The National Academies of
SCIENCES • ENGINEERING • MEDICINE

TRANSPORTATION RESEARCH BOARD

Pavement Design Role Reversal: Mixtures Before Design and Construction

Thursday, August 23, 2018
2:00-4:00 PM ET

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Providers Program. Credit earned on completion of this program will be reported to RCEP. A certificate of completion will be issued to participants that have registered and attended the entire session. As such, it does not include content that may be deemed or construed to be an approval or endorsement by RCEP.

RCEP

REGISTERED CONTINUING EDUCATION PROGRAM

Purpose

Discuss case studies where asphalt mixtures were specifically designed to meet situations in which conventional design approaches were not appropriate.

Learning Objectives

At the end of this webinar, you will be able to:

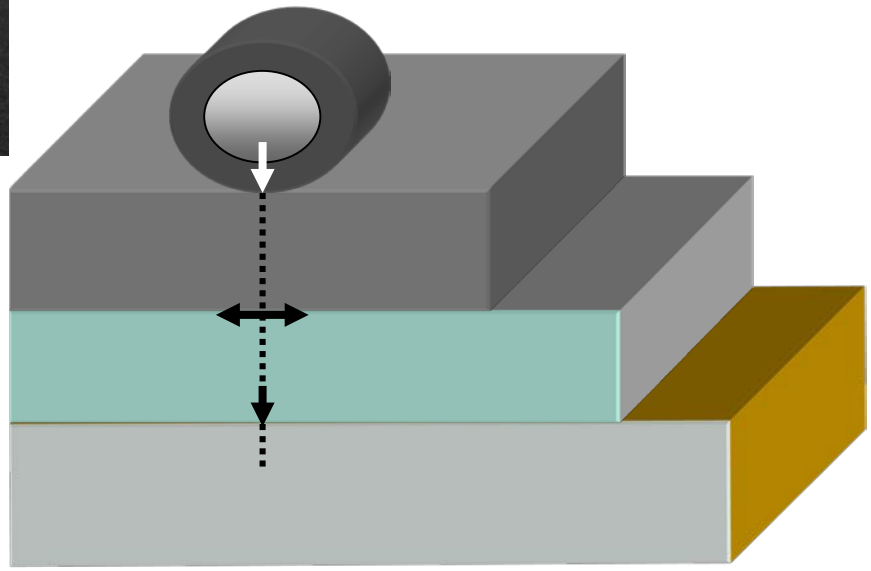
- Describe the concepts of engineering mixtures to meet specific pavement design problems
- Identify how states have carried out an engineered mixture solution and explain using specific examples
- Discuss the distinctive differences between engineered mixture solutions and the conventional design process

Pavement Design Role Reversal: Mixtures Before Design and Construction or…

Engineering Pavement Performance

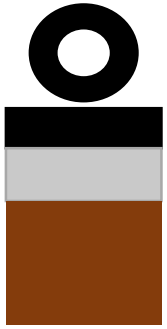
ISAP

Kevin D. Hall, Ph.D., P.E.
Hicks Professor of Infrastructure Engineering
University of Arkansas



The Pavement Life Cycle (simplified)

Rehabilitation



Structural Design

Which of these stages is the MOST important to pavement performance?

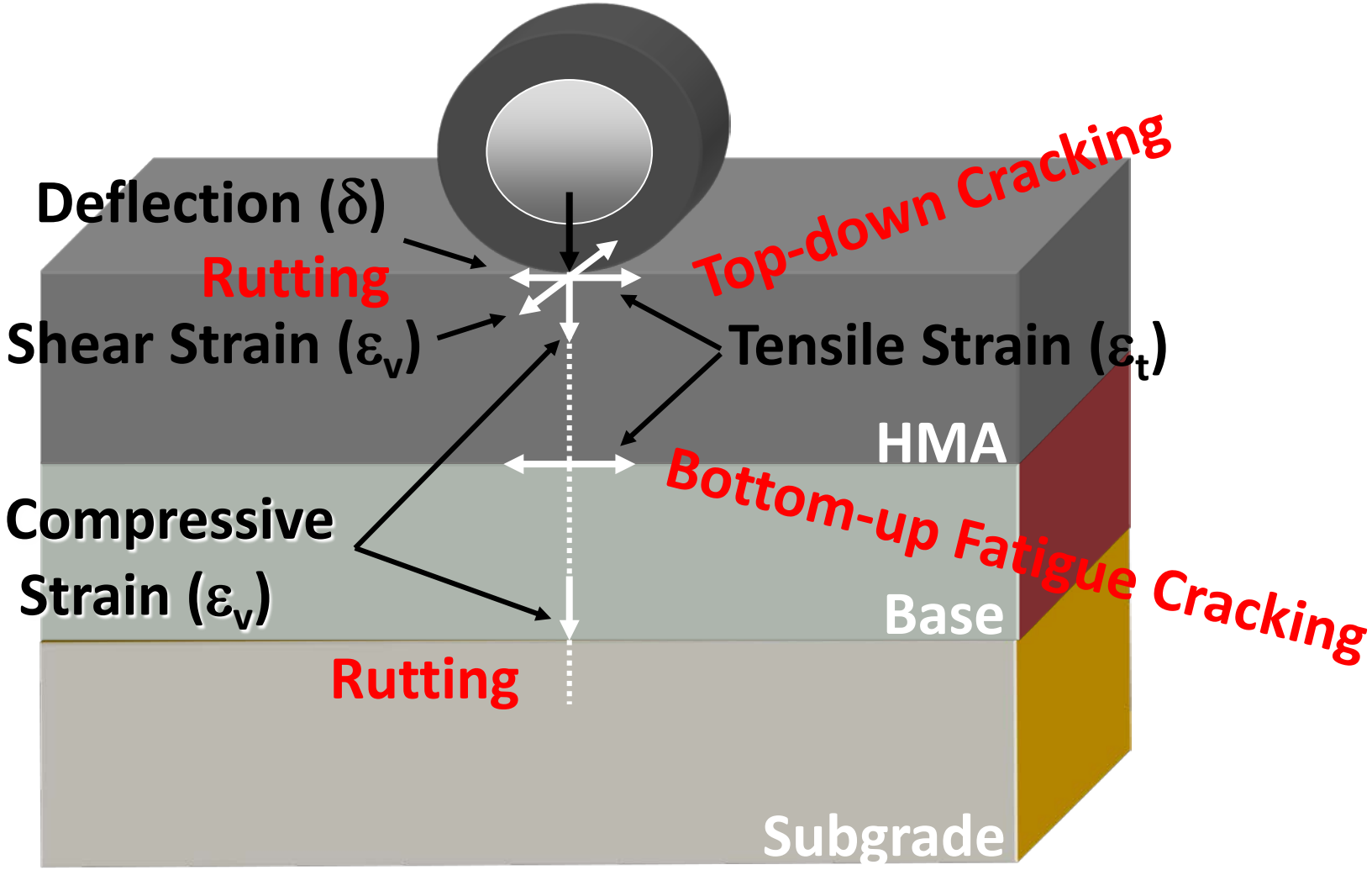
Preservation

Materials/Mix Design

Maintenance

Construction

The Mechanics of Pavement Response



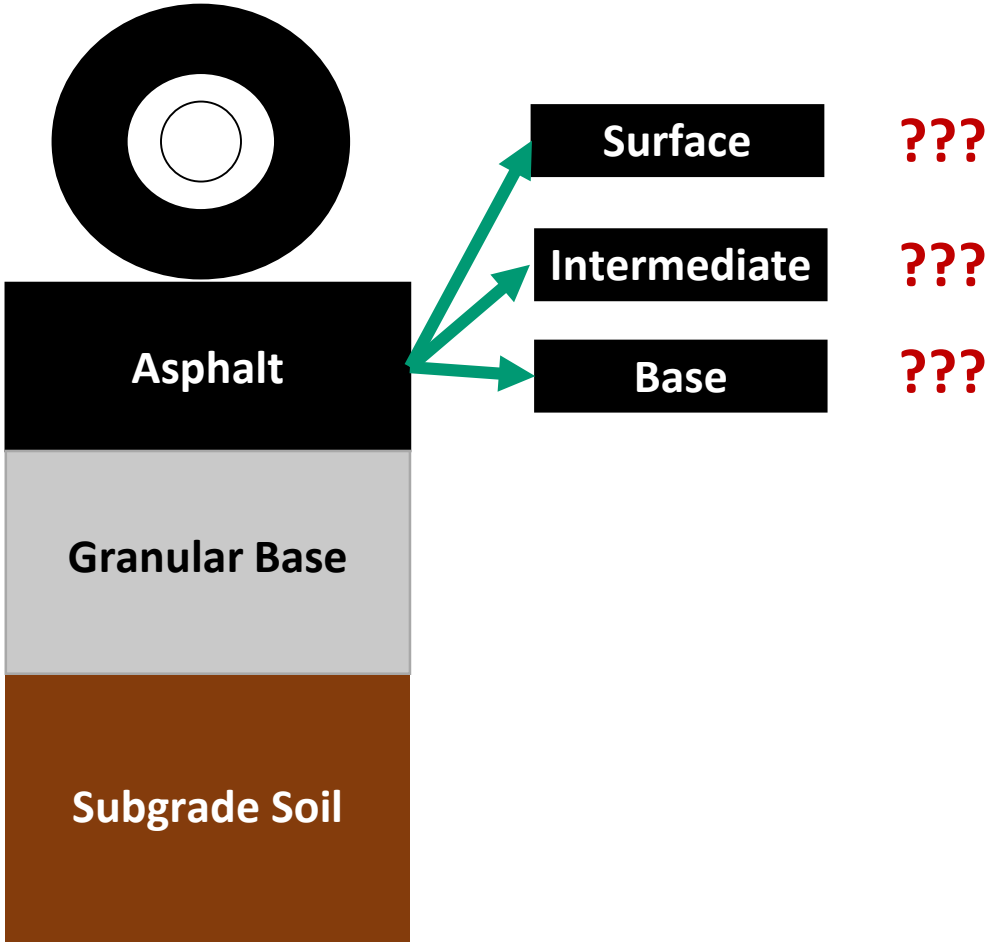
Pavement Layers: Roles?

Protect the base / subgrade

Provide durable wearing surface with comfortable ride under traffic

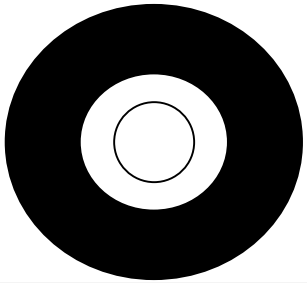
Protect the subgrade

Provide structural stability to pavement system



A Traditional Approach: Arkansas

Binders: PG 64-22
PG 70-22
PG 76-22



Asphalt (Surface Mix)

- 9.5 mm, 12.5 mm NMAS
- P_b based on 4% Air Voids
- 1993 AASHTO: a_1 = 0.44
- MEPDG: E*
- Density: 92-96% of G_{mm}

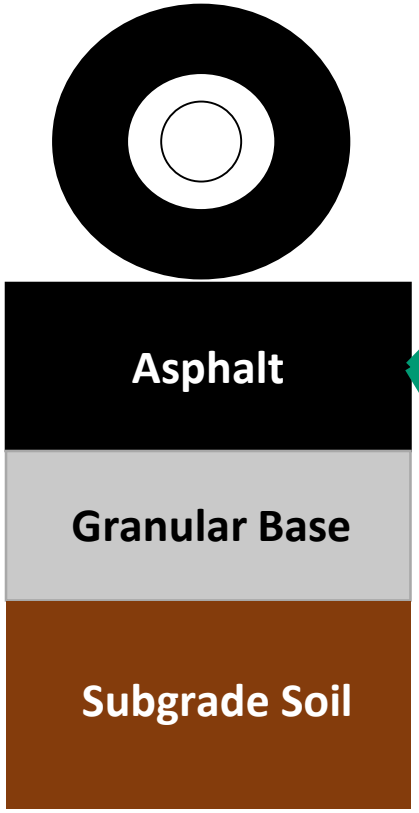
Asphalt (Binder Mix)

- 25 mm NMAS
- P_b based on 4% Air Voids
- 1993 AASHTO: a_1 = 0.44
- MEPDG: E*
- Density: 92-96% of G_{mm}

Asphalt (Base Mix)

- 37.5 mm NMAS
- P_b based on 4% Air Voids
- 1993 AASHTO: a_1 = 0.36
- MEPDG: E*
- Density: 90-94% of G_{mm}

Asphalt Pavement Layers: Roles? Characteristics?



Surface

Ride quality
Rut resistant
Crack resistant
Durable (time/climate)

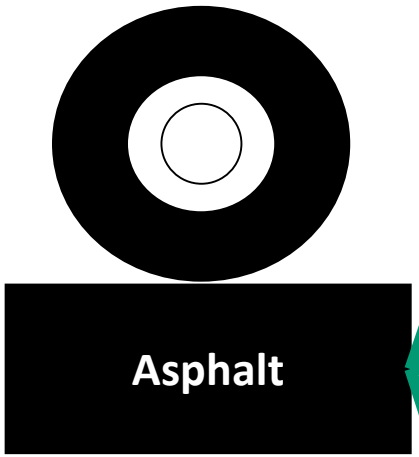
Intermediate

Protect underlying layers
Support surface layer
Rut resistant
High modulus (stiffness)

Base

Protect underlying layers
Support upper layers
Crack/fatigue resistant
Durable (moisture damage)

Asphalt Pavement Layers: HOW??



Surface

Ride quality
Rut resistant
Crack resistant
Durable (time/climate)

Polymers?
Balanced Mix Design?
Recycle?

Intermediate

Protect underlying layers
Support surface layer
Rut resistant
High modulus (stiffness)

Polymers?
Recycle?

Base

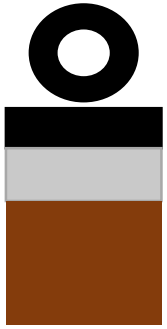
Protect underlying layers
Support upper layers
Crack/fatigue resistant
Durable (moisture damage)

High binder?
(low voids?)
No recycle?
Moisture damage
additives?

Making It Work…

Rehabilitation

Structural Design



Do these people

Know what these people do?

Materials/Mix Design

Preservation

Do these people

Know what these people do?

Construction

Maintenance

Do these people

Know how their role ‘fits’

with design & materials?

To Summarize: the 'DUH' Statements…

- The various layers in a pavement play different roles in performance
- All materials (e.g. asphalt mixes) are not the same
- To 'optimize' performance, match the right material to the right role in the pavement
- A good start: the Roadway Design folks and the Materials (mix design) folks should talk to each other – and let the Construction folks know what they are doing
- A better S.O.P. : *engineer* the pavement – *integrate* Design, Materials, and Construction processes…

Thank You!!

kdhall@uark.edu

Now…on to some case studies!

PAVEMENT DESIGN ROLE REVERSAL: MIXTURES BEFORE DESIGN AND CONSTRUCTION NJ CASE STUDY

Presented by

Robert Blight
Supervising Engineer, Pavement Design
New Jersey Department of Transportation

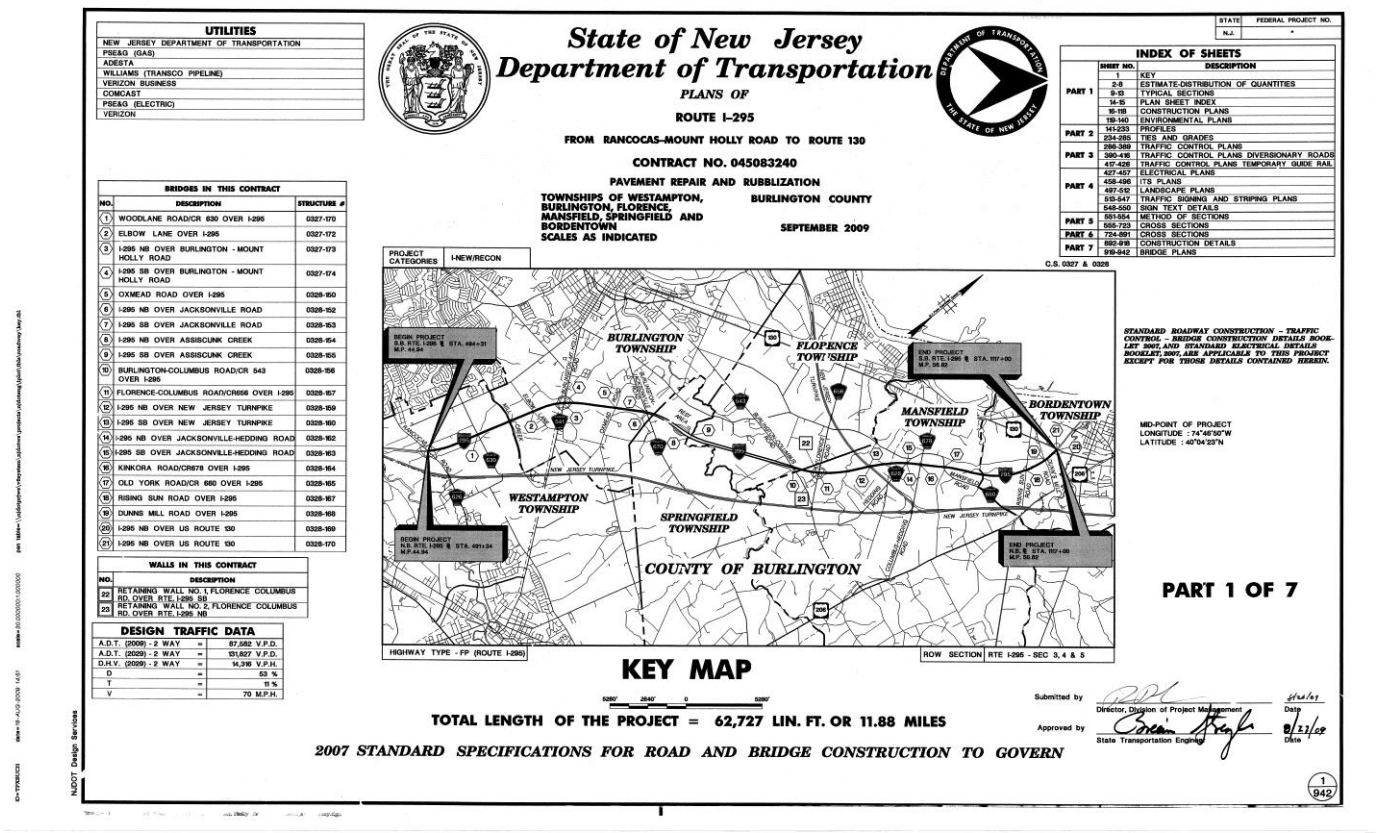
Presented to

TRB Webinar

ACKNOWLEDGEMENTS

- Thomas Bennert, Ph.D., Rutgers University-CAIT
- Robert Sauber, RWS Consulting, LLC (NJDOT retired)
- Vahid Ganji, Michael Baker Inc.
- Mahesh Patel, NJDOT Project Manager
- Susan Gresavage, NJDOT
- Narinder Kohli, NJDOT
- Eileen Sheehy, NJDOT Materials (retired)
- William Gaus, NJDOT Project Resident Engineer
- NJDOT Construction & Materials staff
- Frank Fee, NuStar (retired)
- Wayne Byard, Trap Rock Industries
- Joint Venture Intercounty Paving - Haines & Kibblehouse, Inc. (contractor)

NJ CASE STUDY: I-295 - RANCOCAS-MT. HOLLY ROAD TO ROUTE 130



UTILITIES
NEW JERSEY DEPARTMENT OF TRANSPORTATION
PSE&G (GAS)
ADESTA
WILLIAMS (TRANSCO PIPELINE)
VERIZON BUSINESS
COMCAST
PSE&G (ELECTRIC)
VERIZON

State of New Jersey
Department of Transportation

PLANS OF

ROUTE I-295

FROM RANCOCAS-MOUNT HOLLY ROAD TO ROUTE 130

CONTRACT NO. 045083240

PAVEMENT REPAIR AND RUBBLIZATION

TOWNSHIPS OF WESTAMPTON, BURLINGTON, FLORENCE, MANSFIELD, SPRINGFIELD AND BORDENTOWN — **BURLINGTON COUNTY**

SCALES AS INDICATED — **SEPTEMBER 2009**

STATE	FEDERAL PROJECT NO.
N.J.	*

INDEX OF SHEETS		
	SHEET NO.	DESCRIPTION
PART 1	1	KEY
	2-8	ESTIMATE-DISTRIBUTION OF QUANTITIES
	9-13	TYPICAL SECTIONS
	14-15	PLAN SHEET INDEX
	16-118	CONSTRUCTION PLANS
	119-140	ENVIRONMENTAL PLANS
PART 2	141-233	PROFILES
	234-285	TIES AND GRADES
PART 3	286-389	TRAFFIC CONTROL PLANS
	390-416	TRAFFIC CONTROL PLANS DIVERSIONARY ROADS
	417-426	TRAFFIC CONTROL PLANS TEMPORARY GUIDE RAIL
PART 4	427-457	ELECTRICAL PLANS
	458-496	ITS PLANS
	497-510	LANDSCAPE PLANS
	515-547	TRAFFIC SIGNING AND STRIPING PLANS
	548-550	SIGN TEXT DETAILS
PART 5	551-554	METHOD OF SECTIONS
	555-723	CROSS SECTIONS
PART 6	724-891	CROSS SECTIONS
PART 7	892-918	CONSTRUCTION DETAILS
	919-942	BRIDGE PLANS

BRIDGES IN THIS CONTRACT		
NO.	DESCRIPTION	STRUCTURE #
1	WOODLANE ROAD/CR 630 OVER I-295	0327-170
2	ELBOW LANE OVER I-295	0327-172
3	I-295 NB OVER BURLINGTON - MOUNT HOLLY ROAD	0327-173
4	I-295 SB OVER BURLINGTON - MOUNT HOLLY ROAD	0327-174
5	OXMEAD ROAD OVER I-295	0328-150
6	I-295 NB OVER JACKSONVILLE ROAD	0328-152
7	I-295 SB OVER JACKSONVILLE ROAD	0328-153
8	I-295 NB OVER ASSISCUNK CREEK	0328-154
9	I-295 SB OVER ASSISCUNK CREEK	0328-155
10	BURLINGTON-COLUMBUS ROAD/CR 543 OVER I-295	0328-156
11	FLORENCE-COLUMBUS ROAD/CR656 OVER I-295	0328-157
12	I-295 NB OVER NEW JERSEY TURNPIKE	0328-159
13	I-295 SB OVER NEW JERSEY TURNPIKE	0328-160
14	I-295 NB OVER JACKSONVILLE-HEDDING ROAD	0328-162
15	I-295 SB OVER JACKSONVILLE-HEDDING ROAD	0328-163
16	KINKORA ROAD/CR678 OVER I-295	0328-164
17	OLD YORK ROAD/CR 660 OVER I-295	0328-165
18	RISING SUN ROAD OVER I-295	0328-167
19	DUNNS MILL ROAD OVER I-295	0328-168
20	I-295 NB OVER US ROUTE 130	0328-169
21	I-295 NB OVER US ROUTE 130	0328-170

WALLS IN THIS CONTRACT	
NO.	DESCRIPTION
22	RETAINING WALL NO. 1, FLORENCE COLUMBUS RD. OVER RTE. I-295, SB
23	RETAINING WALL NO. 2, FLORENCE COLUMBUS RD. OVER RTE. I-295, NB

DESIGN TRAFFIC DATA		
A.D.T. (2009) - 2 WAY	=	87,582 V.P.D.
A.D.T. (2029) - 2 WAY	=	131,827 V.P.D.
D.H.V. (2029) - 2 WAY	=	14,316 V.P.H.
D	=	53 %
T	=	15 %
V	=	70 M.P.H.

