Balanced Mix Design

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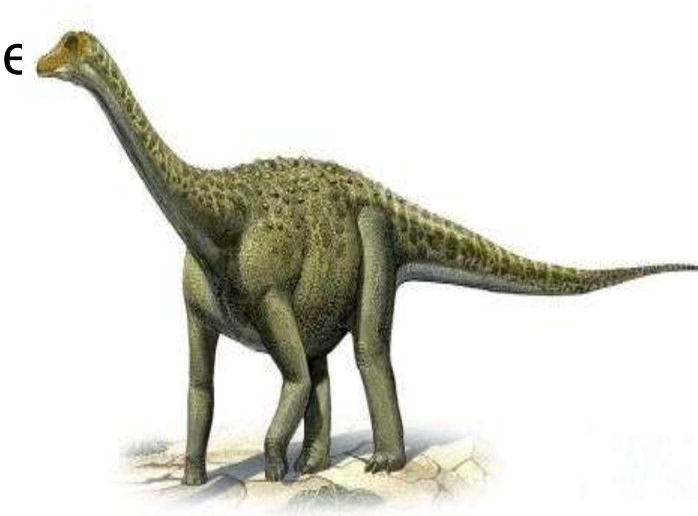
How have asphalt materials changed?

- 1901 – 2000 **Age of Uncomplicated**
  - Almost all unmodified asphalt
  - Recycling in 1970s – 90s: Low amounts of RAP
  - Almost all dense-graded mixes
  - Marshall and Hveem become displace
  - Volumetric design works OK

