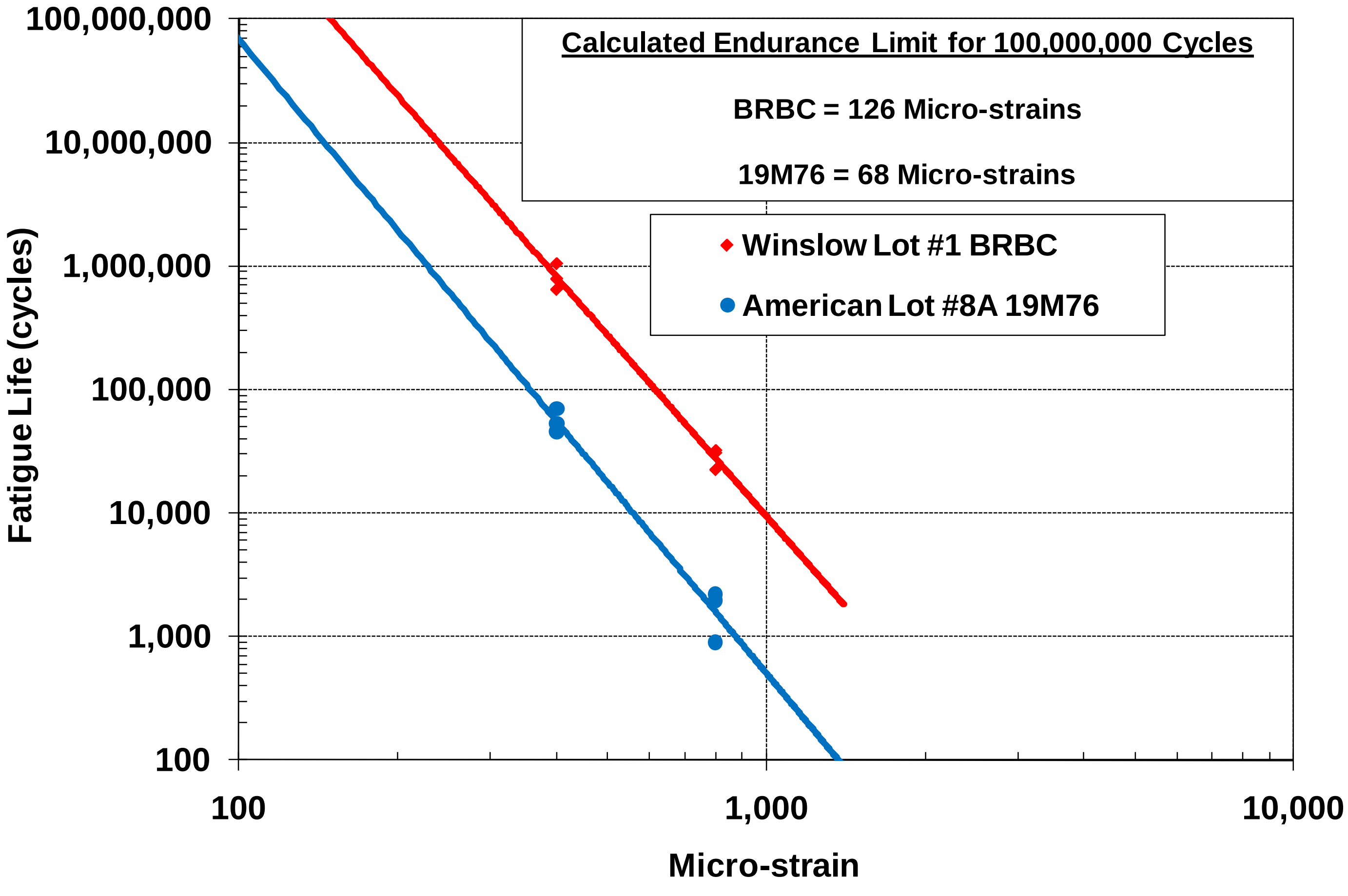
- Conduct volumetric mix design
- Supply loose mix for performance testing (fatigue and rutting)
- If pass, conduct test strip
  - Loose mix sampled and again tested (fatigue and APA)
- If pass, allowed to produce for project
  - 2 suppliers had passing designs
  - 1 supplier had failing design

General Bid Costs

- Bid price for BRBC lower than cost of SMA on the project
- Polymer modification kept at a cost effective price point that could be mass produced in large quantities