PROJECT CATEGORIES: I-NEW/RECON

C.S. 0327 & 0328

BEGIN PROJECT S.D. RTE. I-295 S STA. 494+31 M.P. 44.94

END PROJECT S.D. RTE. I-295 S STA. 1117+00 M.P. 56.82

BEGIN PROJECT N.B. RTE. I-295 S STA. 491+34 M.P. 44.94

END PROJECT N.B. S STA. 1117+00 M.P. 56.82

BURLINGTON TOWNSHIP
FLORENCE TOWNSHIP
MANSFIELD TOWNSHIP
BORDENTOWN TOWNSHIP
WESTAMPTON TOWNSHIP
SPRINGFIELD TOWNSHIP
COUNTY OF BURLINGTON
NEW JERSEY TURNPIKE

HIGHWAY TYPE - FP (ROUTE I-295)

ROW SECTION: RTE I-295 - SEC 3, 4 & 5

KEY MAP

STANDARD ROADWAY CONSTRUCTION - TRAFFIC CONTROL - BRIDGE CONSTRUCTION DETAILS BOOKLET 2007, AND STANDARD ELECTRICAL DETAILS BOOKLET, 2007, ARE APPLICABLE TO THIS PROJECT EXCEPT FOR THOSE DETAILS CONTAINED HEREIN.

MID-POINT OF PROJECT
LONGITUDE : 74°48'50"W
LATITUDE : 40°04'23"N

PART 1 OF 7

TOTAL LENGTH OF THE PROJECT = 62,727 LIN. FT. OR 11.88 MILES

2007 STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION TO GOVERN

Submitted by: Director, Division of Project Management — Date 6/22/09

Approved by: State Transportation Engineer — Date 6/11/09

NJDOT Design Services

1/942

NJ CASE STUDY

- Route I-295 MP 45 – 56.8 constructed of JRCP between 1972 to 1974
  - 9" thick slabs, length = 78'2"
  - Doweled expansion joints
- ASR (alkali-silica reactivity) and insufficient structural design based on current traffic loading (20 year ESAL's = 80+ million ESAL's)
- Two CPR (concrete pavement rehab) projects
  - 1989 & 1997

NJ CASE STUDY

- Concrete pavement reached terminal serviceability in 2002
- Limited pavement program funding
- High traffic volumes that must be maintained during reconstruction (ADT – 88,000 vpd)

I-295 Concrete Pavement Condition Assessment (2007)

- Performed Visual Pavement Condition Survey and FWD Testing
- Pavement distresses
  - Transverse and Longitudinal Joint spalling
  - Mid-slab Spalling
  - Alkali-Silica Reaction (ASR)
  - High IRI
  - Dowel Bar Failures
  - Deteriorated Patches
  - Faulting

Required Frequent Repairs by NJDOT Maintenance and Operation Unit

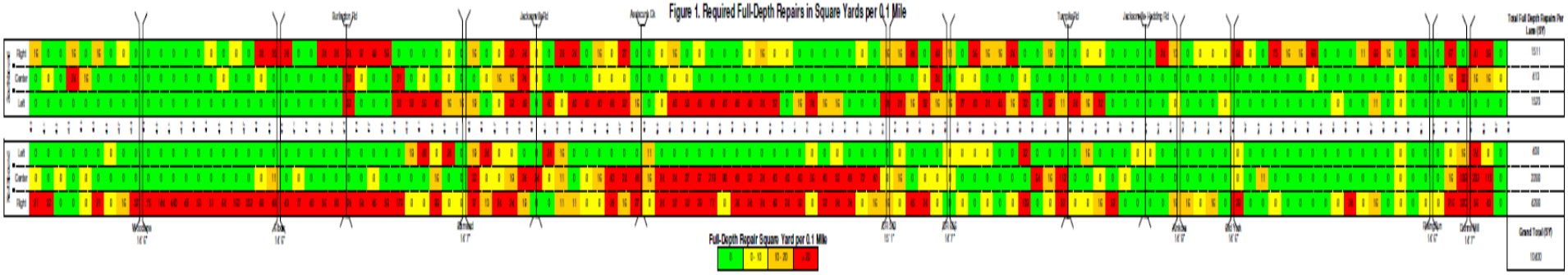
POTENTIAL SOLUTIONS

- Concrete repair and asphalt overlay
  - Approximate cost $30 million
  - Short service life not cost effective
  - Ultimate fix will be more difficult
- Replace broken slabs and diamond grind or overlay
  - Too slow and expensive, cost overrun risk
  - Not feasible due to ASR
  - Rule-of-Thumb: Less than 5% slab repairs for CPR to be cost effective

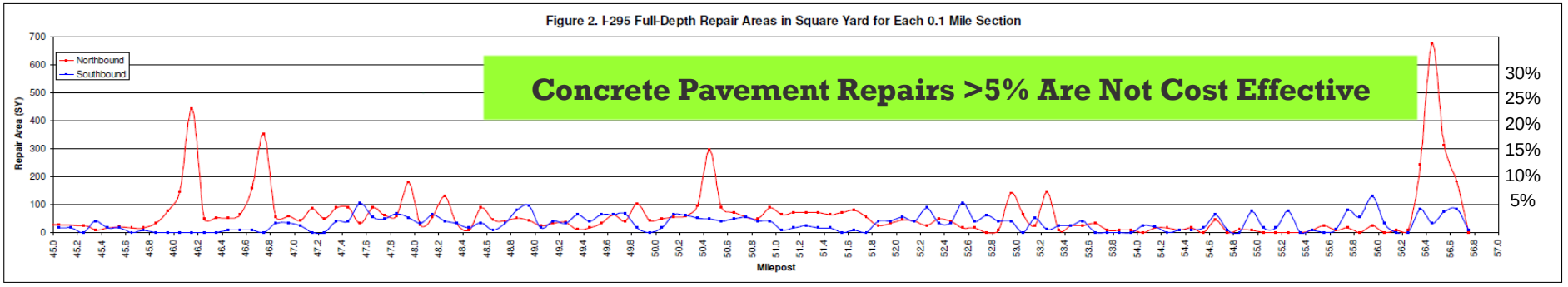
I-295 Concrete Pavement Condition Assessment (2007)

Pavement Evaluation Using FWD, GPR, Visual Survey, and Coring

Required Full-Depth Repairs for 0.1 Mile Sections Based on Visual Survey (2007)



Required Full-Depth Repairs Based on Visual Survey (2007)



CHOSEN SOLUTION

- LCCA Indicated Rubblization as Most Cost Effective
  - Full-Depth Reconstruction in Transition Areas
- Full Closure to increase production and lower project cost (time is $$$)
- Hyperbuild (accelerated construction) to reduce traffic impact and obtain public buy in for full closure
- **Rubblization** to recycle concrete in place, reduce cost, and duration of the project
- Perpetual Asphalt Pavement Overlay (50 year)

PROJECT SPECIFICS

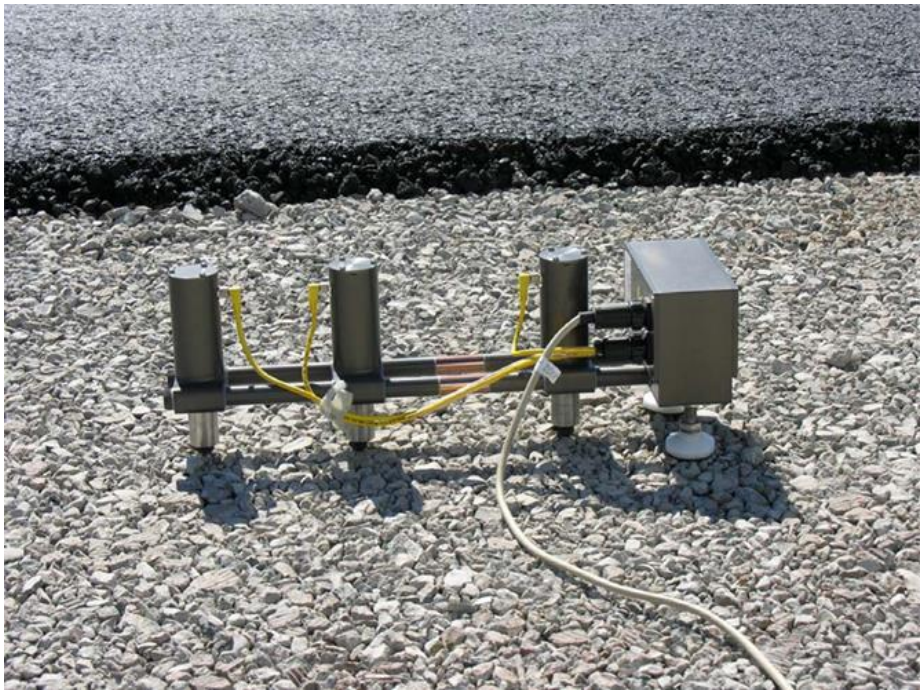
- Project Limits
  - Rt. I-295 NB & SB MP 45 to 56.8 (11.8 miles length, 72 lanes miles)
  - Three 12' travel lanes with 4' inside and 12' outside shoulders in each direction
  - Total paved width of 52 ft each direction
- 21 structures within project limits resulting in 20 undercut locations to maintain underclearance or avoid raising the bridge
- Full closure limited to 59 days during the summer when traffic volume was lower

PROJECT SCHEDULE

- Spring 2010 – Install underdrains, pave SB shoulders, construct crossovers
- Summer 2010 – Close NB roadway, crossover traffic to SB, maintain two lanes each direction on the SB side of the roadway. 59 days
- Summer 2011 – Close SB roadway, two lanes each direction on the NB side of the roadway. 59 days
- Fall 2011 – Pave NB surface course (in daily lane closures).

INITIAL PAVEMENT DESIGN FOR I-295

- Initial design used 1993 AASHTO Pavement Design
- 12" of HMA over rubblized PCCP
- Rubblized PCCP modulus from FWD and PSPA data similar rubblized PCCP projects
- Subgrade modulus determined using FWD data from pavement evaluation
- The 59 day closure required extremely high HMA production and placement – 15,000 tons/day



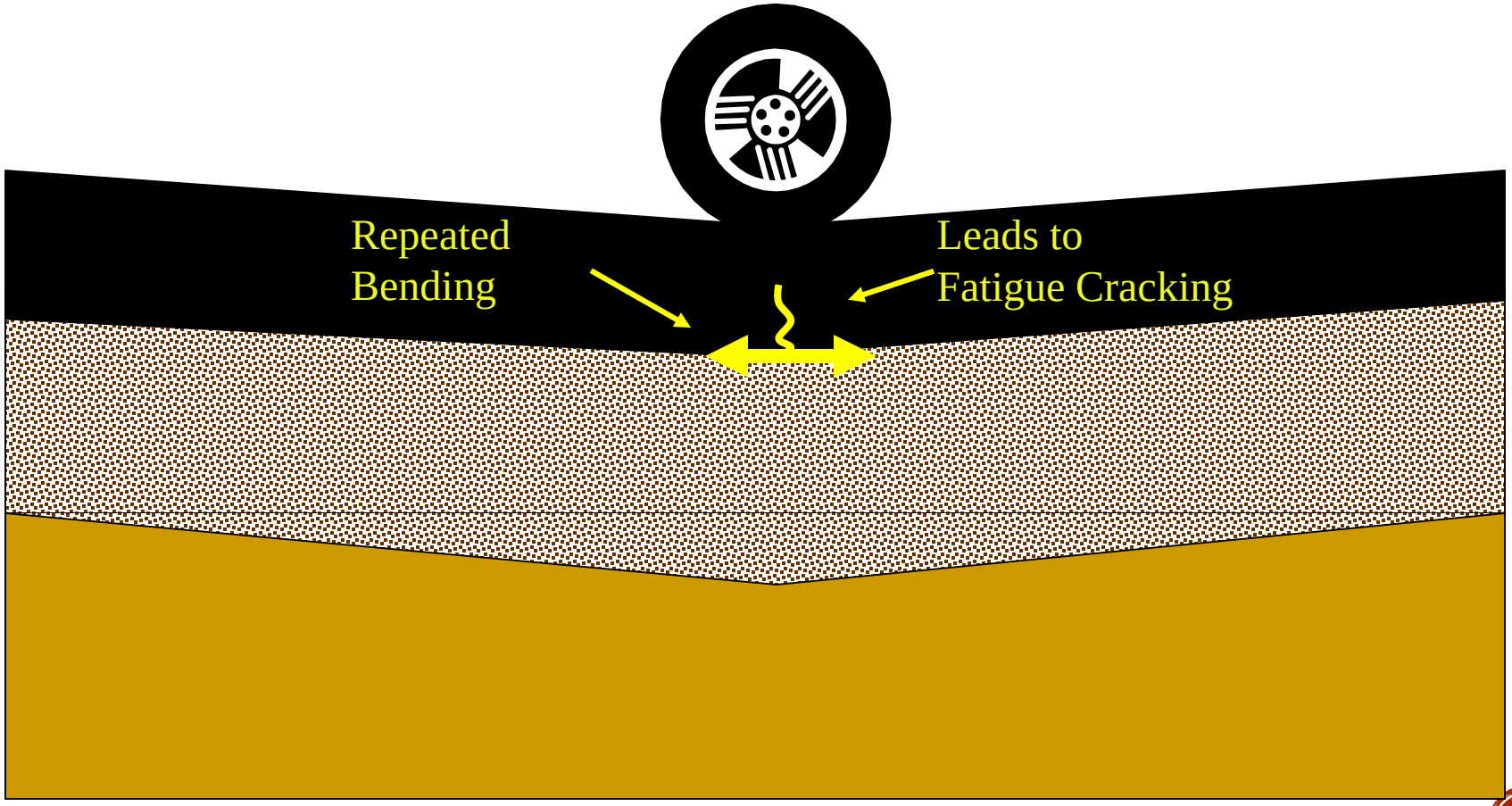
PROBLEM WITH DESIGN THICKNESS

- For 12" asphalt overlay thickness, 2400 linear feet (+ width of bridge) of PCCP removal and box out at each structure, 100' transition per inch
- From past experience, box outs are problematic because they are often at low points
- Many times box outs ended up requiring an undercut (clay subgrade)

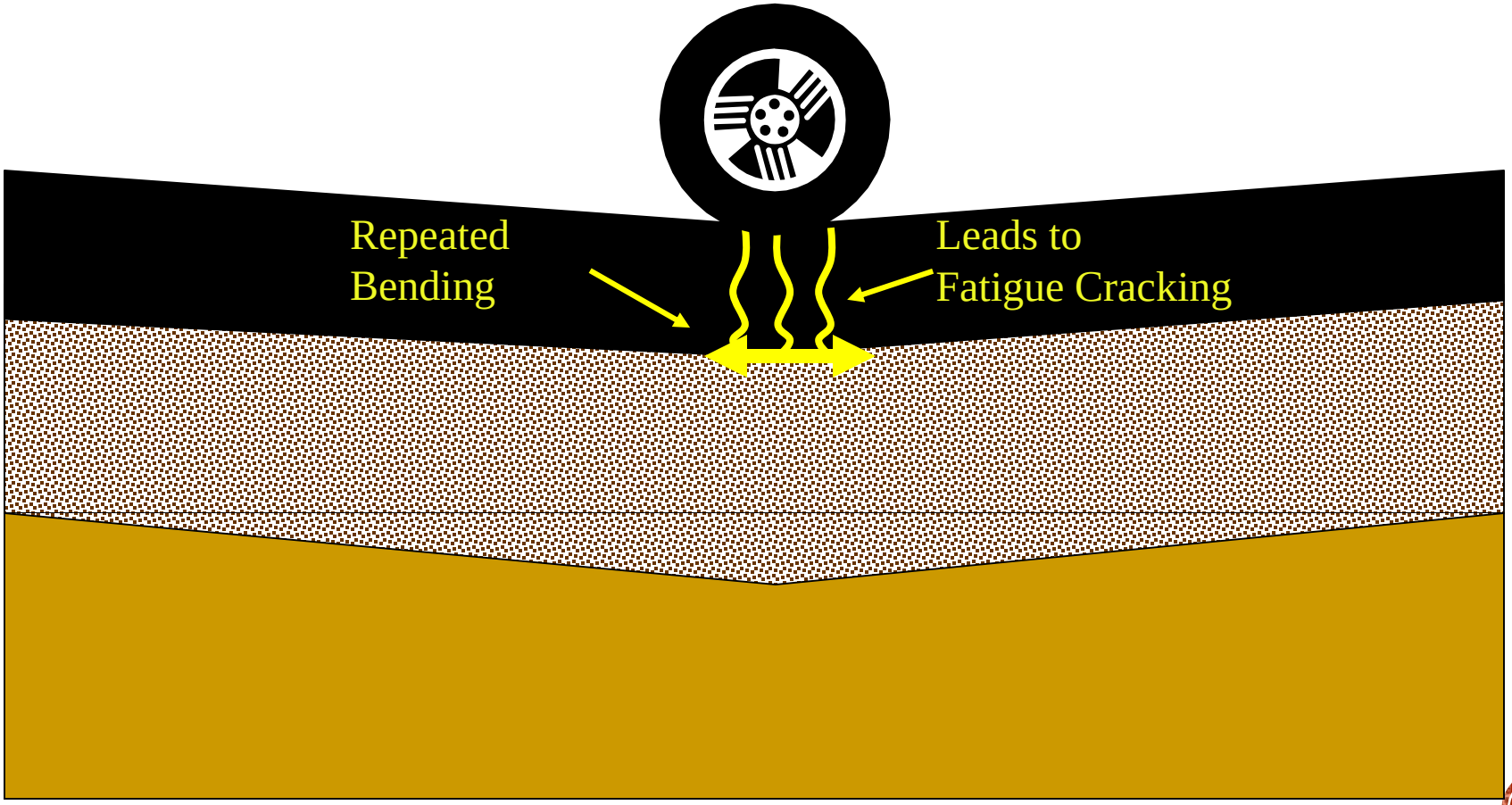
DIFFERENT DESIGN APPROACH

- NJDOT could save a lot of time and money on box out and undercuts if total HMA thickness were 8 inches instead of 12 inches
- Looked at pavement response in MEPDG (typical NJ HMA materials) and noted bottom-up cracking could be potential issue at 8 inches thick