Recycled as Roads

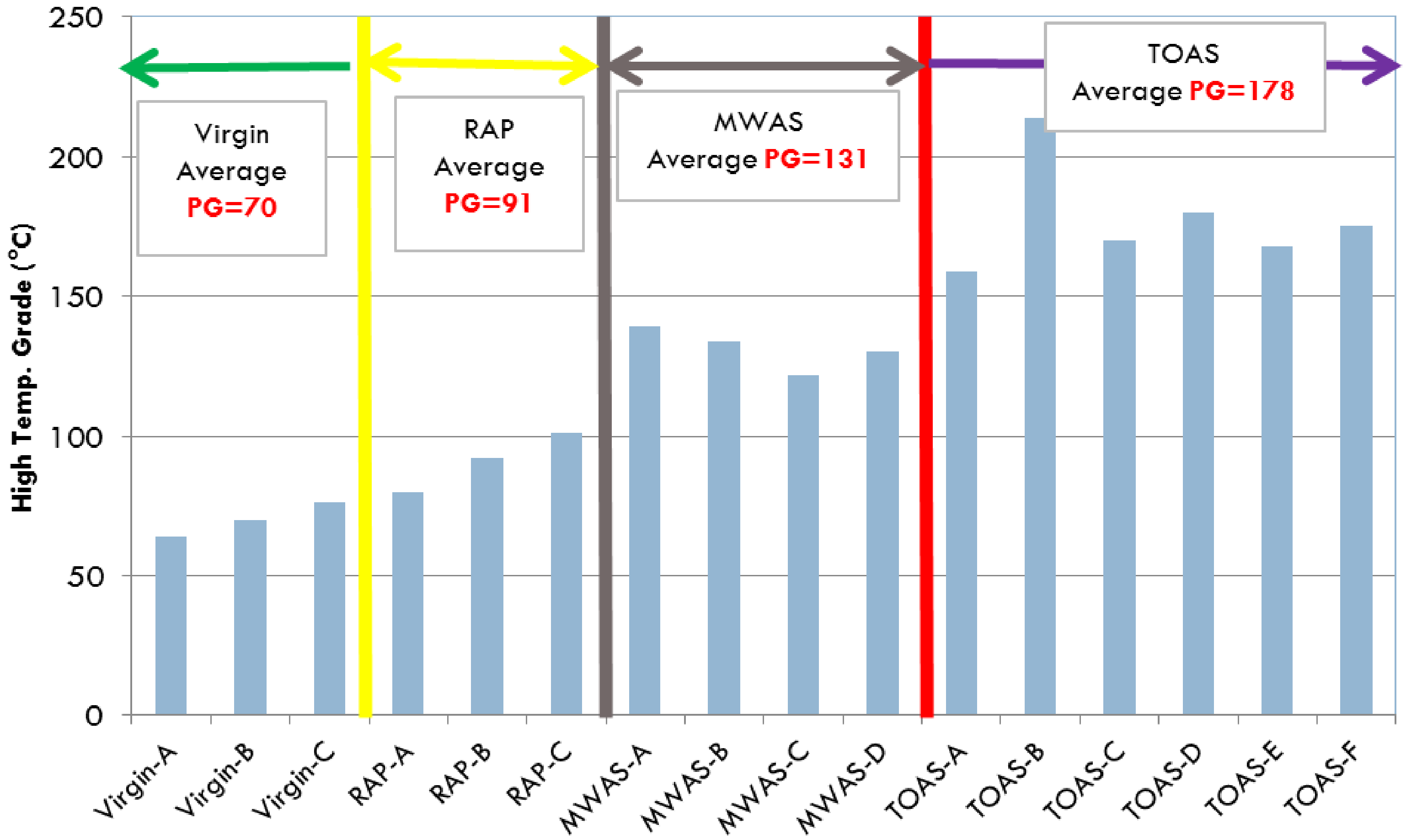


How have asphalt materials changed?

- 2000 – 2016
  - PG System in full swing
  - Refineries change – asphalt gets expensive
  - Warm mix
  - PPA to make high PG
  - REOB to make low PG
  - Polymers
  - More RAP and RAS
  - Smaller NMAS
  - SMAs

RAP/RAS and PG

RAP/RAS binder too stiff?



The Need

- Volumetric Mix Design – Does it make sense when our materials have changed so much?
- Balanced Mix Design
  - Max. set by AC for 98% density
  - Max. AC set by rutting test (must be less than 98% density)
  - Min. AC set by cracking test
  - Optimum is between max. AC and min. AC

- *"Asphalt mix design using performance tests on appropriately conditioned specimens that address multiple modes of distress taking into consideration mix aging, traffic, climate and location within the pavement structure."*

- *Basically, it consists of designing the mix for an intended application and service requirement.*

Rutting Tests

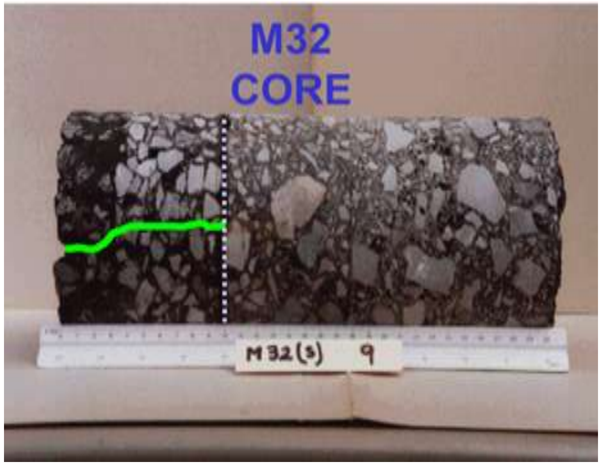
- Asphalt Pavement Analyzer

- Hamburg Wheel Track Test

Types of Cracking

Thermal

Reflection



Top-Down Fatigue

Bottom-Up Fatigue

NCHRP 9-57 Cracking Tests Workshop

- Goals
  - Select cracking tests for 4 cracking types
  - Identify potential field/APT test sections
- What we prepared for the workshop:
  - Interim report
  - Cracking test webinars
  - Cracking test booklet
  - 9 cracking test videos

Available at NCHRP 9-57 web page on TRB web site.

9 Cracking Test Videos

- IDT for low temperature cracking
- SCB at low temperature
- TSRST/UTSST
- DCT
- OT
- RDT
- S-VECD
- Bending beam fatigue
- SCB at intermediate temperature

Available at NCHRP 9-57 web page on TRB web site.