LINE NO / ITEM CODE / ALT ITEM DESCRIPTION	QUANTITY	(1) I5964 INTERCOUNTY PAVING J/V H. & UNIT PRICE	AMOUNT	(2) S6836 SOUTH STATE INC UNIT PRICE	AMOUNT	(3) C7444 CRISDEL GROUP, INC UNIT PRICE	AMOUNT
0078 408003P BOTTOM RICH BASE COURSE	177628.000 T	85.75000	15231601.00	90.90000	16146385.20	91.20000	16199673.60
0079 401099M HOT MIX ASPHALT 25 M 64 BASE COURSE	155975.000 T	54.75000	8539631.25	62.35000	9725041.25	63.40000	9888815.00
0080 401108M CORE SAMPLES, HOT MIX ASPHALT	950.000 U	72.85000	69207.50	500.00000	475000.00	112.68000	107046.00
0081 404006M STONE MATRIX ASPHALT 12.5 MM SURFACE COURSE	82228.000 T	97.75000	8037787.00	82.00000	6742696.00	97.53000	8019696.84

Endurance Limit -19M76 vs BRBC

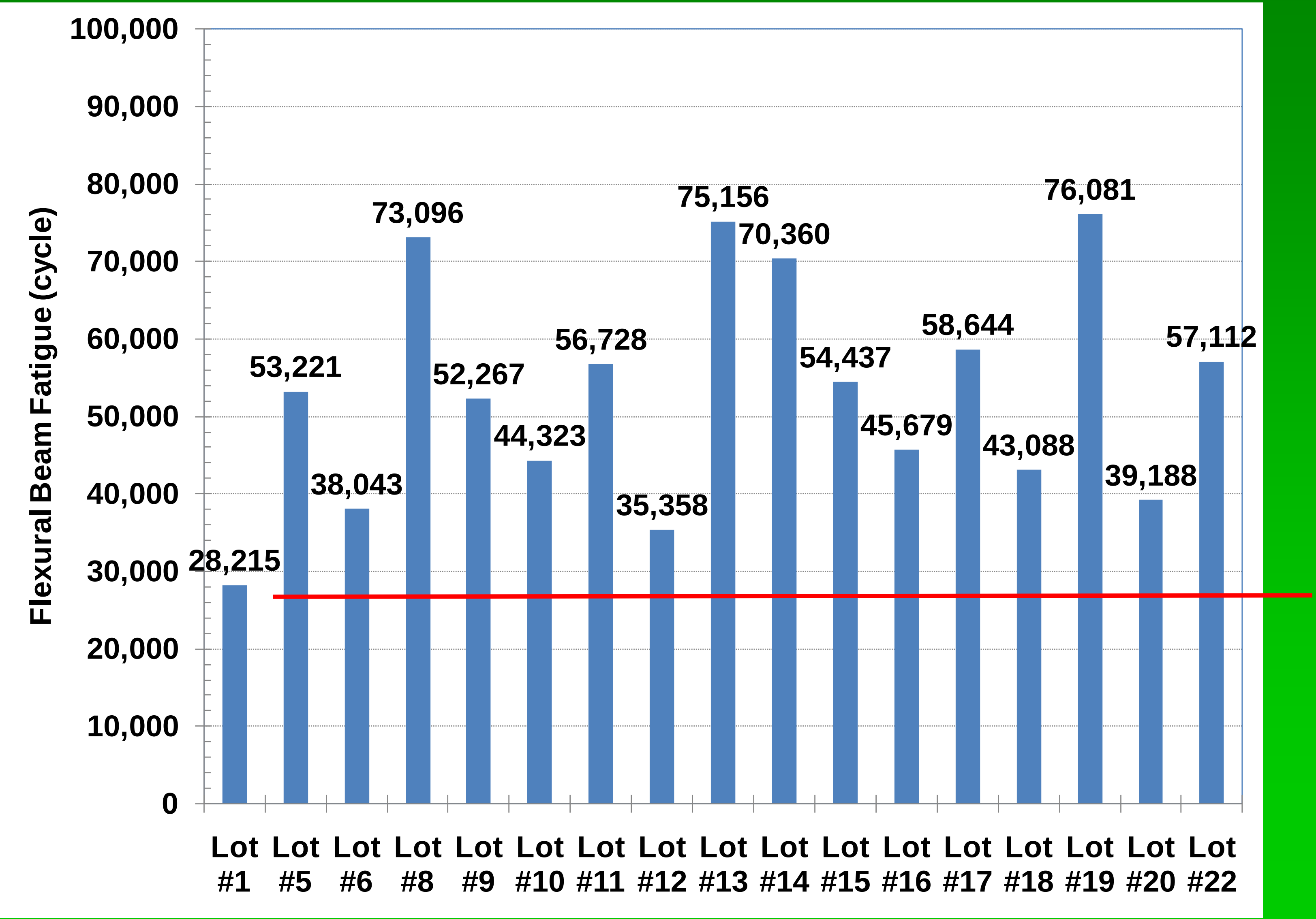


BRBC in Field

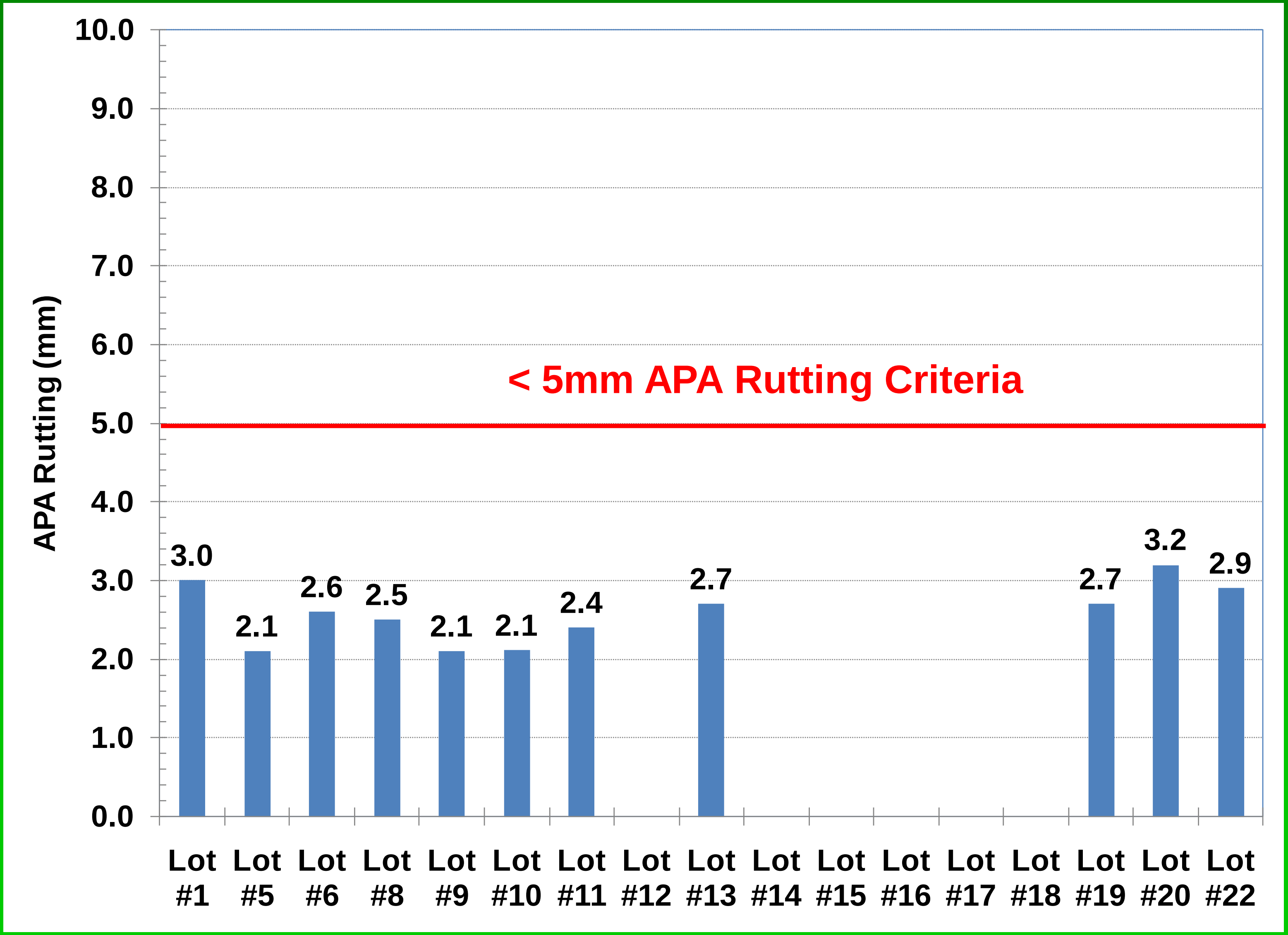
BRBC Core Sample

BRBC Core Samples

QC Test Results - Fatigue



QC Results - APA



Final Project Quantities

- **Project cost: $79 million (significantly lower than engineers estimate)**
  - **BRBC eliminated 170,000 tons of HMA**
  - **Reduced PCCP removal and replacement material by 64,000 SY, 3 miles x 3 lanes**
- **BRBC = 177,628 T, 3” min to 5” max**
- **19M76 Intermediate = 127,078 T, 3” lift**
- **12.5 SMA = 82,228 T, 2” lift**
- **25M64 Base = 156,000 T**

Summary

- NJDOT utilized a performance-based approach to design and build a “perpetual pavement” out of an aging I-295 PCC pavement
  - Engineered an asphalt material to meet a project specific performance requirement
- Consisted of the final development of the NJDOT BRBC mix specification
  - Saved NJDOT over $7 million
  - Performance testing required for acceptance


Thank you for your time!
Robert Sauber, NJAPA
robert@njapa.com
ACME
SuperCard
Price