Bottom-up Cracking



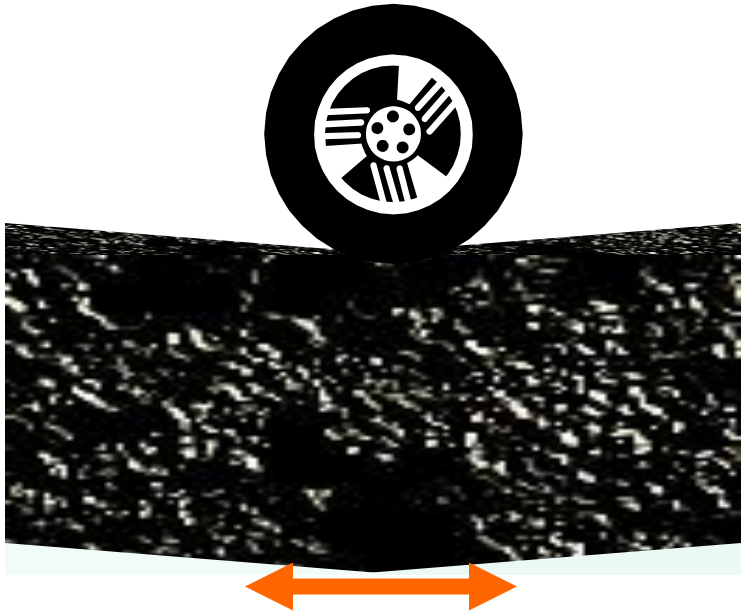
Bottom-up Cracking

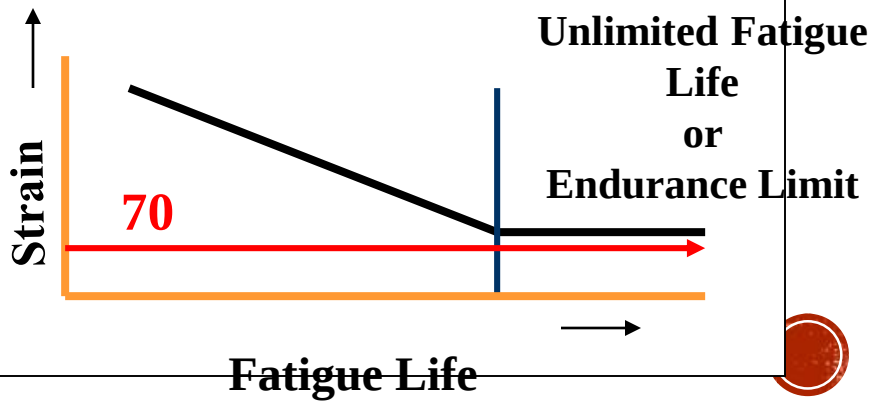


Fatigue Theory for Perpetual Pavements

High Strain = Short Life

Low Strain = Unlimited Life





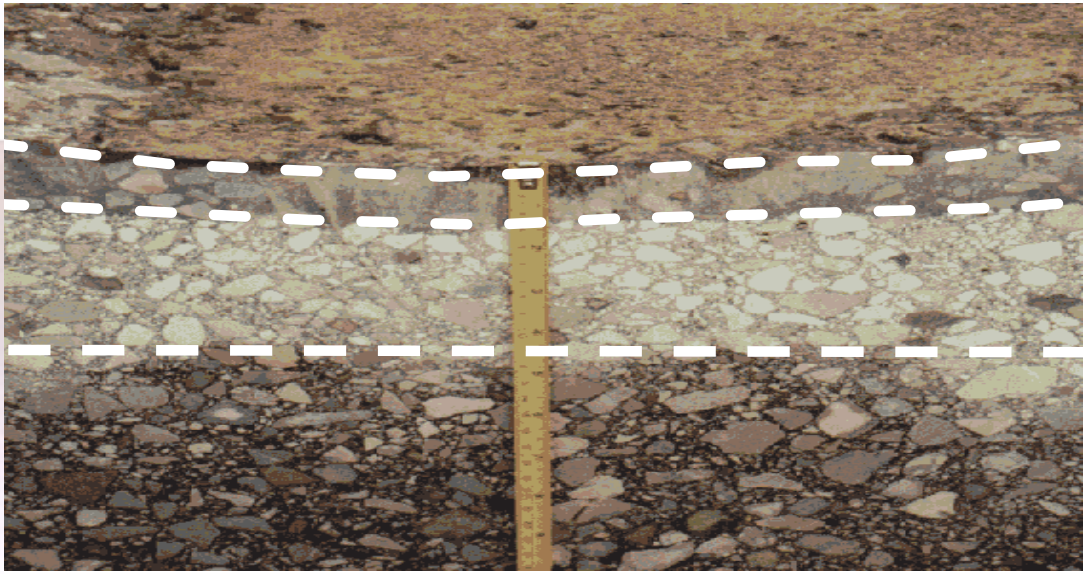
PERPETUAL PAVEMENT DESIGN CONSIDERATIONS

- Design the pavement 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 remedied from surface
- Result in a structure with 'Perpetual' or 'Long Life'

SURFACE DISTRESSES ONLY

Top Down Cracking

Non-Structural Rutting



I-295 DESIGNING FOR PERPETUAL PAVEMENT

- 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 AASHTO MEPDG
  - Resulted in 82 micro-strains (rounded up to 100 microstrains to be conservative)

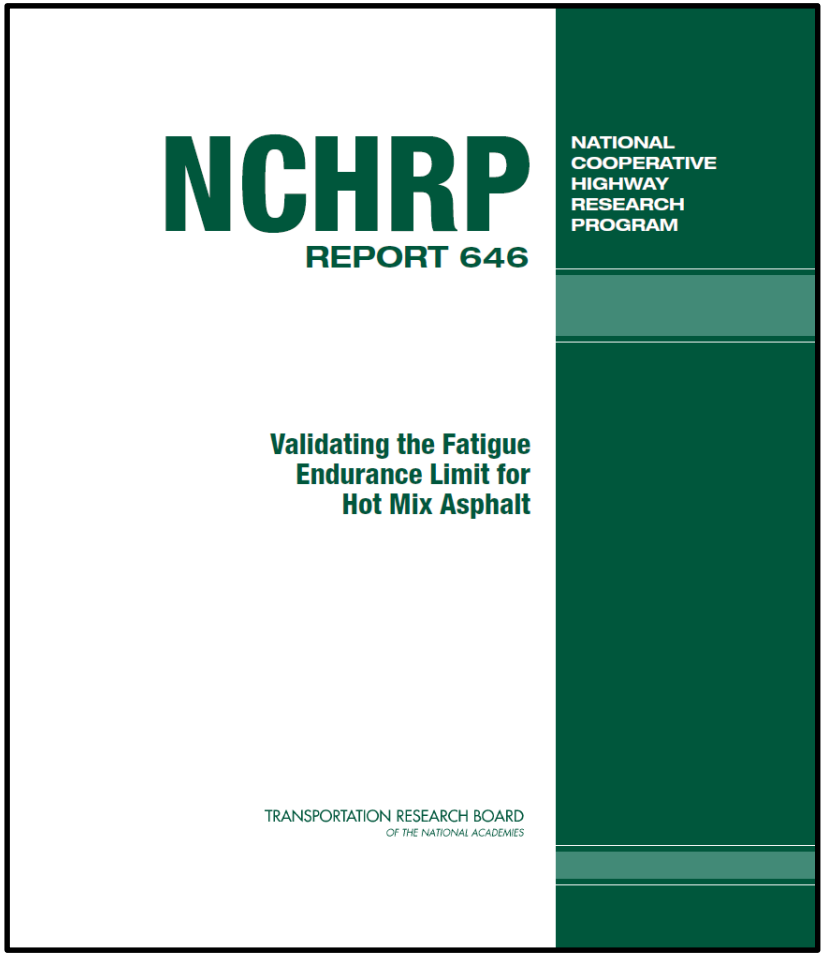
CHANGE DESIGN METHODOLOGY

- Final design pavement cross-section
  - 2" SMA Surface
  - 3" HMA 19M76 I.C.

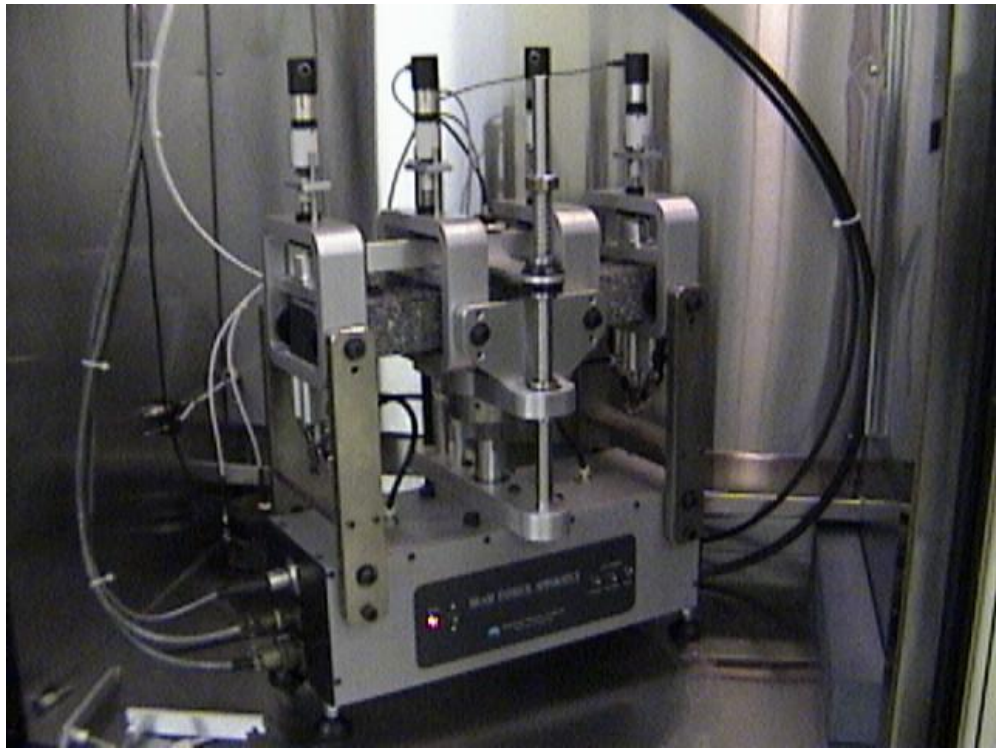
    (19 mm NMA, 75 gyrations, PG 76-22)
  - 3" of Specialty Mix
    - Designed specifically for this project
    - Utilizing Endurance Limit concept

ENDURANCE LIMIT

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

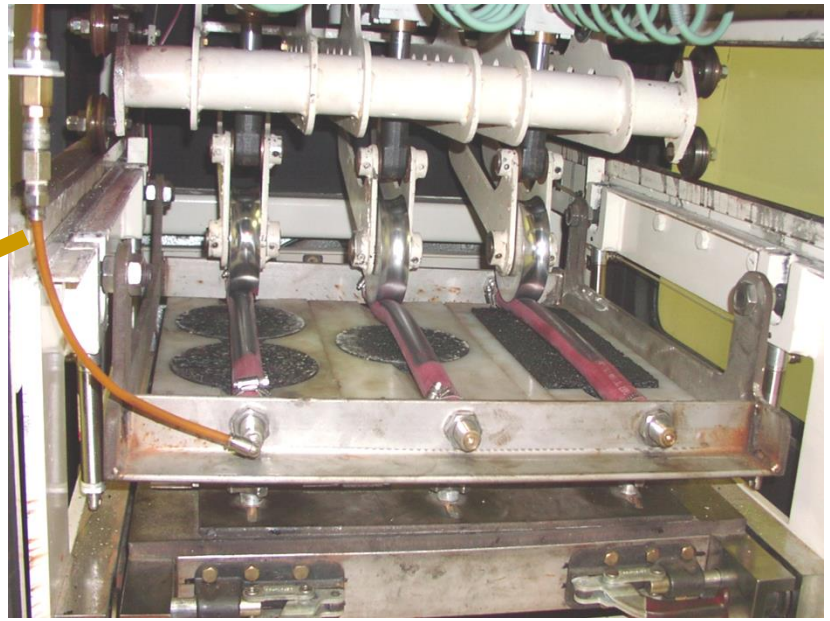


FLEXURAL FATIGUE TESTING OF HMA



- Flexural Beam Fatigue Device, AASHTO T-321
- Tests mix's ability to withstand repeated bending
- Data = number of loading cycles to failure (Fatigue Life)
- Run at 400 and 800 microstrain to determine Endurance Limit

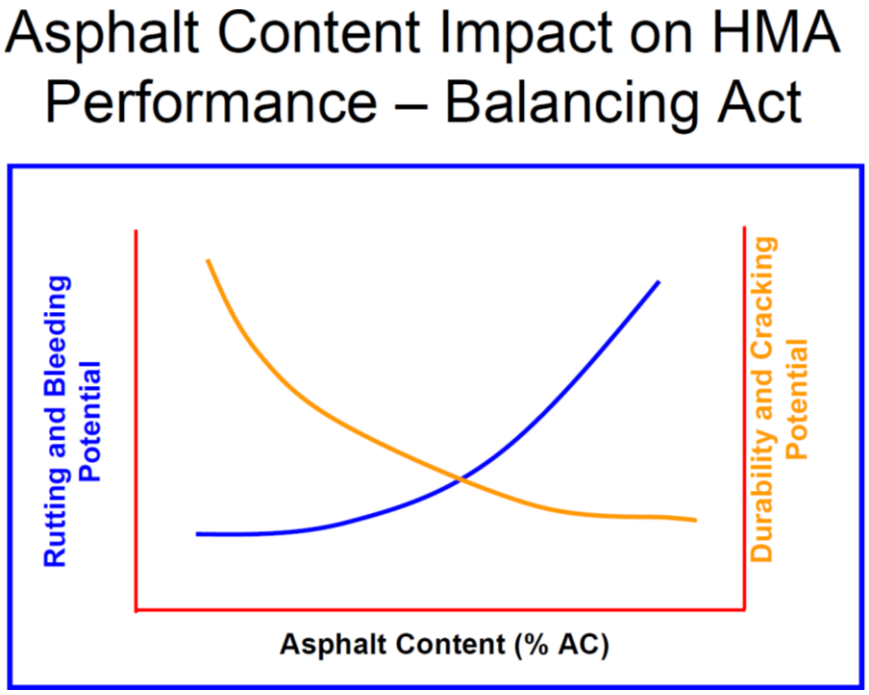
ASPHALT PAVEMENT ANALYZER



- AASHTO TP 63
- 100 lb wheel load; 100 psi hose pressure
- Tested at 64°C for 8,000 loading cycles
- Max rut depth 5 mm

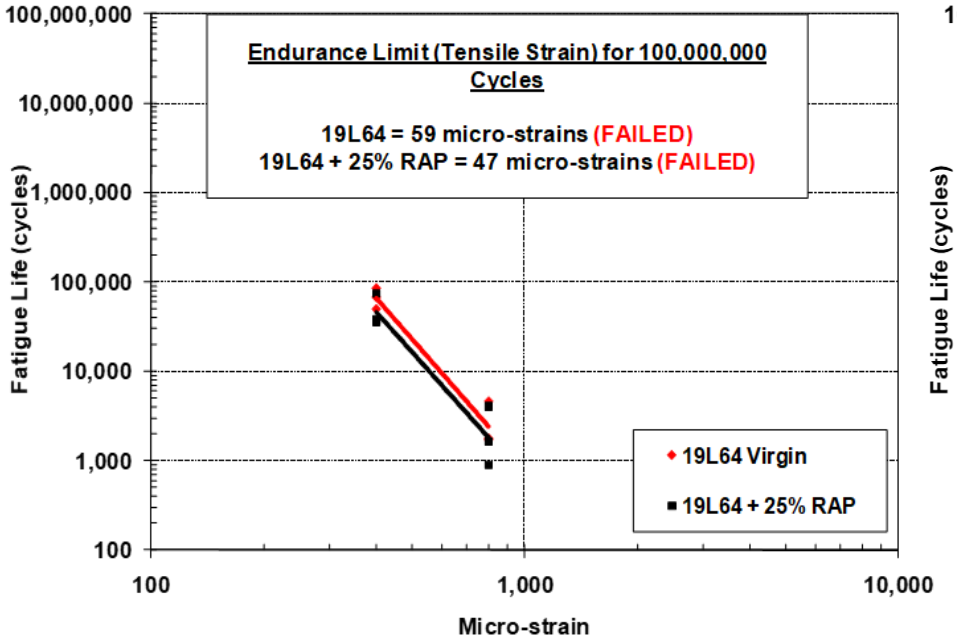
WHAT MIX TO USE?

- With performance evaluation in place, Rutgers University began testing plant produced mixes in Fall 2009
- Different base course mixes were evaluated – none were successful
  - Pavement Design Requirement: Must achieve an Endurance Limit greater than 100 microstrains at 100,000,000 cycles

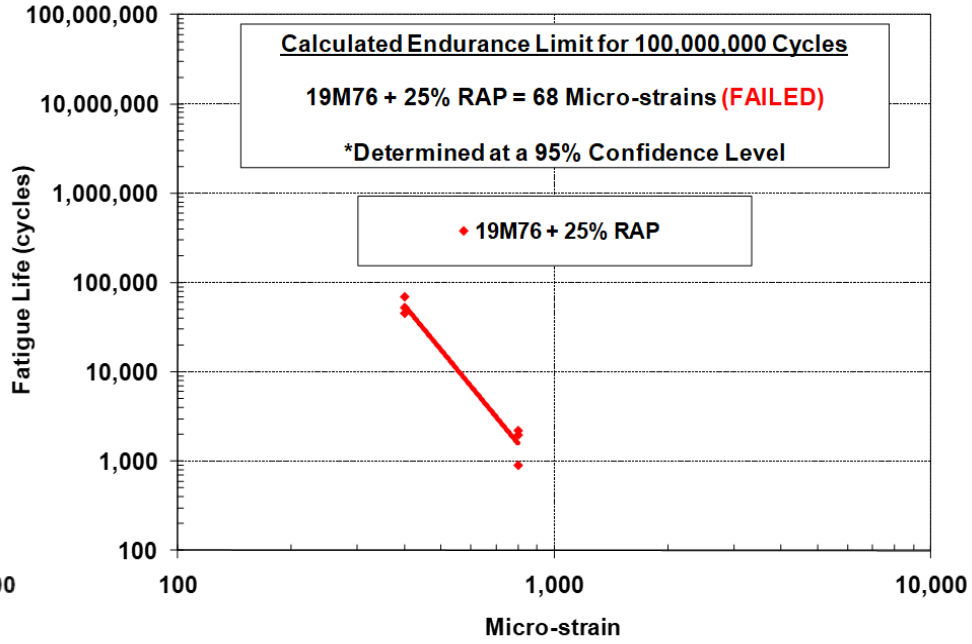


ENDURANCE LIMIT – 100 MICROSTRAIN MINIMUM

HMA 19L64 - FAILED



HMA 19M76 - FAILED



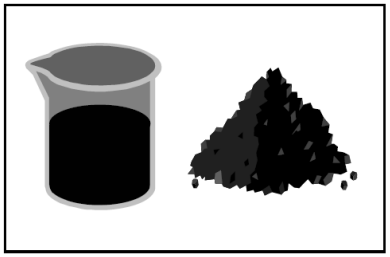
BOTTOM RICH BASE COURSE SPECIFICATION

- **19 mm NMAS Mix**
- **Minimum Asphalt Binder 5%**
  - PG 76-28
  - RTFO Elastic Recovery > 60% @ 25°C (AASHTO T301)
- **3.5 % air voids @ 50 gyrations**
- **No RAP**
- **No natural sand, 100% crushed**
- **Mix Performance Specification**
  - APA (<5 mm) and Flexural Beam (>100 ms)

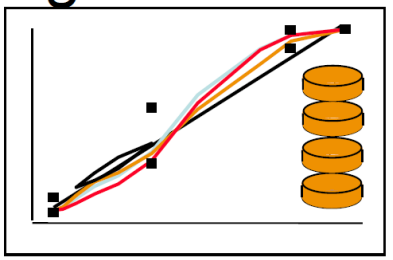
REQUIRED BRBC MIX PERFORMANCE TESTING PROTOCOL

- Conduct volumetric mix design
- Supply loose mix for performance testing (**FATIGUE & APA RUT TESTING**)
- If pass performance testing, conduct **test strip (off project site)**
  - Loose mix (**plant produced**) sampled and again tested (**FATIGUE & APA RUT TESTING**)
- If mix from off site test strip passes, allowed to perform test strip on project site
  - 1st lot of production paving

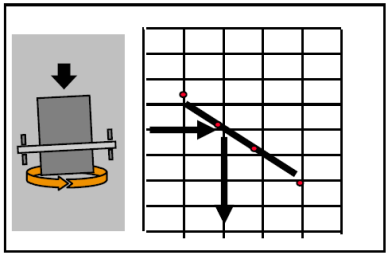
4 Steps of Superpave Mix Design



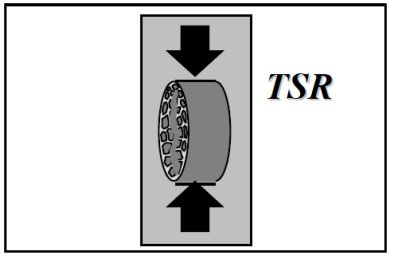
1. Materials Selection



2. Design Aggregate Structure



3. Design Binder Content



4. Moisture Sensitivity

PROJECT BID COSTS

- Total project bid: $79 million (30% < engineers estimate)
- BRBC = 177,628 T, $85.75 per T
- HMA 19M76 I.C. = 127,078 T, $60.55 per T
- 12.5 SMA = 82,228 T, $97.75 per T
- 25M64 Base = 156,000 T, $54.75 per T
  - Box out areas