Cracking Test Videos

- DCT: https://www.youtube.com/watch?v=Ynsbs_M8gbk
- SCB at low temperature: https://www.youtube.com/watch?v=YW5E69iKAPA
- UTSST: https://www.youtube.com/watch?v=gDdHMhAhnTU
- IDT: https://www.youtube.com/watch?v=xycvHX0XoyA
- OT: https://www.youtube.com/watch?v=5Np6lGSPfLA
- SCB at int temp: https://www.youtube.com/watch?v=vd-rdQCW2Pk
- BBF: https://www.youtube.com/watch?v=3V0SW0vQ8mY
- S-VECD: https://www.youtube.com/watch?v=9sGb2lkYb8I
- RDT: https://www.youtube.com/watch?v=_1Avh5nMV-g

Workshop Outcomes

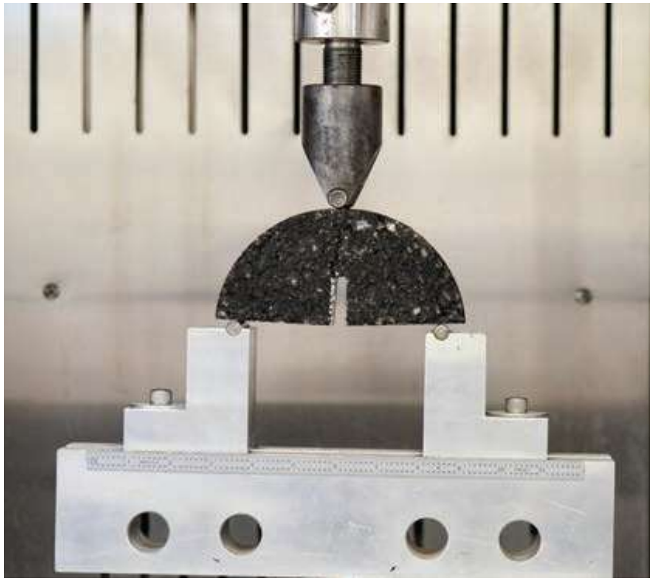
Items	Thermal Cracking	Reflection Cracking	Bottom-up Fatigue Cracking	Top-down Fatigue Cracking
Selected cracking tests	1. DCT 2. SCB-IL 3. SCB at low temp.	1. OT 2. SCB at intermediate temp. 3. BBF	1. BBF 2. SCB at intermediate temp.	1. SCB at intermediate temp. 2. IDT-UF
Key factors for designing field experimental test sections	1. Climate (temperature, moisture, solar radiation); 2. Traffic; 3. Pavement structure and subgrade; 4. Asphalt mixtures; 5. Existing pavement conditions for reflection cracking.			
Potential field test sections	1. LTPP; 2. SPS10; 3. MnRoad; 4. NCAT Test Track; 5. Test sections under NCHRP 9-55, 9-58, and 9-59.			

Disk Compact Tension (DCT)