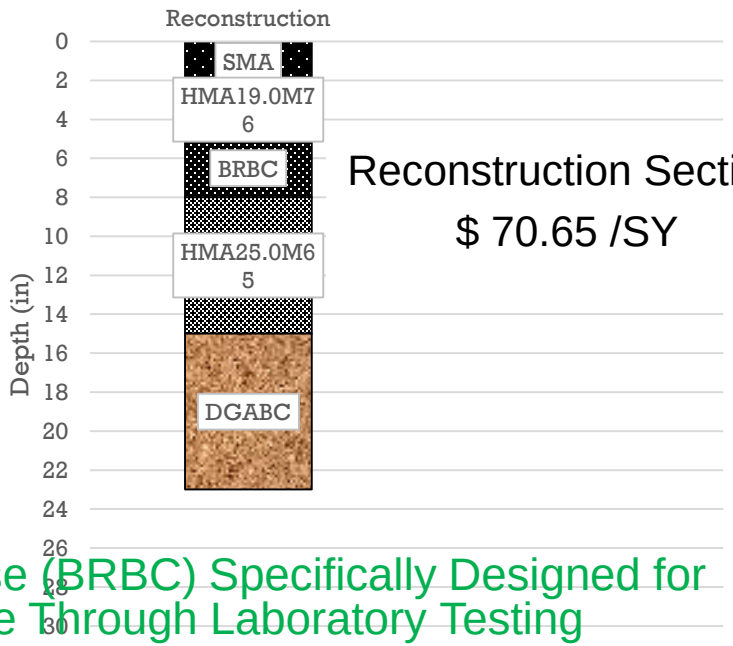
PROJECT BID

- BRBC saved 170,000 tons of HMA
- Reduced PCCP removal and replacement by 3 miles compared to 12" thickness
- (400' + 400') x 20 locations = 16,000 ft
- Final bid costs of BRBC equal or less than that of SMA on job

Comparison of Pavement Sections (Rubblization vs. Reconstruction)

Rubblized Section

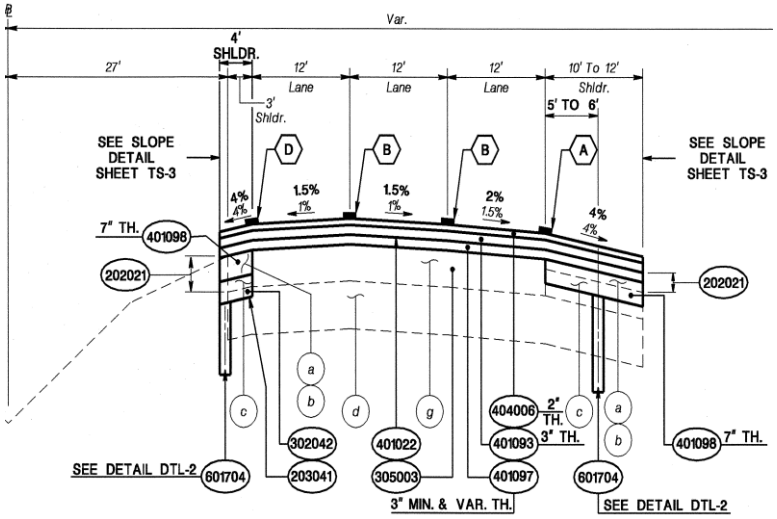
$37.06 /SY

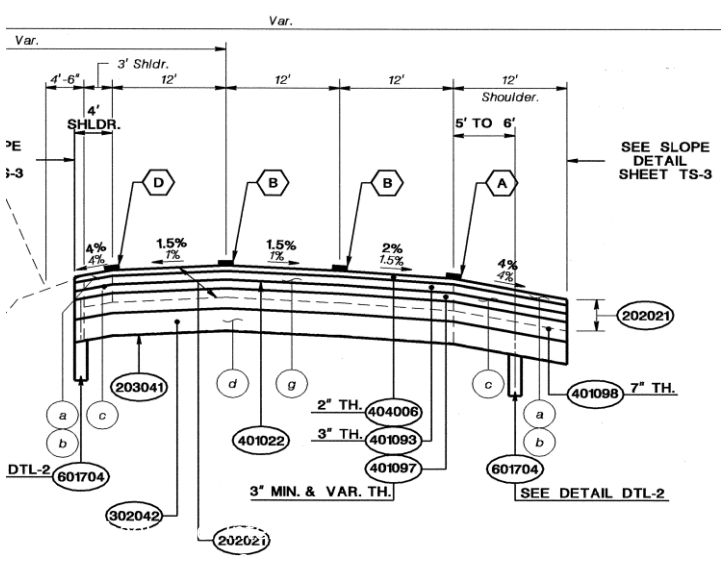


Reconstruction Section

$ 70.65 /SY

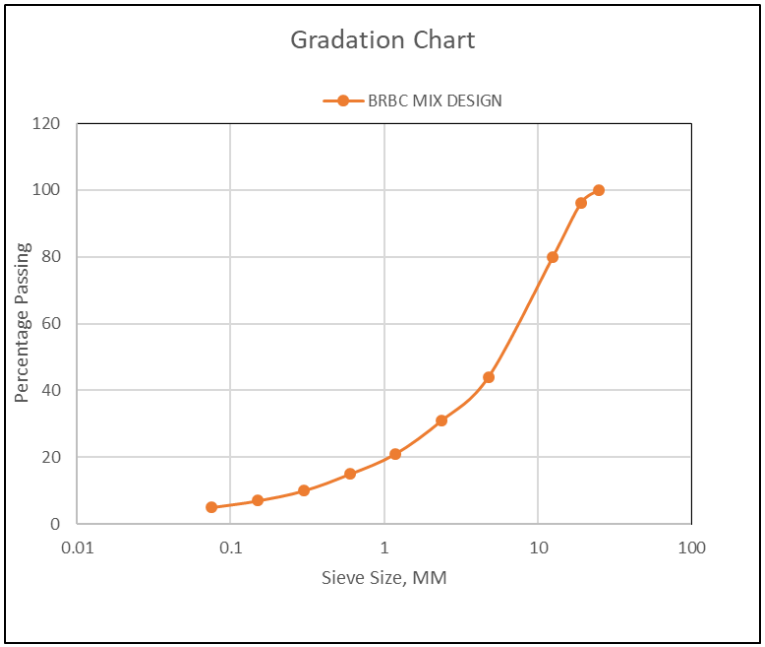
Bottom Rich Base Course (BRBC) Specifically Designed for Fatigue Resistance Through Laboratory Testing





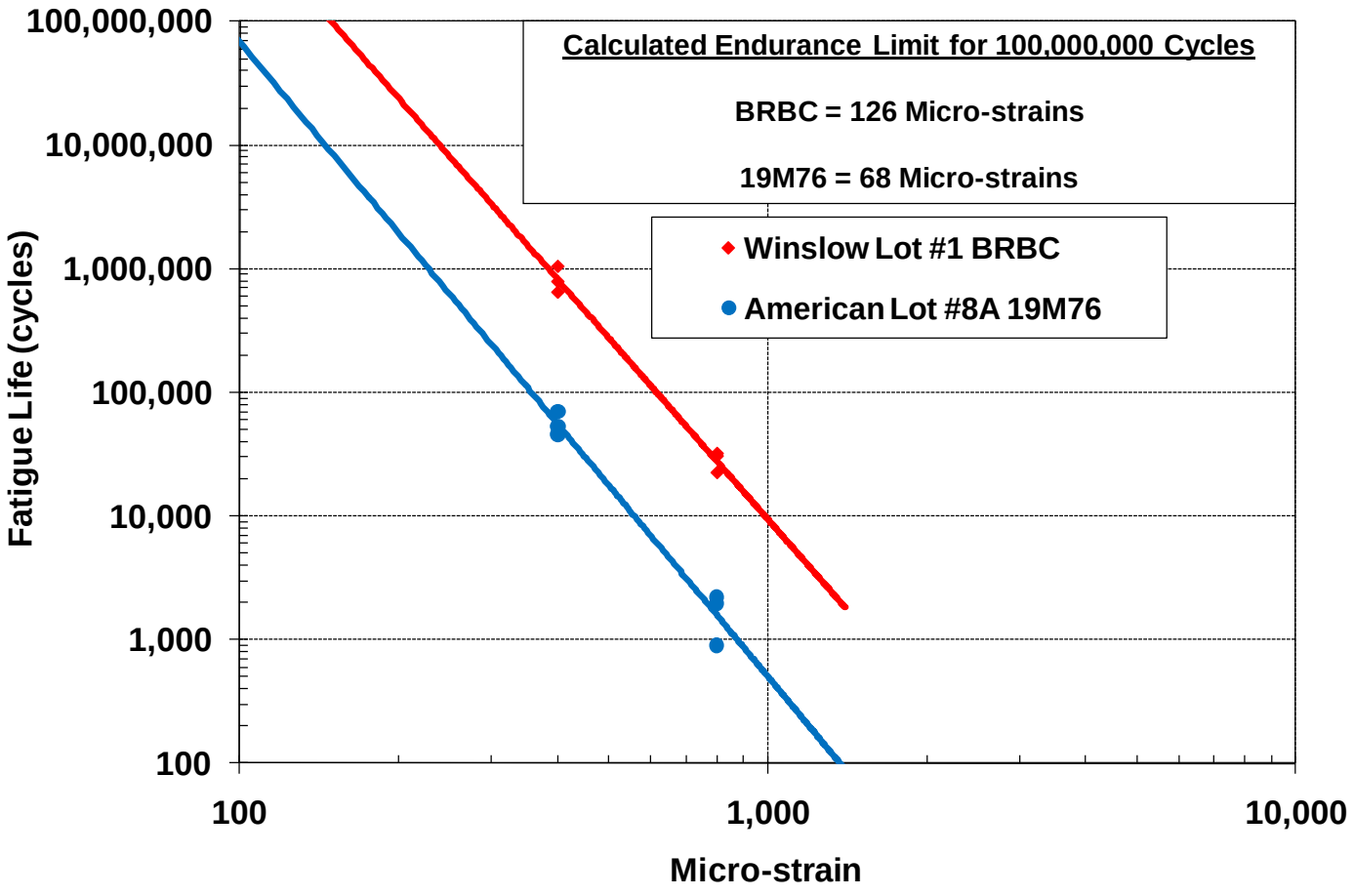
BRBC MIX DESIGN

- 6.0 % Asphalt (PG 76-28)
- 19 mm Mix
- 3.5 % air voids @50 gyrations



Sieve (mm)	% Passing
25	100
19	96
12.5	80
9.5	72
4.75	44
2.36	31
1.18	21
.600	15
.300	10
.150	7
.075	5.0

ENDURANCE LIMIT - 19M76 VS BRBC

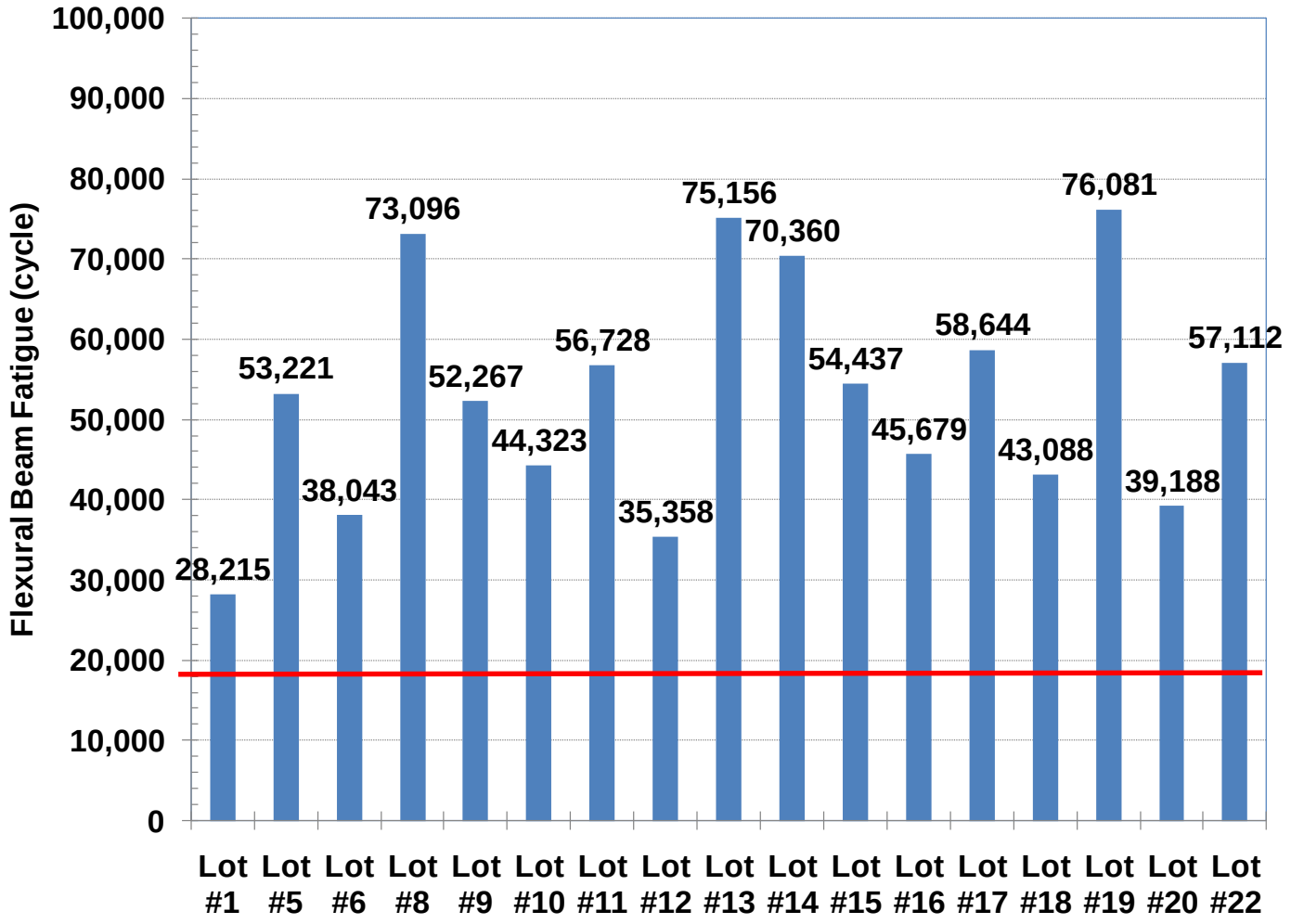


CONSTRUCTION CHALLENGES

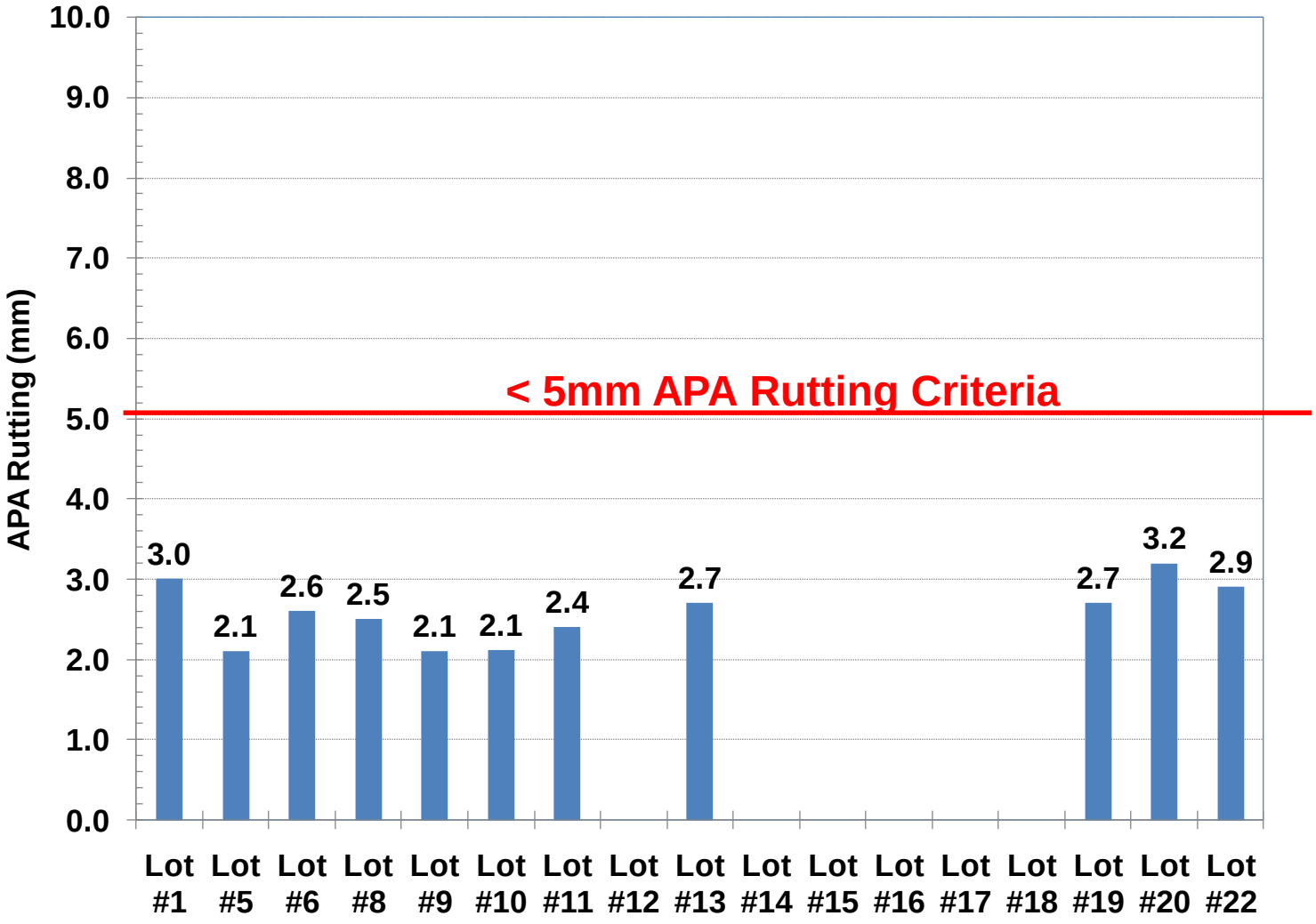
- Deterioration of the pavement in the winter of 2010 necessitated daily patching.
- Condition of the SB pavement necessitated paving some of the SB mainline prior to closing the NB side.
- Rubblization production rates falling behind schedule.
- Box out areas at structures encountered unsuitable acid producing clay
- 1st lot of BRBC
  - Low AC % (±0.4%)
  - Low AC % = Low Fatigue Resistance

Clay Layer →

QA TEST RESULTS - FATIGUE



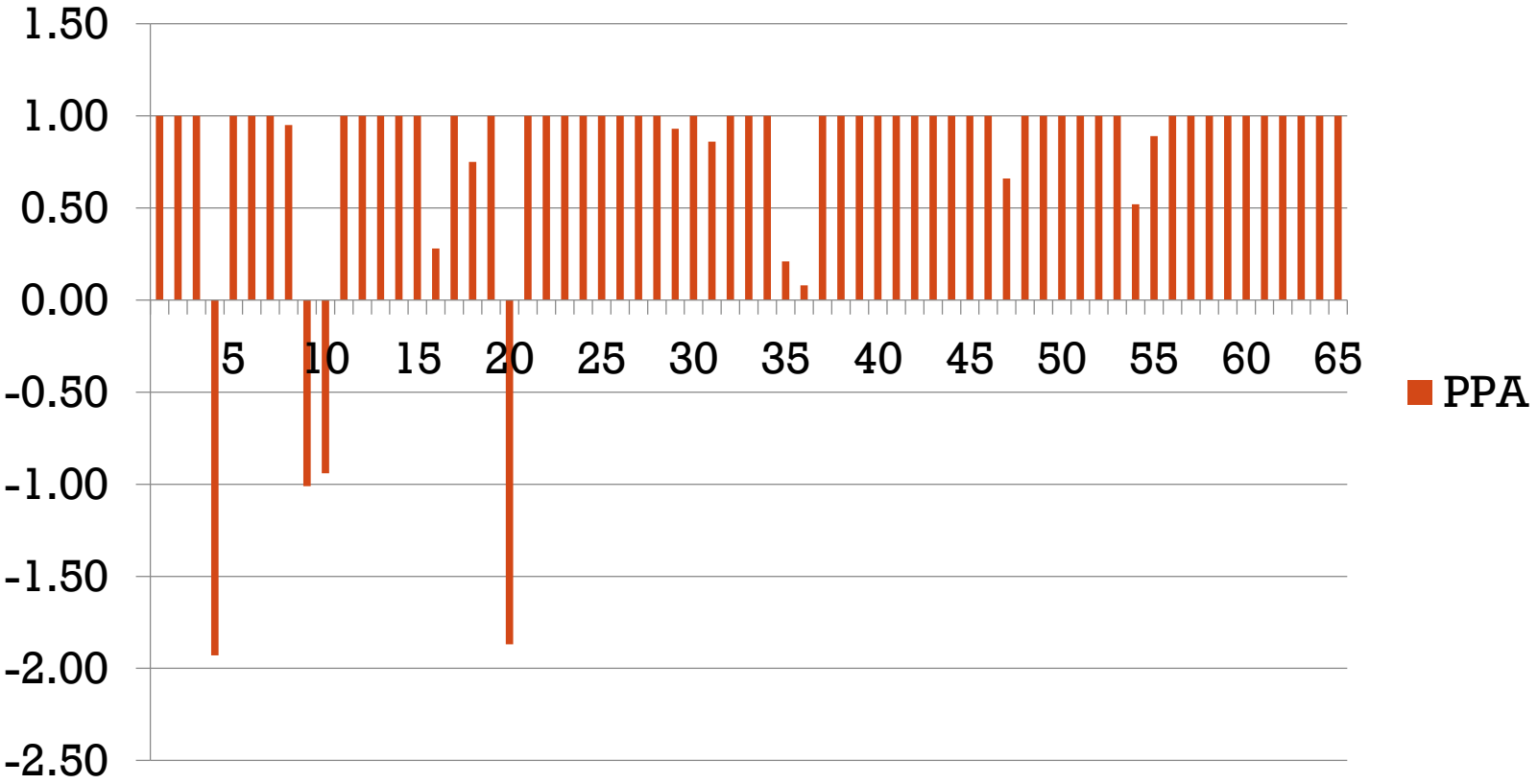
QA RESULTS - APA



CORE DATA ON BRBC

[% PAY ADJUSTMENT]

(REQUIREMENT: 1 - 8 % AIR VOIDS)



CONSTRUCTION SUCCESSES

- PG 76-28 for Bottom Rich Base Course (BRBC) was produced by NuStar out of Paulsboro and Gloucester City PMA facilities
- BRBC produced from 2 HMA plants
- In total, 3 HMA plants used to produce material for the project in order to maintain the schedule for the project (approximately 10,000 T per day)

BRBC – CORES & FIELD

CONSTRUCTION SUCCESSES

- Accelerated pavement construction (APC)
  - All rubblization and asphalt courses constructed in one season ahead of schedule (between May 2010 to October 2010)
  - Incentive Clause - $100,000 per calendar day early completion Stage 2 & Stage 4, maximum $3,000,000 per stage
  - Disincentive Clause - $100,000 per calendar day after 59 calendar days per stage, maximum $3,000,000 per stage
- Technology
  - GPS – numerous dozers
  - ATS (Automated Tracking System) – 3 ATS graders were utilized
  - Robotics – survey
  - NJDOT provided digital design files for H&K to develop project controls

CONSTRUCTION SUCCESSES

- **NJDOT utilized a performance-based approach to design and build a perpetual pavement out of an aging I-295 PCC pavement using NJDOT BRBC mix**
  - **Engineered specifically for the requirements of this project**
  - **Performance testing required for quality acceptance**

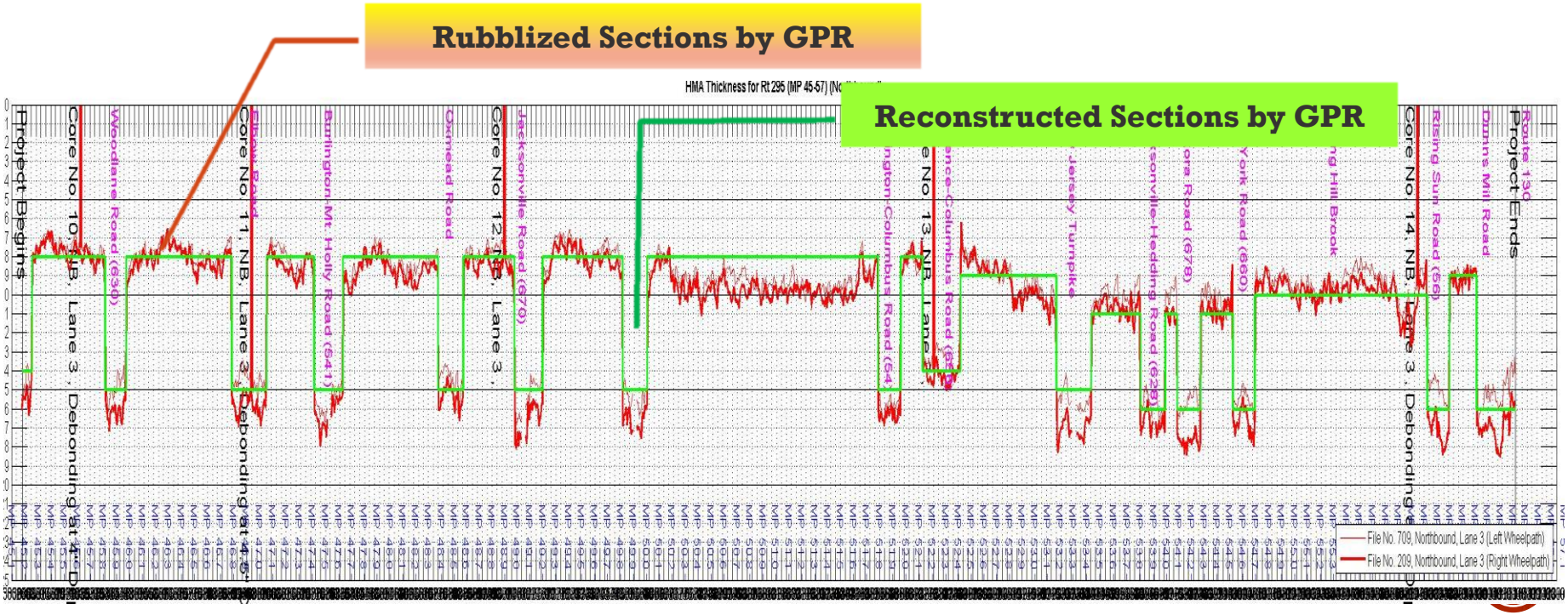
HOW IS I-295 PERFORMING?
2018 EVALUATION USING GPR & FWD

Falling Weight Deflectometer

Ground Penetrating Radar

GPR Results (2018)

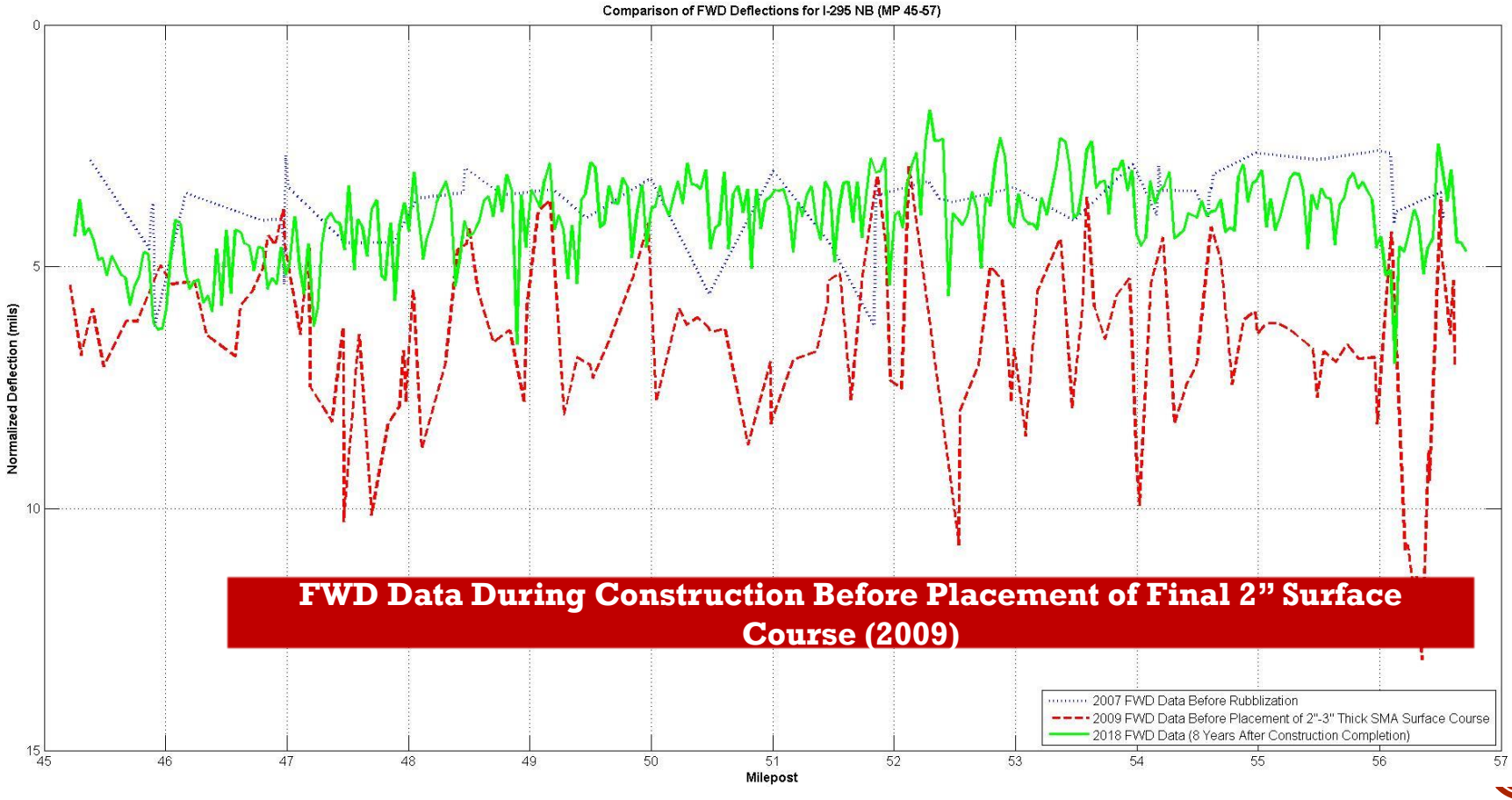
- Full-Depth Reconstruction at Bridges
- GPR Indicated Slightly Thicker Pavement than As-Built
- GPR Results Indicated Southbound Pavement is 1" Thicker Than Northbound and Performing Better



Comparison of FWD Date Before (2007), During (2009), and After Construction (2018)

FWD Data on Concrete Before Construction (2007)

FWD Data After 8 Years of Service (2018)



I-295 Concrete Pavement Condition Assessment (2018)

- Both Full-Depth Reconstructed Sections and Rubblized Section Show Low Deflections
- Rubblized Sections Indicate Similar or Lower Deflections than Reconstructed Sections
- Southbound Rubblized Sections Had Smallest Increase in IRI (0.4 in/mile per Year)
- Northbound Rubblized Sections Had Largest Increase in IRI (2.1 in/mile per Year)
- Rubblized Concrete Indicated a Layer Coefficient of 0.24 in 2018 and 0.23 in 2009
- The Rubblized Sections Expected to Far Exceed 30-Year Design Life (>50-Years)
- The Reconstructed Northbound Sections Expected to Exceed 30-Year Design Life by 2 Years
- The Reconstructed Southbound Sections Expected to Exceed 30-Year Design Life by 16 Years
- Both Rubblized and Reconstructed Sections Perform as Perpetual Pavement
- NJDOT Continues to Monitor the Performance of I-295 Pavement

Summary of I-295 Pavement Evaluation After 8 Years of Service		Avg. HMA Thickness	Normalized Deflection	Base Type	Base Layer Coef.	2017 IRI	2017 PSI	Remaining Service Life	
								2018	2025 (After 1st Resurfacing)
NB	Rubblized	8.7 in	4.1 Mils	9" Rubblized PCC	0.24	74	4.05	>50	>50
	Reconstructed	15.2 in	4.1 Mils	8" Dense Graded Aggregate	0.15	65	4.15	24	35
SB	Rubblized	10.0 in	4.1 Mils	9" Rubblized PCC	0.23	64	4.17	>50	>50
	Reconstructed	16.1 in	4.2 Mils	8" Dense Graded Aggregate	0.16	63	4.18	38	38

Southbound Has Thicker Pavement ~1”

Low IRI Values

SUMMARY

- Collaboration and Cooperation between NJDOT, Rutgers Asphalt Pavement Laboratory and Industry = Success
- Incentives/Disincentives for early/late completion = Resolution of issues quickly and efficiently = contractor Incentives
- BRBC designed specifically for the project conditions ahead of the final pavement design and construction
- Long Life Asphalt Pavement Achieved = Perpetual Pavement (>30 years)
- Currently performing very good structurally
- I-295 scheduled for Pavement Preservation treatment
  - 1" High Performance Thin Overlay (HPTO) in 2019 or 2020

THANK YOU

ROBERT.BLIGHT@DOT.NJ.GOV

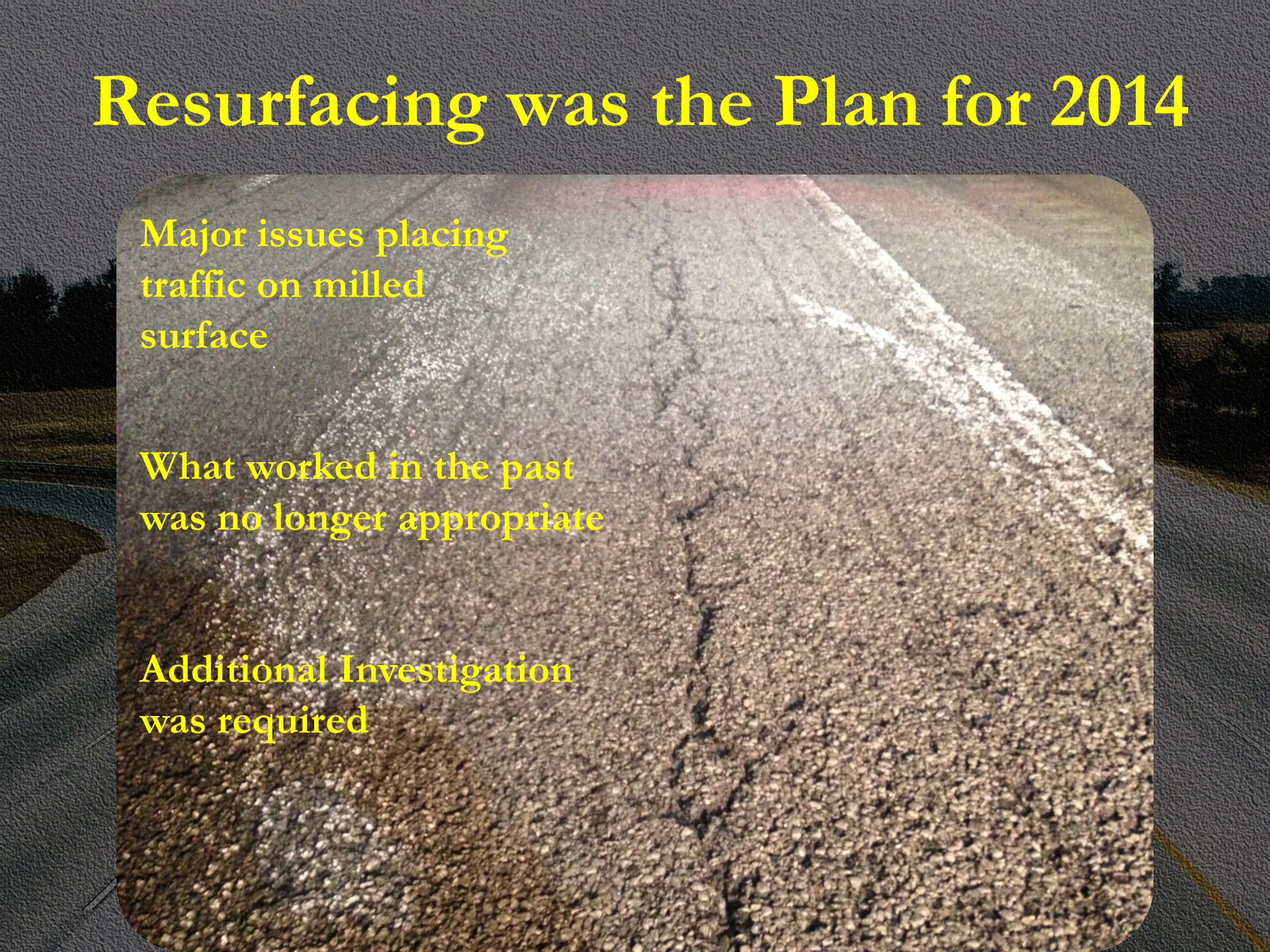
Reconstruction of South Carolina Interstates Using Intermediate B Special

Jay Thompson, PE, SCDOT State Pavement Design Engineer

I-85 Greenville

- 2 Sections Completed 1958 and 1962
  - 150 psy Surface
  - 250 psy Intermediate
  - Double or Single Bituminous Treatment
  - 12 inches GABC
  - 4 inches Stabilizer Material Subgrade
- Built up over time incrementally with overlays
- Approximately 90,000 ADT with 30% trucks

Resurfacing was the Plan for 2014



Major issues placing traffic on milled surface

What worked in the past was no longer appropriate

Additional Investigation was required

Design Limitations

- Structurally deficient. Existing SN was 7.45. Design required 8.20.
- Cant build up significantly for additional structure.
- Deterioration in upper 5 inches throughout.
- 50% or more of critical lane has distress 8 inches to full depth.
- Traffic control limited to nightly closures and extended weekend closure.
- Very limited time to figure this all out.

Intermediate B Special Mix Design

Intermediate B Special

Mix Design Objectives:

- Mixture must hold up under traffic (stiffness) and serve as a riding course if left exposed for several months, or until next construction season until final surface and OGFC could be placed on top.
- Make a mix that is relatively easy to compact.
- Return to heavy traffic the next morning on a high volume interstate.
- Don't change mixes during a shift.

Intermediate B Special

What mix could we use that would be good under traffic (Strength and Durability) and would be fine enough to seal out water if left exposed for months-years?

- Use a older 12.5mm Superpave Surface, now called Intermediate B.
- Use PG 64-22 vs. PG 76-22
- Allows up to 30% Aged Binder (RAP)
- Current Intermediate B Mix is typically placed at 2”depth.

Intermediate B Special

How do we make the current Intermediate B mix more durable and easier to compact?

- Lower Design / Field Air Void Targets
- 4.00% to 2.75% (increase binder content)
- Lower Gyrations 100 to 75 gyrations (increase binder content)
- Still allow RAP to increase stiffness – adding rut resistance
- Use WMA to aid in compaction process

Intermediate B Special

How do we obtain the lowest return to traffic temperature, reducing the chance of premature rutting and pavement damage?

- Use WMA Technology - WMA Chemical Process

Intermediate B Special

How do we measure in place compaction and ensure we are confident in the contractor's efforts?

SCDOT Concerns:

- We did not want to cut full depth cores every night and leave holes that could not be compacted properly full depth.
- Concerns with requiring the contractor to stop early enough so QC could cool the pavement down and cut cores and fill holes prior to opening to morning traffic.
- Concerns with vertical edges -joints getting enough compaction.

Require a Test Section….

Intermediate B Special

Test Section Requirements….

- Obtain full depth cores only in the test section and take gauge shots to establish offsets.
- Cores and gauge shots taken in mainline and within 6-12” of vertical joints.
- Cores sliced into multiple layers to ensure density was obtained from bottom up.
- Several different gauges used in case of malfunction and in anticipation of starting two milling-paving operations.
- Nuclear and Electronic Gauges used.

Intermediate B Special

*Require a Contractor QC Plan**

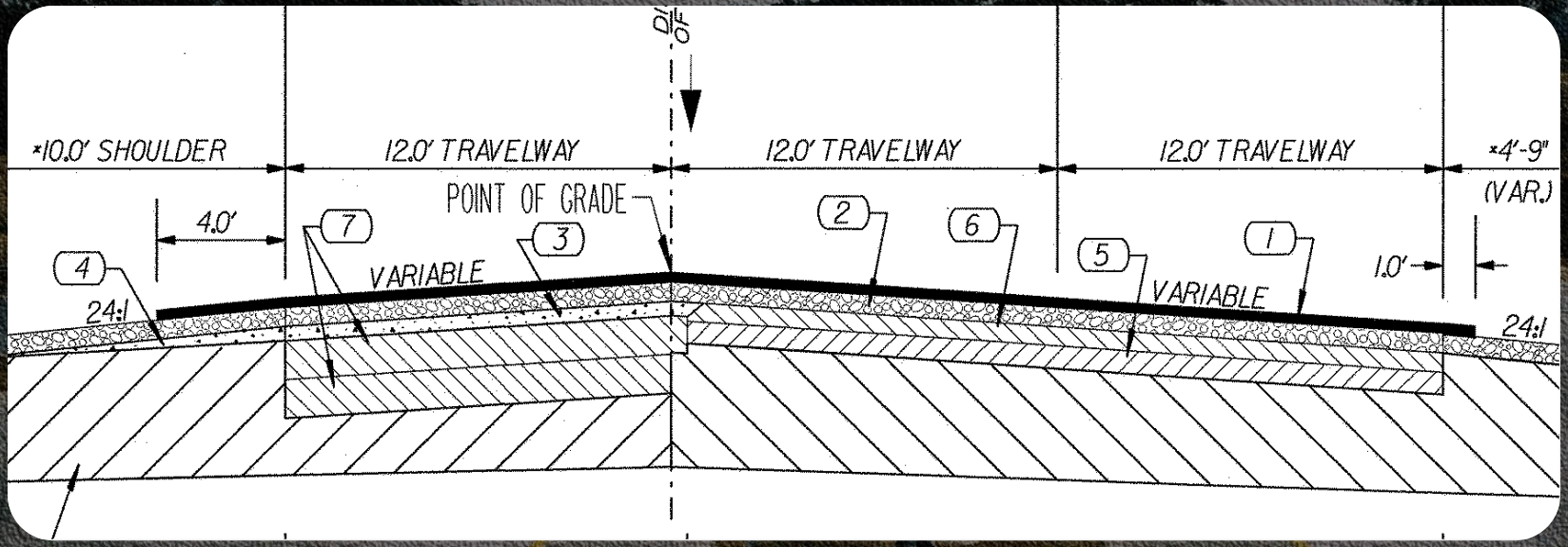
Required to make contractor come up with an approved plan ahead of paving that would address concerns with:

- Lane Closure Restrictions – High Traffic
- Milling Operations – Staging (stagger 1st and 2nd cut with milling to establish offset)
- Backup asphalt plant - available in case of breakdown
- Cleanup – sweeping operations – deep hole
- Tack – Address concerns with break time - coverage
- Paving – MTV and Trucks

* Ability to amend the QC plan nightly if needed to maximize production and quality.