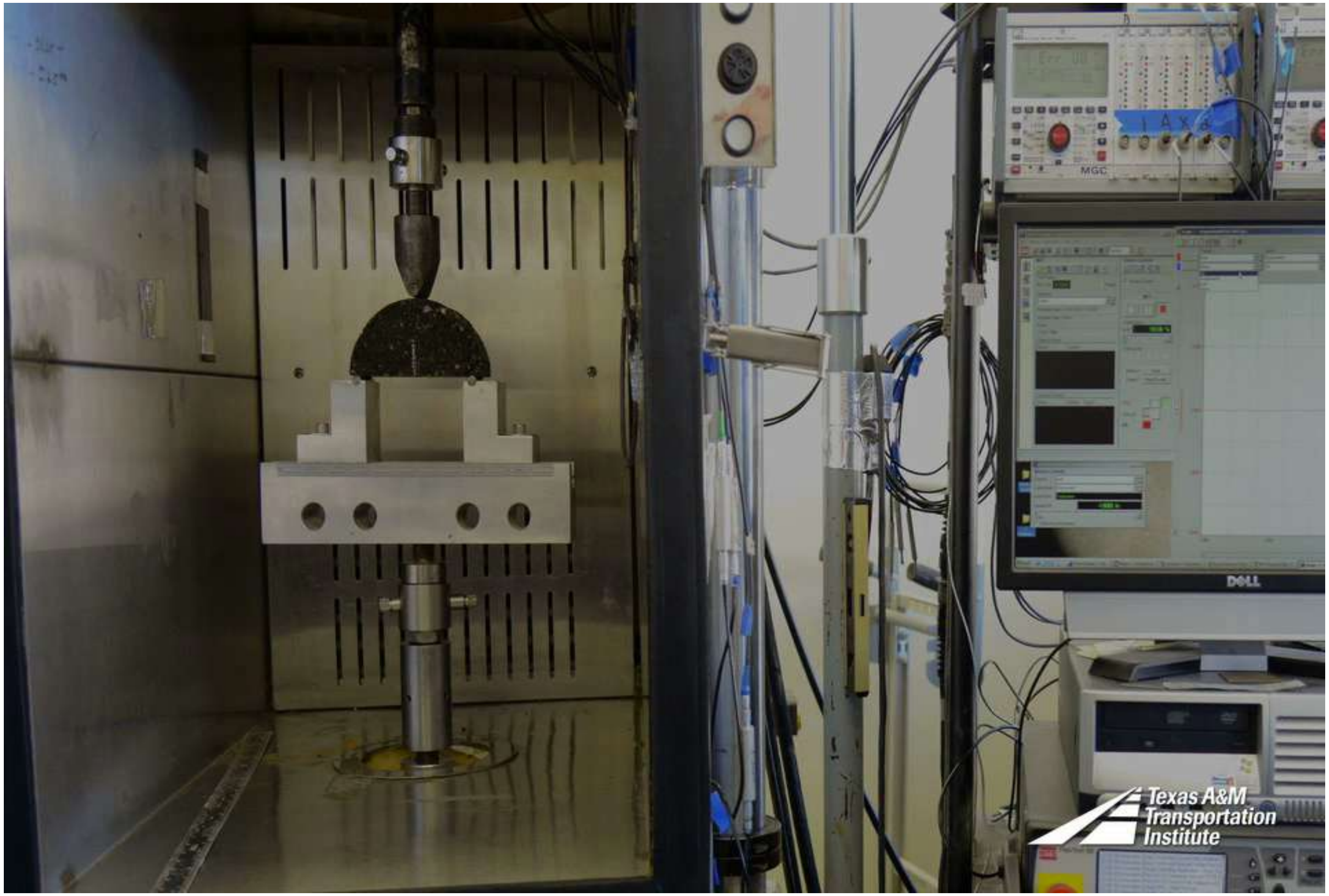
- Low Temp. Cracking
- ASTM D7313
- Fracture Energy
- Relatively Simple
- Low Variability
- Correlated to Thermal Cracking at MnROAD
- Cost ~ $49,000
- State Adoption: MN and WI. Under review in CO, SD, MT

Semi-Circular Bend (SCB)

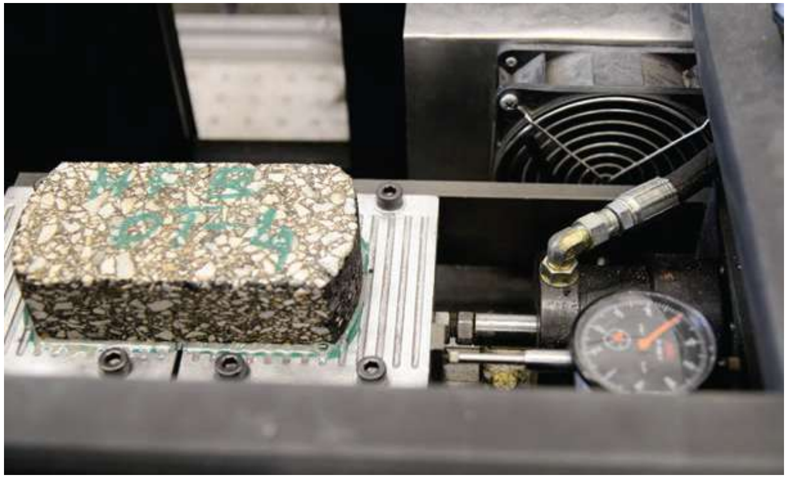
- Thermal, Reflection, Bottom-Up, Top-Down
- AASHTO TP105
- Fracture Energy
- Relatively Simple
- Medium Variability
- Correlated to Thermal Cracking at Mn/ROAD
- Cost ~ $52,000
- State Adoption:
  - Low Temp: Under Review by UT, SD, PA, MT
  - Intermed Temp: LA, WI. Under Review by OK, NM. IL adopting mod version.