Final Design

Mill 10 inches in right lane and Mill 5 in left and middle lanes. Maximum lift 400 psy using a new mix. Place additional Structure



Required a lift of Surface E on right lane and 2 lifts of Intermediate B Special on the middle and left lanes.

Design Changes

- Design was further altered post award (VE) working with contractor.
- Reduced to 1 lift of 450 psy in left and middle lanes and 2 lifts of 495 psy in right lane. Eliminating Surface E.
- Required test strip
  - Some initial concerns about compaction and production
  - Results were good, lets move forward!!

SN Results in Outside Lane

- Original SN 7.45 (2014), 7.47 (2008)
- After 10 inch mill and 9 inch replacement SN 8.31
  - This exceeds the design and still had surface and OGFC to be placed.
  - Final thickness of new HMA will be approximately 11.8 inches in critical lane.

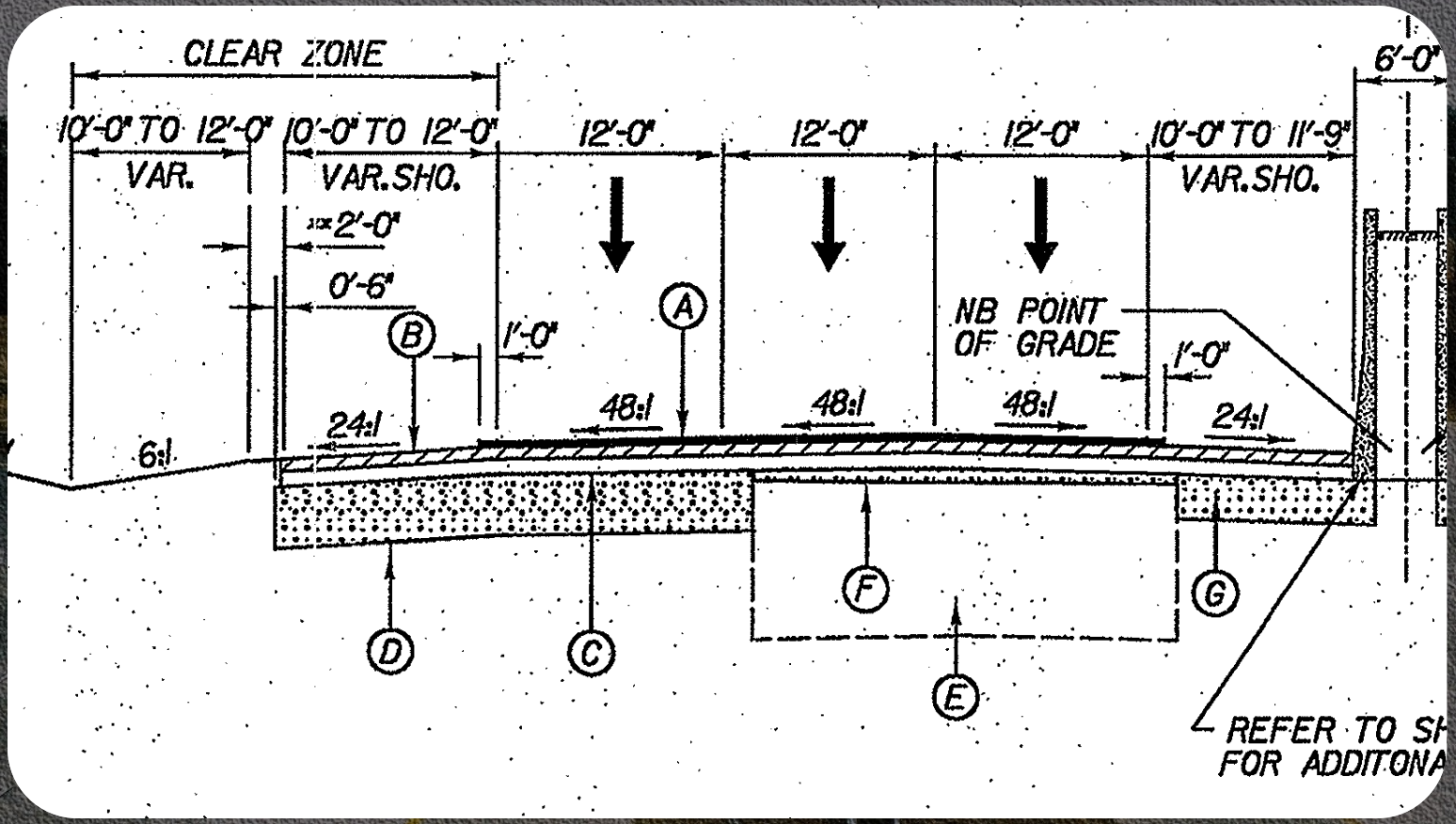
Construction I-85

- Contractor produced from 2 plants and ran 2 crews in opposing directions.
- Thick lifts allowed for placement in lower temperatures maximizing production.
- It was 31 F at the conclusion of the first test strip.
- Production temperatures varied to keep the delivery temperature between 260-270 F.

Construction I-85

- Placed 150,985 Tons between February and August, completing the initial reconstruction work in the first year.
- Average production 600 – 1000 Tons per day per crew. Best day 3,221 Tons in NB direction.
- Subsequent 200 psy Surface A and OGFC were placed over the following year.
- 2 years elapsed between start of work and substantial work complete. Mile Markers 54 - 68

I-385 Greenville



Approximately 95,000 ADT with 5% Trucks

I-385 Greenville Existing Conditions

Relatively consistent distresses

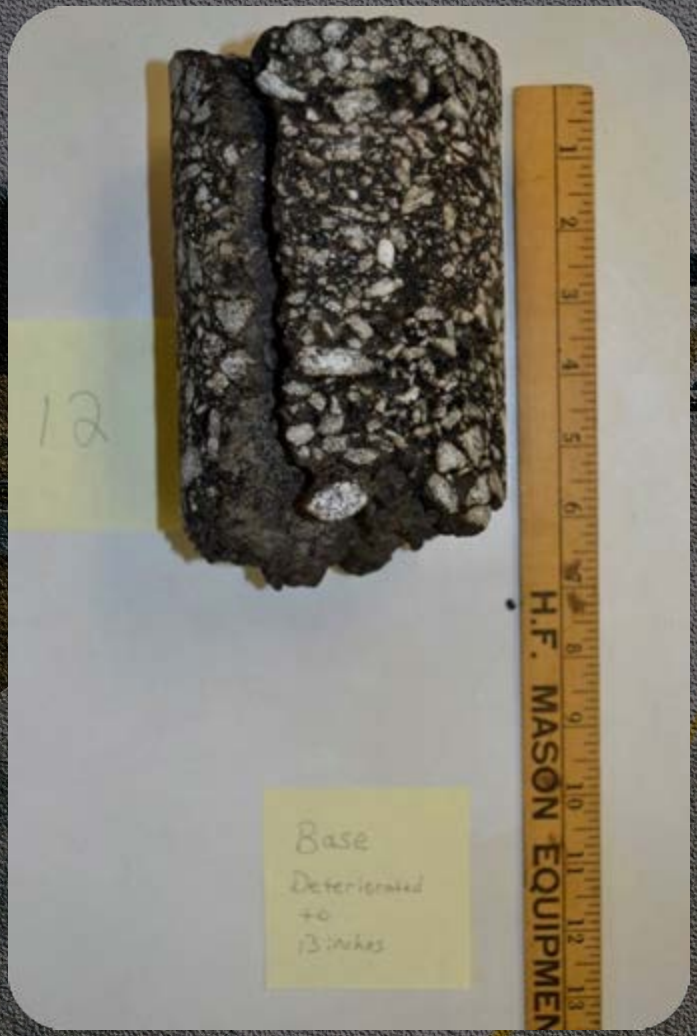
Isolated fatigue cracking

4 mile section SB outside lane significant deterioration

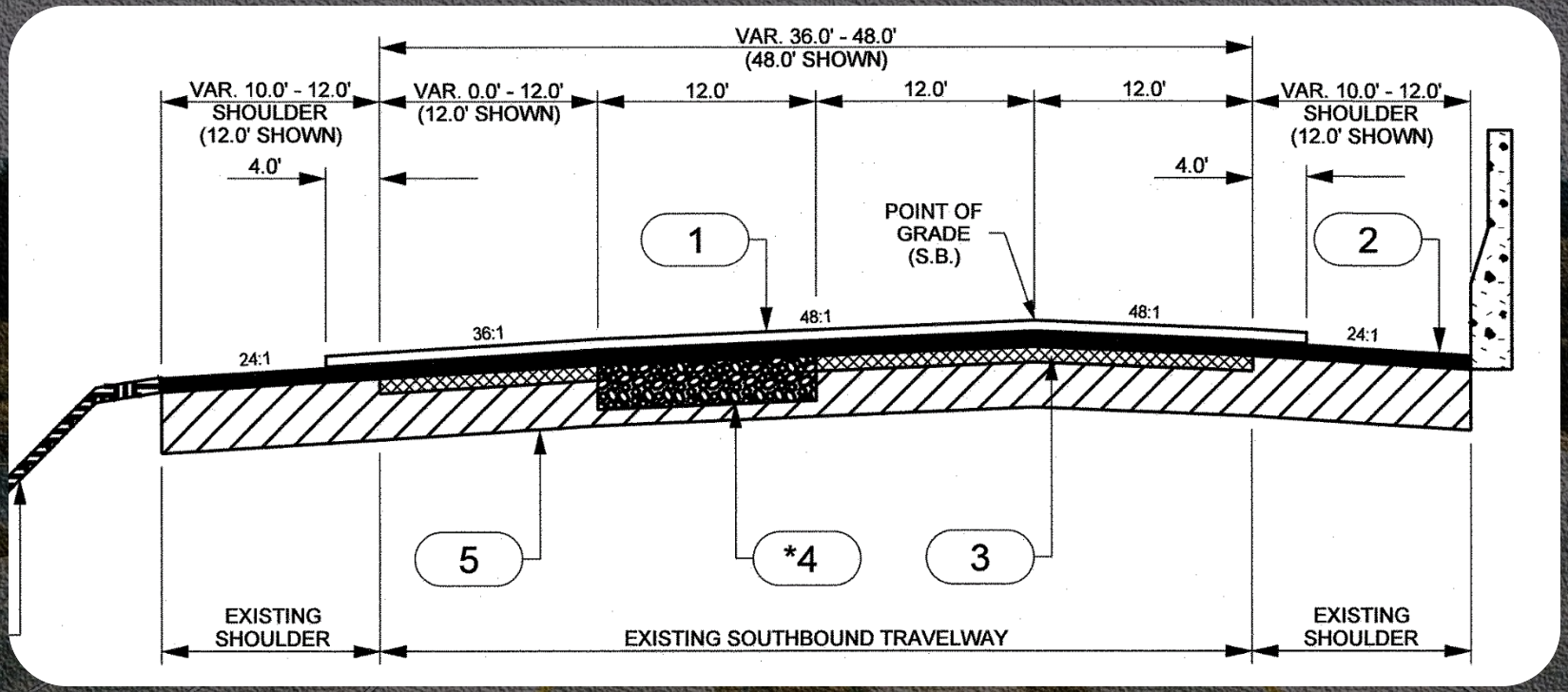
Overlay I-385

Widening I-385

Widening I-385



I-385 Greenville Design



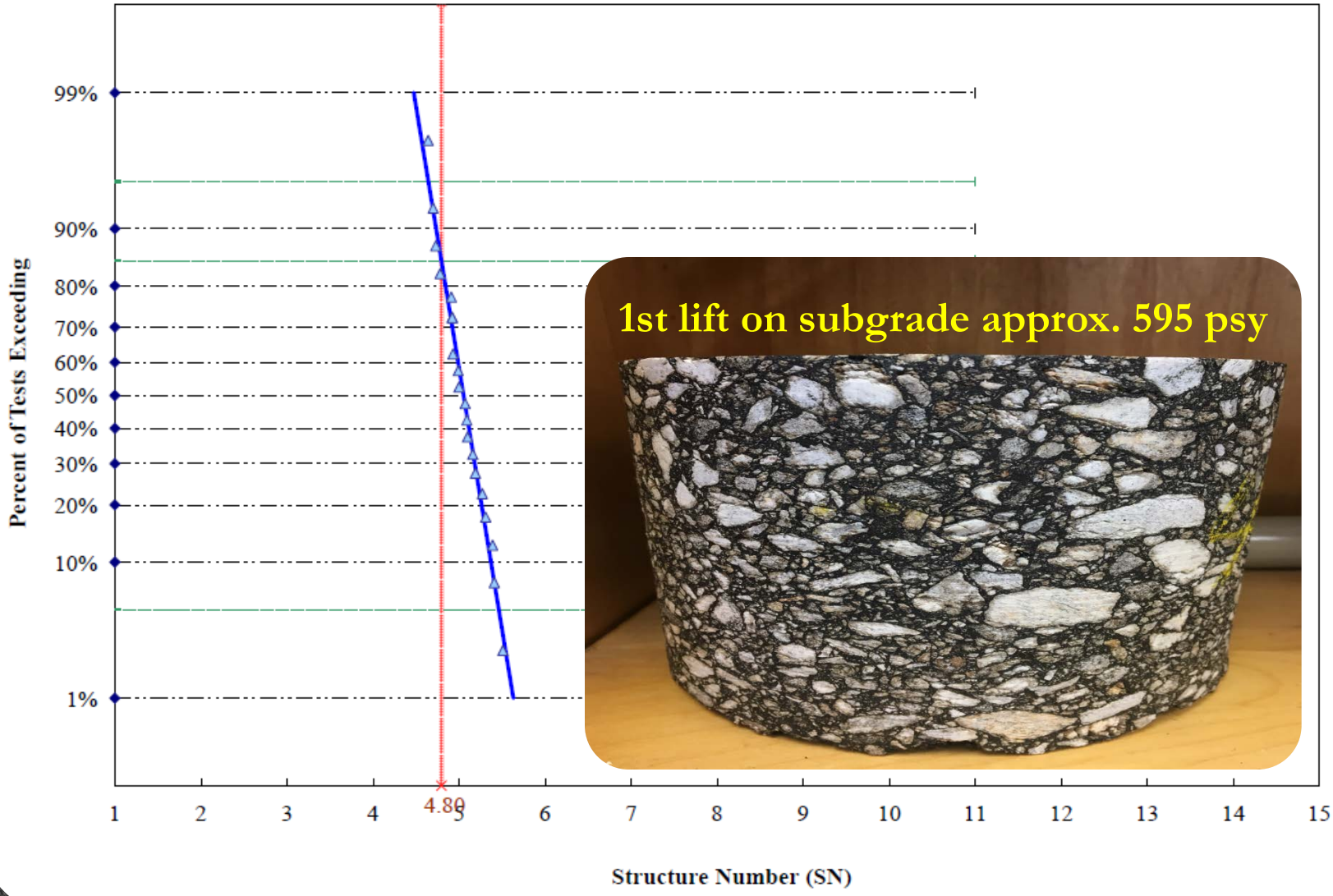
Nightly double and single lane closures for most of the work. Extended single lane closures were allowed Monday through Wednesday

I-385 Subgrade Challenges

I-385 Asphalt Placement

Contractor averaged 1000 to 1500 feet per 24 hour period

I-385 Greenville SN



Is There A Future?

- Section to be placed on test track at NCAT this cycle.
- Methods have already been incorporated into FDP procedures.
- Upcoming primary route project, 5 inch mill and replace with diamond grinding for rideability.

Engineering Asphalt Pavement Mixtures to Meet Pavement Design and Construction Needs: California Case Studies

John Harvey
University of California Pavement Research Center
UC Davis

On behalf of many colleagues from Caltrans, industry and UCPRC

Goals of California Asphalt Long Life Rehabilitation

- Goals: Long Life and Fast Construction and Minimum Traffic Delay
- Long life =
  - 30 to 40 years to next rehabilitation for structural layers
  - 10 to 15 years for rubberized open-graded surfacing
- Fast construction =
  - As fast as possible without causing unacceptable traffic delay
- Minimum traffic delay =
  - Minimum total delay
  - Less than 90 minute queue lengths (generally)
- And want to do this with lowest life cycle cost

Some Heuristics

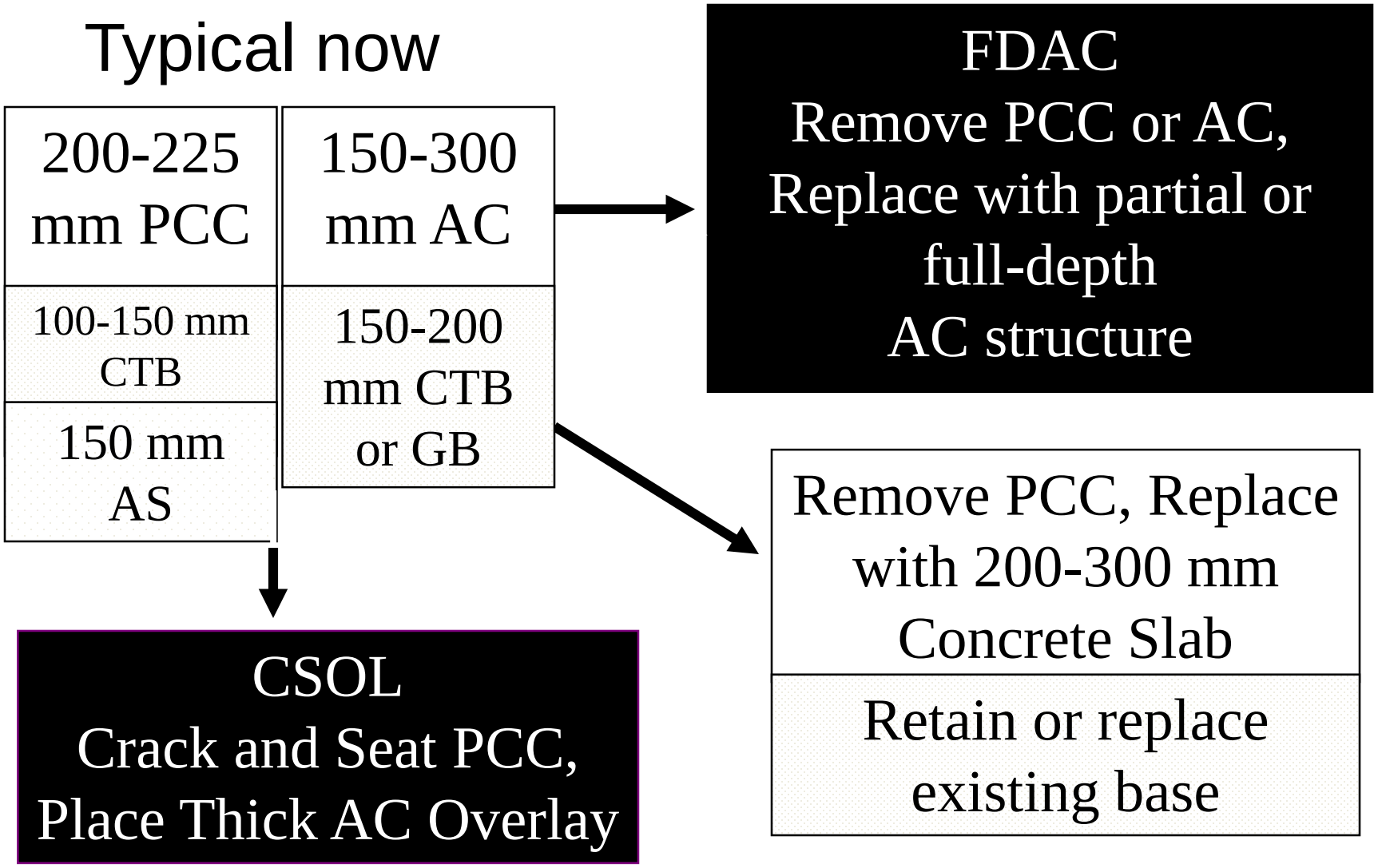
- Construction windows/traffic delays:
  - Windows used: 10 hour, 55 hour weekend continuous, 72 hour weekday continuous, continuous multi-day until finish one side
  - 10 hour windows less efficient for construction, bad for quality
- Mixes and structures:
  - Construction time increases linearly with thickness
    - Trucking material in and out are constraints
  - Use materials design and improved compaction to reduce thickness and keep design life
  - Keep mix designs as simple and constructible as possible
  - Contractor designs mixes to meet performance related test requirements used to design the pavement
- Materials Engineering + Pavement Engineering + Construction Engineering + Traffic Engineering