SCB Intermediate Temp Video



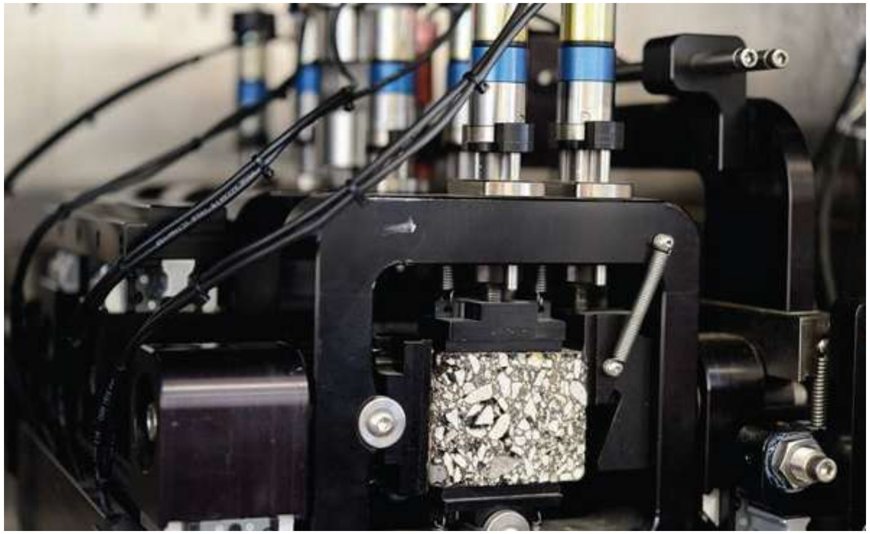
Overlay Tester (OT)



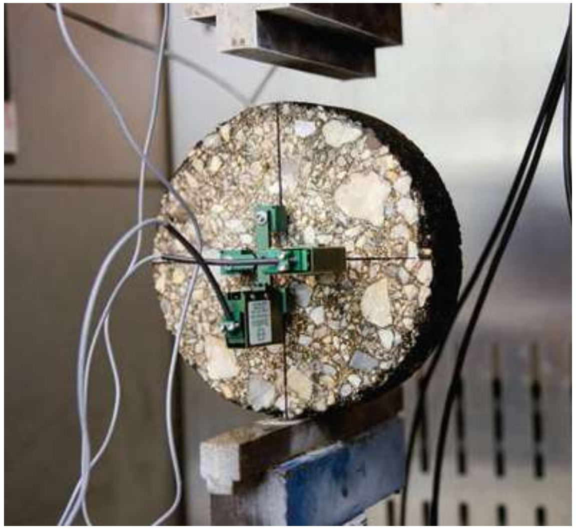
- Reflection, Bottom-Up Fatigue
- Tex-248-F
- No. Cycles to Failure
- Relatively Simple
- High Variability
- Correlated to Refl. Cracking in TX, NJ, CA. Fatigue Cracking at ALF, NCAT
- Cost ~ $46,000
- State Adoption: TX and NJ. Under review in NV, FL, OH, MT

Bending Beam Fatigue (BBF)

- Bottom-Up Fatigue
- AASHTO T321
- No. Cycles to Failure or 50% Modulus Reduction
- Relatively Simple
- Very High Variability
- Correlated to Bottom-Up Cracking
- Cost could be > $100,000
- State Adoption: CA for Long-life asphalt. Under review in NV and GA



Indirect Tension (IDT)



- Thermal Cracking
- AASHTO T322
- Creep Compliance/Tensile Strength
- Relatively Simple
- Low Variability
- Correlated to Thermal Cracking in SHRP and MEPDG
- Cost can be > $100,000 (hydraulic test machine)

Balanced RAP/RAS Mix Design for Project- Specific Service Conditions

Texas Example

Introduction

- Benefit of RAP/RAS
  - Economics
    - Saving aggregates
    - Saving asphalt binder
  - Reducing rutting
  - Environment
    - Reducing demands of non-renewable resources
    - Reducing landfill space demands
- RAP/RAS must be used!