Typical Structures Needing Long-Life Rehabilitation

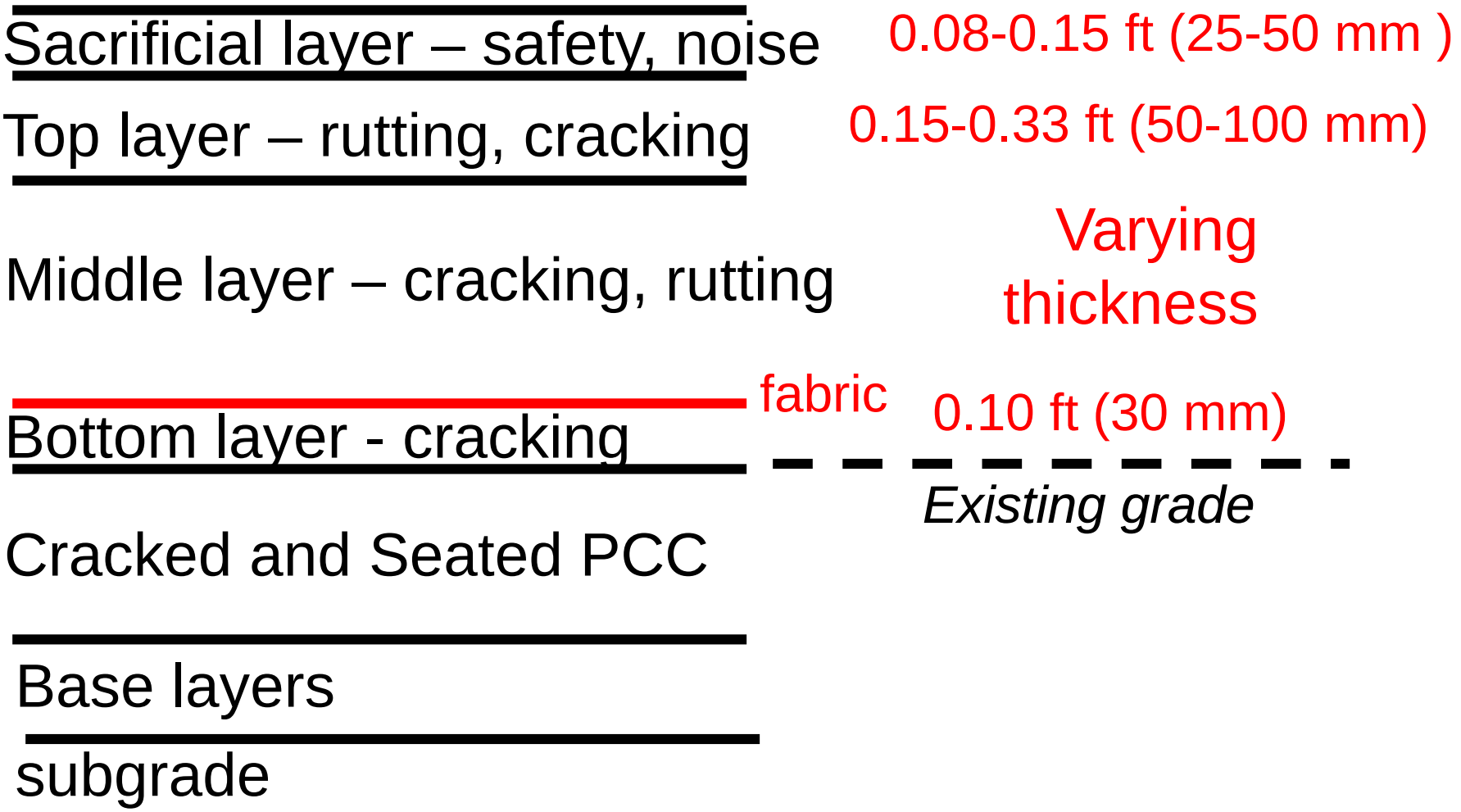
- Urban
  - Cracked jointed plain PCC
  - No dowels

- Rural
  - Asphalt
  - Fatigue cracking, moisture damaged asphalt
  - Reflection cracks from CTB, PCC, old asphalt

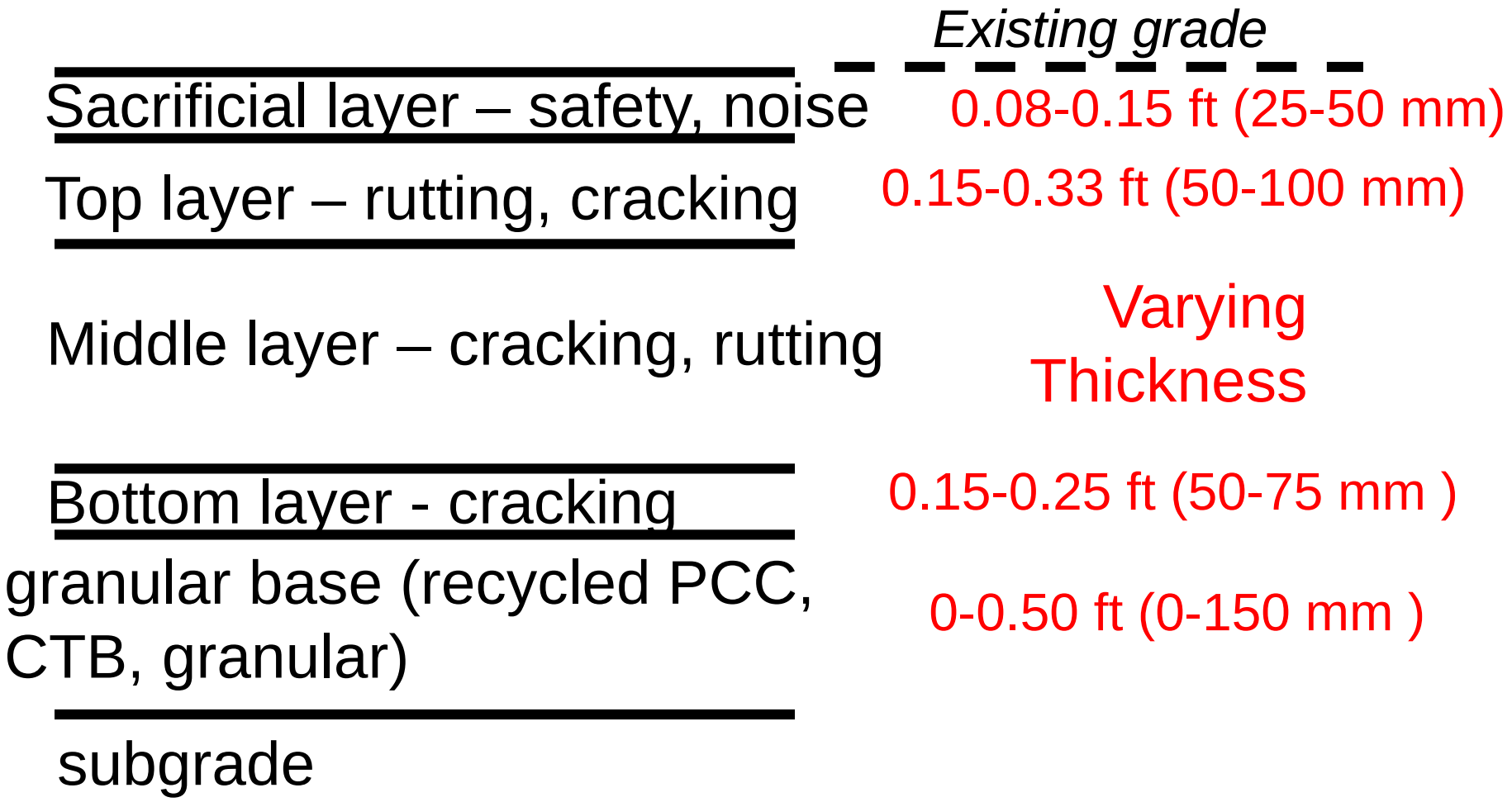
Current Long-Life Rehabilitation Strategies



Crack, Seat and Overlay
Caltrans designs using local baseline mixes

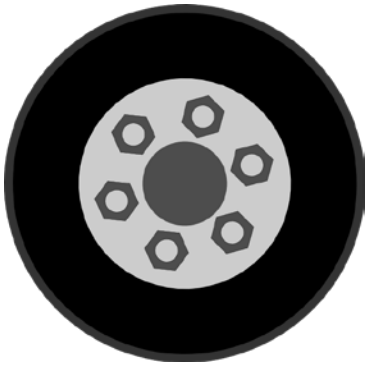


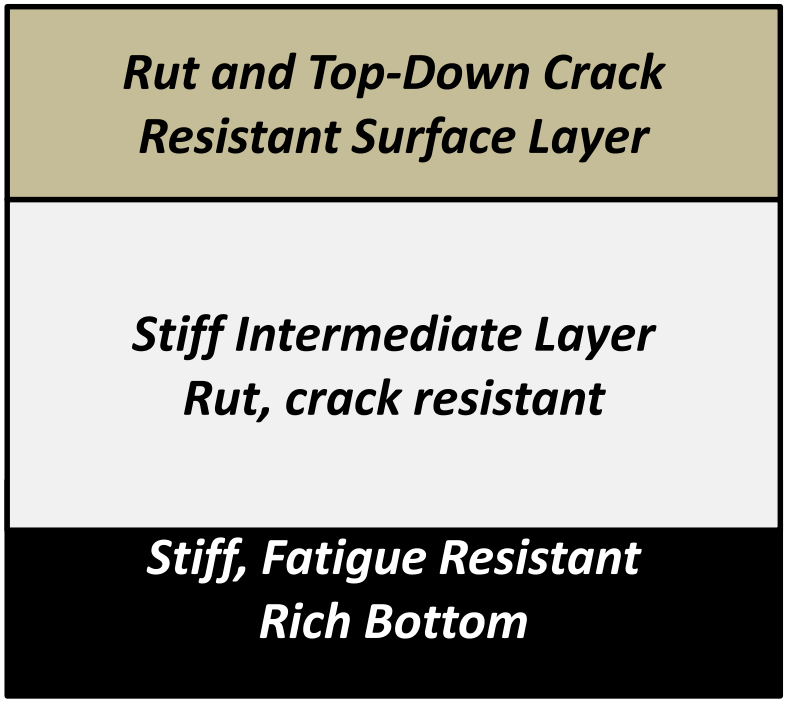
Full-Depth Asphalt Concrete
Caltrans designs using baseline local mixes



Mix component and compaction requirements

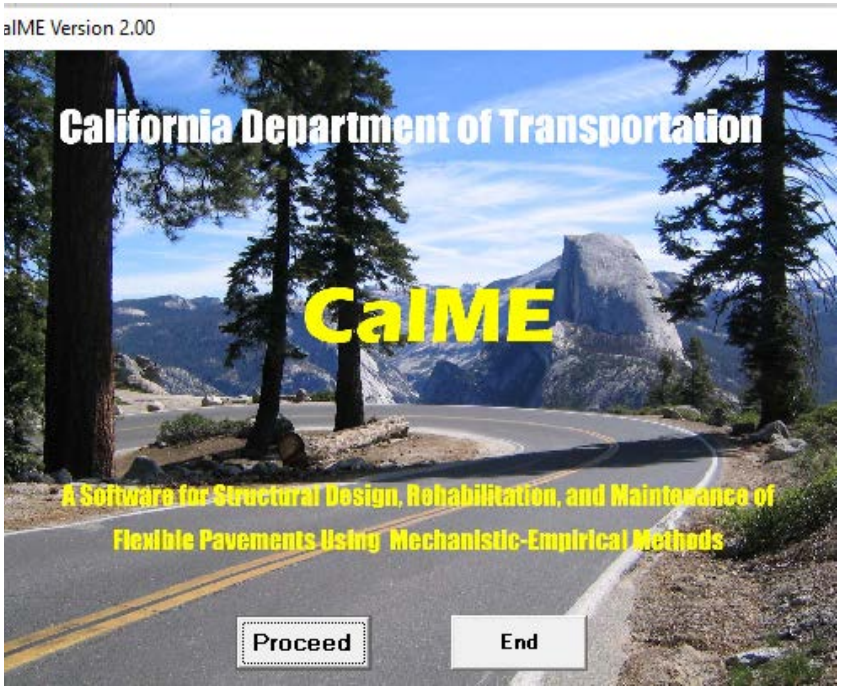
- **Surfacing: RHMA-O**
- **Top Layer**
  - Polymer modified
  - 15% RAP max
  - 6% AV max in place
- **Intermediate Layer**
  - Max 25% RAP
  - 6% AV max in place
- **Rich Bottom Layer**
  - +X% Binder
  - Max 15% RAP
  - 3% AV max in place

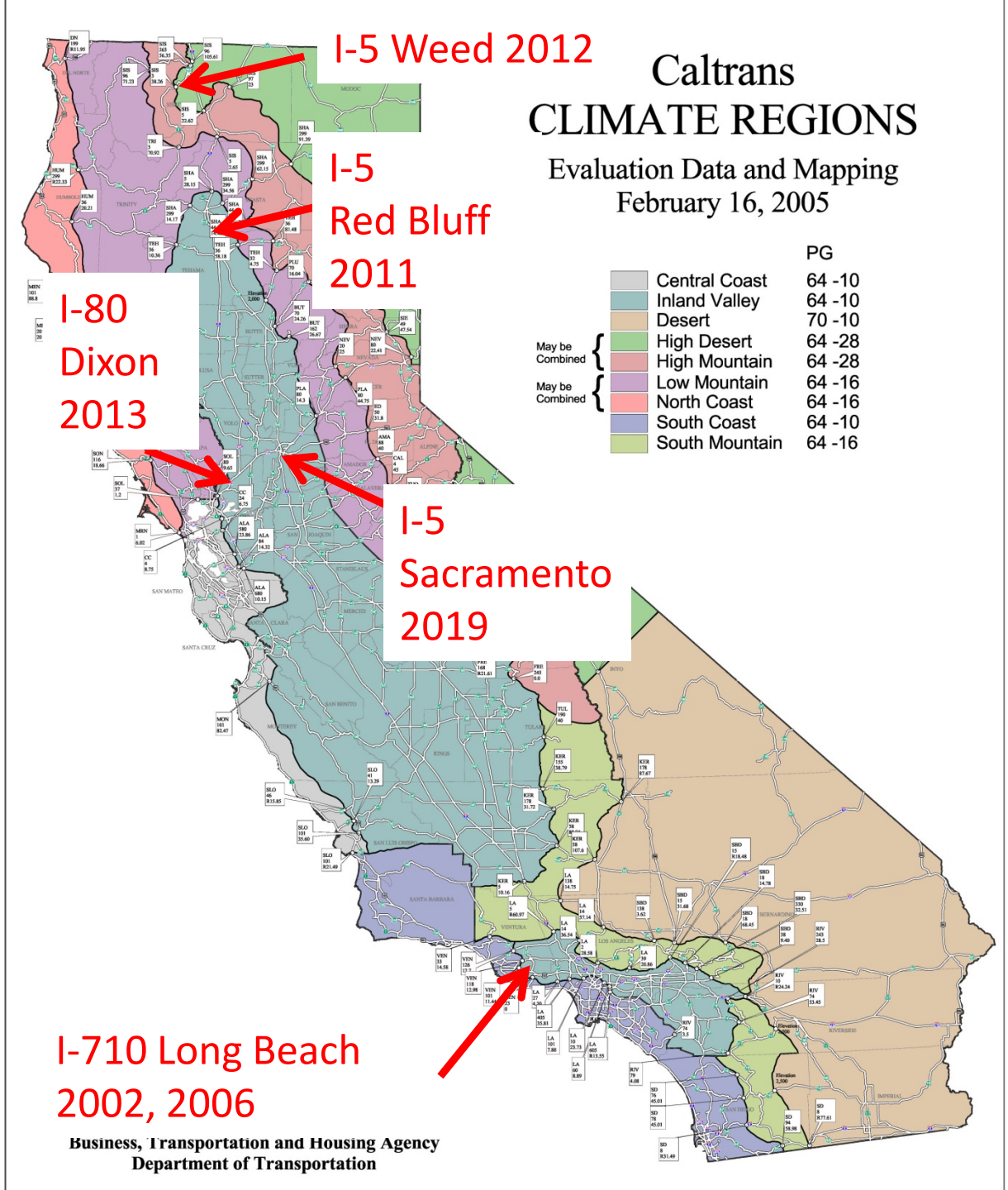




Structural Designs Using Mechanistic-Empirical Design *CalME*

- Introduced in 2006, web-based v3.0 introduced 2018
- Focus on rehabilitation and preservation
- Incremental – Recursive approach
  - Simulation runs one increment of loads/temperatures at a time
  - Calculates damage and permanent deformation
  - Adjusted stiffnesses are used as input for the next increment
- Design for bottom-up or reflective cracking, rutting
- 95% confidence (within project)





Projects to Date and Approach Updates

- Long Beach projects under Hveem, AR binder
- Last three projects included 25% RAP, PG binder
- Next project: I-5 Sacramento, Superpave, use of perf related tested for construction quality

Conventional Approaches vs AC Long Life Effects on Full-depth Thickness (I-710)

Traditional materials, construction and ME design

535 mm thick (21 in.)

8 % air-voids
same mix design throughout
AR-4000 std binder

AC Long Life using

- Improved compaction
- Stiffer binder (RAP)
- Rich Bottom

300 mm thick (12 in.)

75 mm polymer 5% air-voids
150 mm AR-8000
5% air-voids
75 mm AR-8000, 2% air-voids
+0.5% binder

Performance Related Tests (Sac-5)

- **Fatigue/Stiffness (for** JMF approval only)
  - T 321, - Beam Flexural Fatigue test
- **Permanent Deformation (New)**
  - T 378, “Flow number test” using AMPT (asphalt mixture performance tester)
  - Using repetitions to permanent axial strain because Flow Number can be hard to pinpoint for California mixes
- **Fracture Energy Potential (New)**
  - TP 124, semi-circular beam (SCB) fracture test
- **Moisture Sensitivity**
  - T 324 Hamburg wheel tracking test (HWTT)
  - T 283 Tensile strength ratio (TSR)

AC Long Life – Process to Set Baseline Mix Design for Specifications (1/2)

- Sample local materials
  - All local aggregates within HMA haul distance
  - All available binders meeting 64-28PM, 64-16
- Select binder based on binder test results
- Established requirements for rutting
- Put together dense gradation and do volumetric mix design following CT Superpave procedure for surface and intermediate courses, used OBC+0.5% for rich bottom
  - Checked rutting criteria
  - Checked across aggregate types

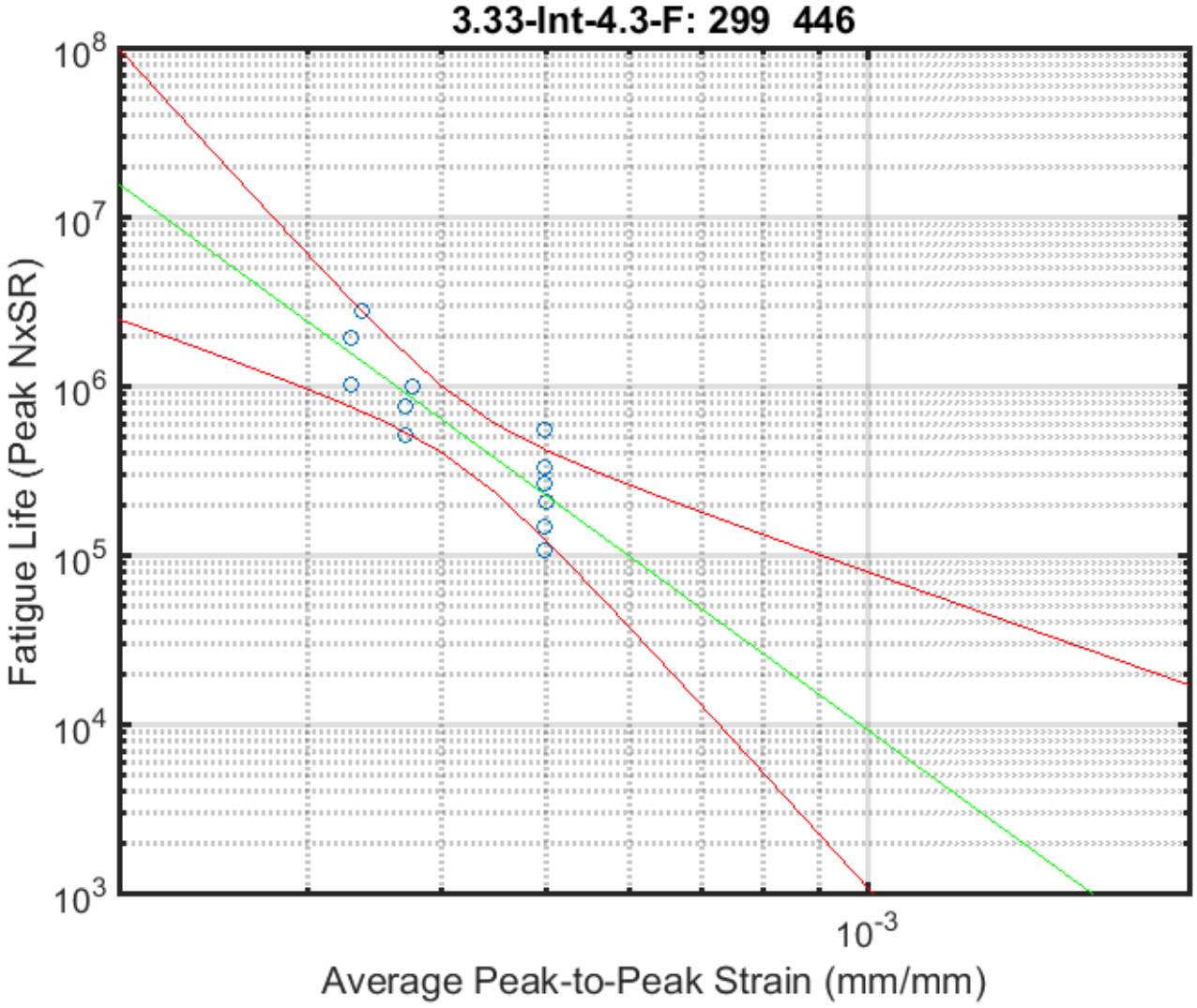
AC Long Life – Process to Set Baseline Mix Design for Specifications (2/2)

- Perform lab test characterizations for CalME structural design
  - Flexural stiffness, flexural fatigue, shear
- Caltrans runs CalME to verify pavement performance

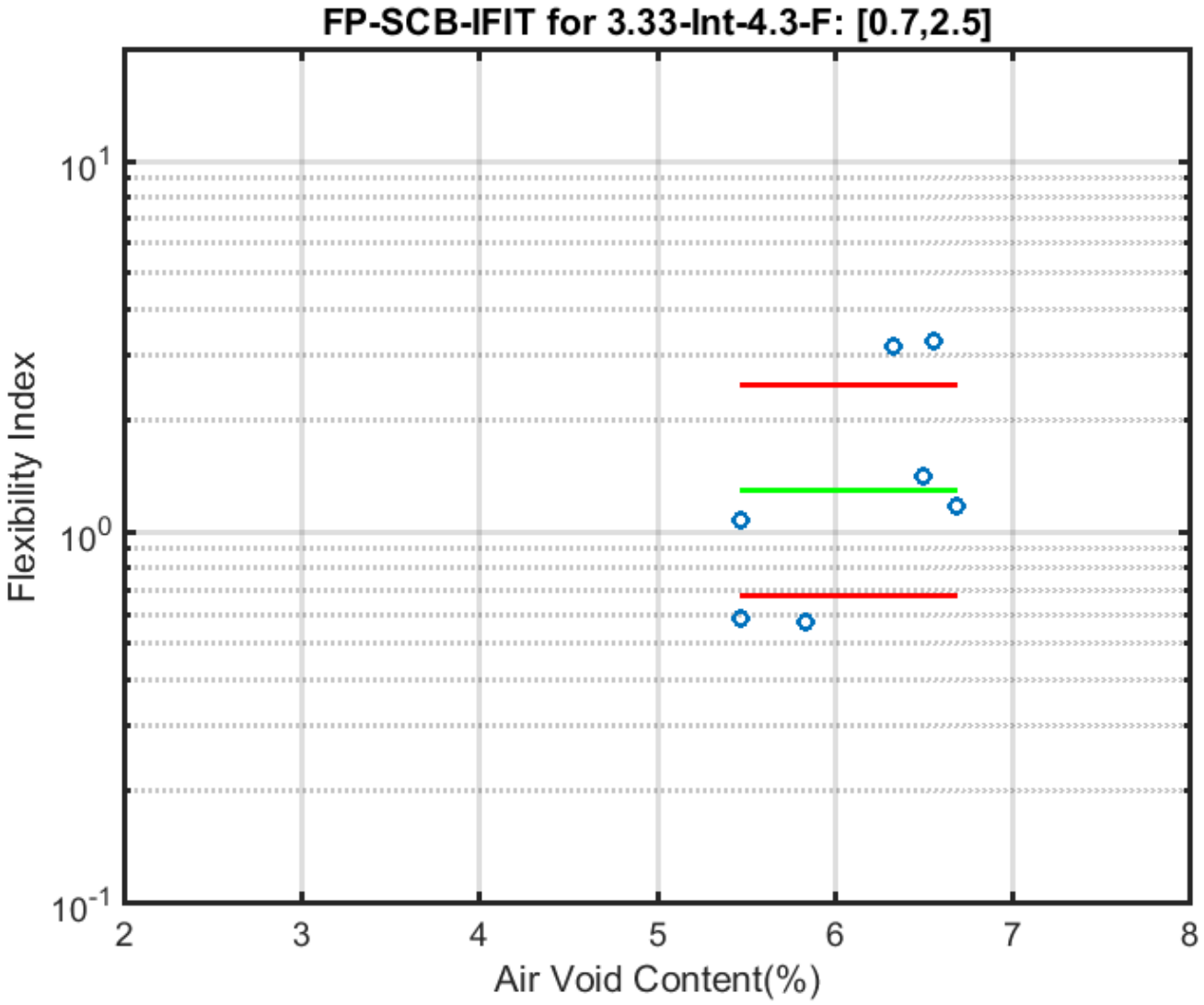
Setting of Baseline Performance-Related Construction Requirements

- 95% confidence intervals determined from baseline mix tests
- Contractor average result needs to meet 2.5% confidence interval
- Intent: take most of testing risk off contractor
- Same approach used on other AC Long Life projects

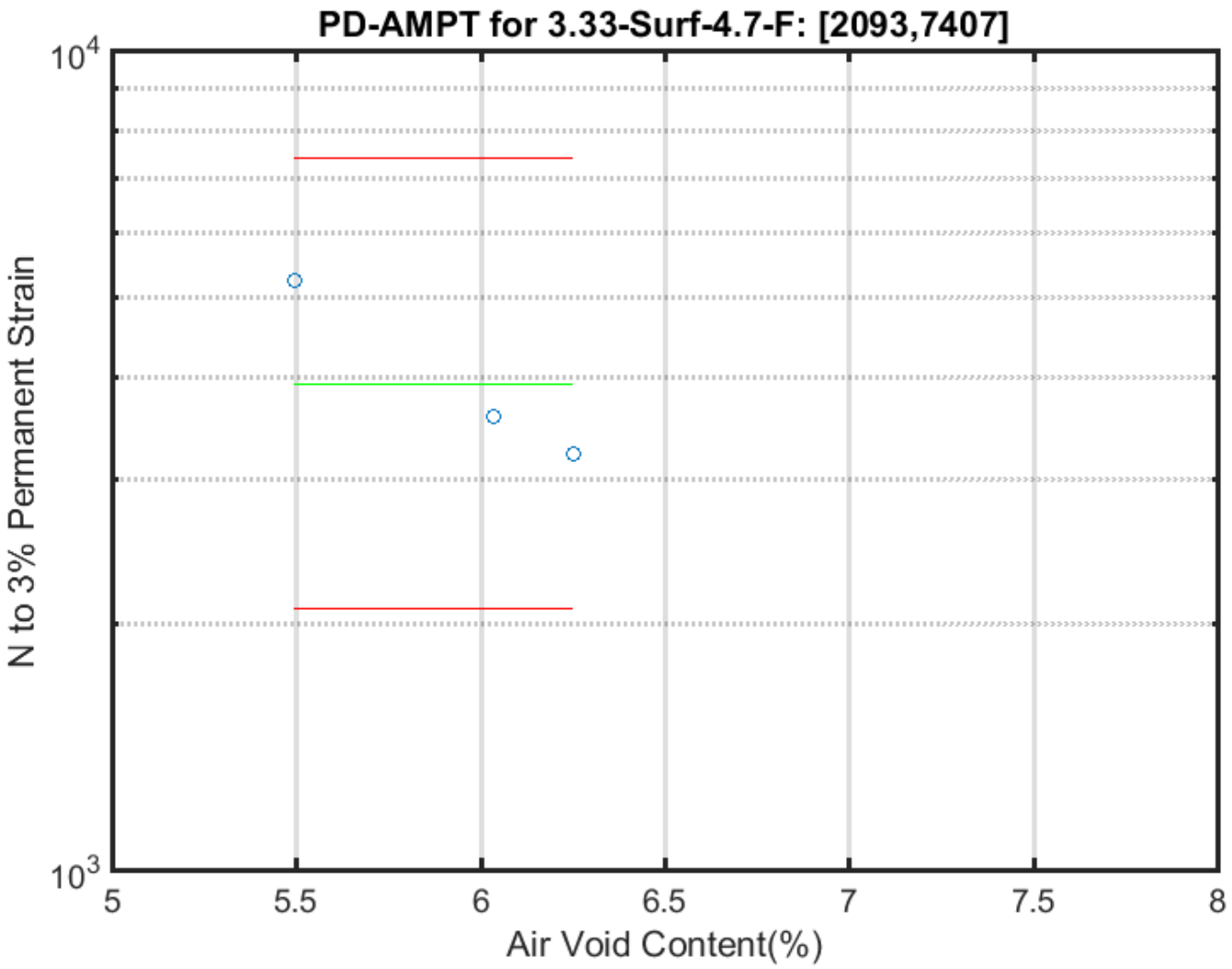
Setting of Baseline Performance Requirements – Flexural Fatigue Life Example



Setting of Baseline Performance Requirements – Fracture Energy Index Example



Setting of Baseline Performance Requirements – Permanent Deformation Example



Baseline Performance Requirements – 1/2

HMA-LL Performance Requirements					
			Requirement		
Design parameters	Test method	Sample Air Voids	HMA-LL, Surface	HMA- LL, Intermediate	HMA-LL, Rich Bottom
Permanent deformation: [1,2]					
Minimum number of cycles to 3% permanent axial strain	AASHTO T 378[3]	Mix specific[4]	2,093	4,131	Not Required
Beam stiffness (psi): [2,5]					
Minimum stiffness at the 50th cycle at the given testing strain level	AASHTO T 321 Modified[3]	Mix specific[4]	214,000 at 952×10^{-6} in./in.	789,000 at 446×10^{-6} in./in.	756,000 at 441×10^{-6} in./in.
Beam fatigue: [2,5]					
Minimum of 1,000,000 cycles to failure at this strain	AASHTO T 321 Modified[3]	Mix specific[4]	617×10^{-6} in./in.	299×10^{-6} in./in.	306×10^{-6} in./in.
Minimum of 250,000 cycles to failure at this strain			952×10^{-6} in./in.	446×10^{-6} in./in.	441×10^{-6} in./in.

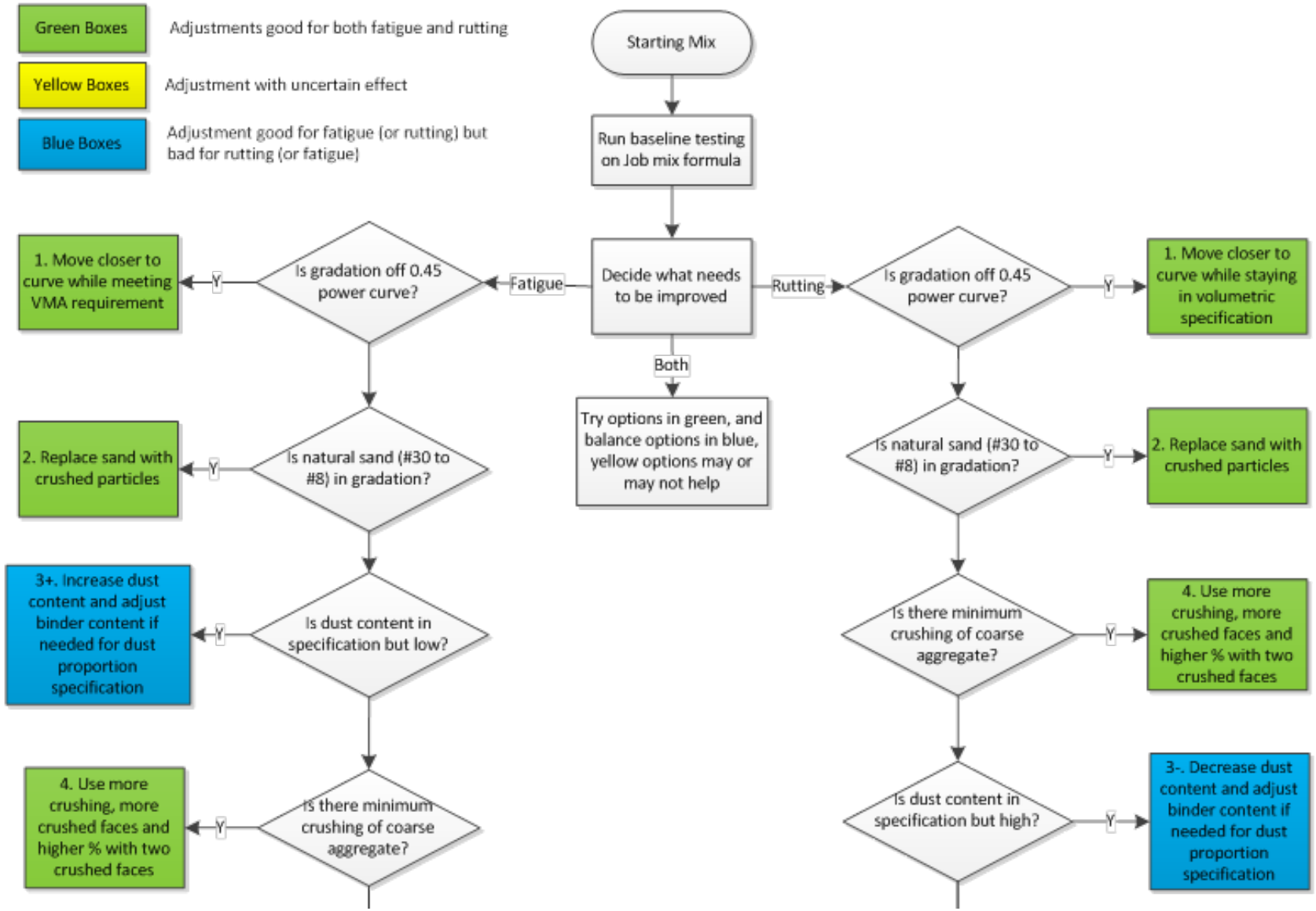
Baseline Performance Requirements – 1/2

HMA-LL Performance Requirements					
			Requirement		
Design parameters	Test method	Sample Air Voids	HMA-LL, Surface	HMA- LL, Intermediate	HMA-LL, Rich Bottom
Semicircular beam fracture potential: [2] **Minimum flexibility index**	AASHTO TP 124[3]	Mix specific[4]	3.0	0.5	0.5
Moisture Sensitivity: [6] **Minimum repetitions**	AASHTO T 324 Modified[3]	Per test method	20,000	20,000	Not Required
NOTES:					
[1] Tested at a temperature of 122°F (50°C), unconfined, 4.4 psi contact stress, and 70 psi repeated axial stress					
[2] Average value determined from tests on 3 specimens and calculated as the geometric (not arithmetic) mean.					
[3] Included in the testing procedure, LLP-AC3, "Sample Preparation and Testing for Long-Life Asphalt Concrete Pavements" available at: http://www.dot.ca.gov/hq/esc/Translab/ormt/fpmlab.htm]					
[4] 6 ± 0.5% for HMA-LL, Surface and HMA-LL, Intermediate mixes, and 3 ± 0.5% for HMA-LL, Rich Bottom mix all following AASHTO T 331					
[5] Perform tests at 10 Hz load frequency and 68°F (20°C) test temperature **[6] Minimum number of repetitions for rut depth of 0.5 in. at 122°F (50°C)**					

What the Contractor Must Do in Mix Design and Construction

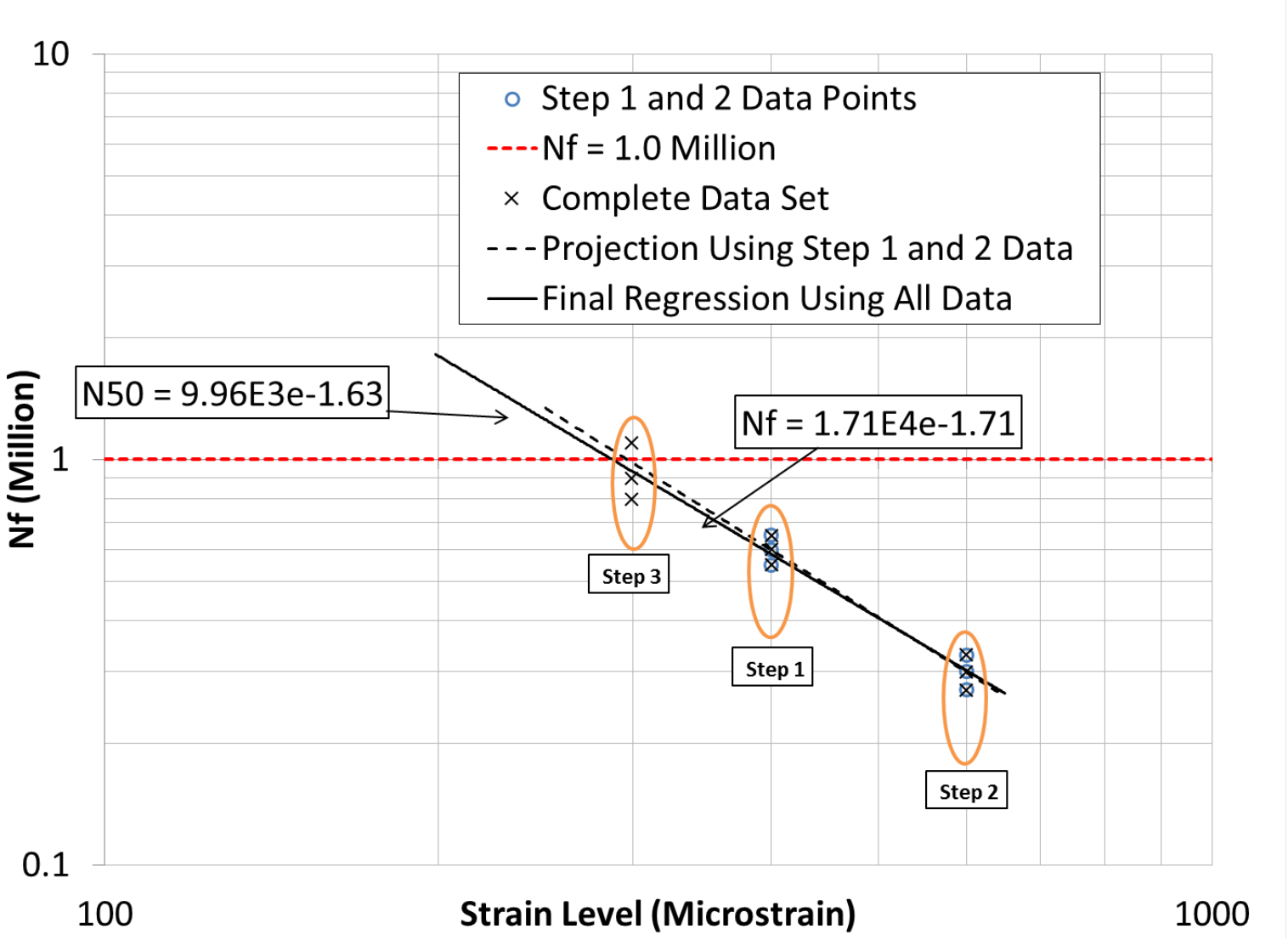
- Job Mix Formula:
  - Must meet performance related test requirements
  - Aggregate gradation, maximum RAP content limits
  - VMA report only
- Construction:
  - Meet JMF gradation and binder content targets with allowable variability
  - Meet repeated load triaxial and SCB requirements
    - Lot size 1500 tons or one lot per day

Mix Design Guidance Report – Alternative ideas to improve rutting and/or fatigue



Questions?

Current Performance Based Laboratory Tests – Fatigue Testing



I-5 Red Bluff, Tehama PM R21.7-42.1

Criteria	JMF, I-005 Red Bluff, Tehama PM R21.7/42.1	JMF, I-005 Red Bluff, Tehama PM R21.7/42.1	JMF, I-005 Red Bluff, Tehama PM R21.7/42.1
Submision Date	2/28/2012	2/28/2012	2/28/2012
HMA Type	3/4" HMA Type A	3/4" HMA Type A	3/4" HMA Type A
Rap	15%	25%	15%
Asphalt Binder Grade	PG 64-28PM	PG 64-10	PG 64-10
Asphalt Binder Content	5.1	5	5.5
Max Specific Gravity	2.504	2.505	2.494
N_D, av	3.8%	4.2%	3.0%
Mix Type	Surface	Intermediate	Rich Bottom

Report to be Published in Next Month:

- Mix Design Guidance for Use with Asphalt Concrete Performance-Related Specifications
- Example mix and guidance on how to improve rutting, stiffness and fatigue performance related properties
  - Gradation
  - Aggregate texture
  - Binder content
  - Binder grade
  - Binder supplier

Other Notable Details

- Use of material transfer vehicle required
- No blending chart for up to 25% RAP binder replacement
- Tolerance for RAP binder content is ±2%
- Use of warm mix asphalt technologies is allowed, but minimum mixing temperature is 300°F
  - To achieve blending of RAP and virgin binders