Limitations of current design methods for RAP/RAS mixes

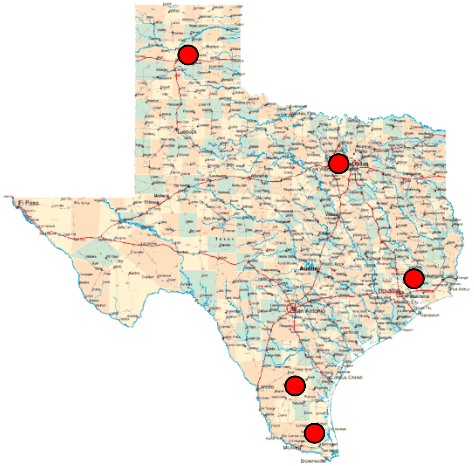
- Feature of RAP/RAS mixes: Unknown VMA (V_{BE})
  - Don't know how RAP/RAS blends with virgin binder.

- Need **a mechanical test** to assure cracking resistance.

Balanced RAP/RAS mix design for project specific condition

- Current mix designs not suitable for RAP/RAS design
  - Need to assure rutting resistance
  - Need to assure cracking resistance
  - Need volumetric-air voids for QC
  - Need project-specific rutting and cracking requirements
    - Traffic
    - Climate
    - Structure

RAP/RAS field test sections and performance



- Amarillo-Overlay: (Aug 2009)
  - IH40: Heavy traffic; Cold weather; Soft binder
  - RAP: 0, 20, 35%
- Pharr district-New Const.: (April 2010)
  - FM1017: low traffic; Hot weather; stiff binder
  - RAP: 0, 20, 35%
- Laredo-Overlay: SH359, 20%RAP (Mar. 2010)
- Houston-New Const.:SH146, 15%RAP/5%RAS (Oct. 2010)
- Fort Worth-AC/CRCP: Loop 820 (July 2012)

RAP/RAS Test Sections

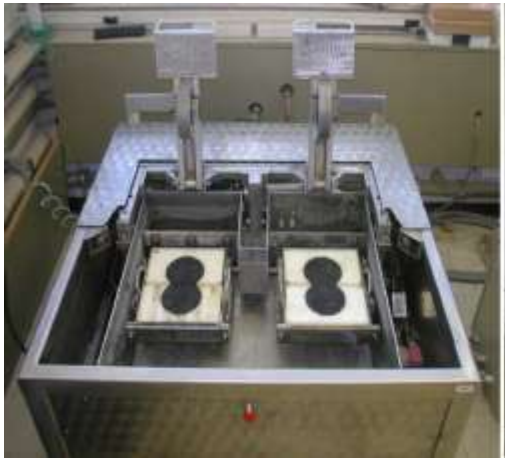
Test sections		Highway	Overlay/ new const.	Weather	Traffic MESAL	OT cycles	Performance
Amarillo	0%RAP	IH40 (severely cracked thick asphalt pavement)	4 inch/ overlay	Cold	30	95	3 yrs: 100% refl. cracking
	20%RAP					103	
	35%RAP					200	3 yrs: 57% refl. cracking
Pharr	0%RAP	FM1017-Very good support	1.5 inch/ new const.	Very hot	0.8	28	3yrs: overall - good conditions
	20%RAP					6	
	35%RAP					7	
Laredo	20%RAP	SH359-regular support	3 inch/ overlay	Very hot	1.5	3	3yrs: No cracking
Houston	15%RAP/ 5%RAS	SH146-Very good support	2 inch/new const.	hot	3.0	3	2.5yrs: No cracking
Dalhart	5%RAS	US87	3 inch/ Overlay	Cold	3.0	48/96	96 cycles-20% RCR; 48 cycles-50%RCR

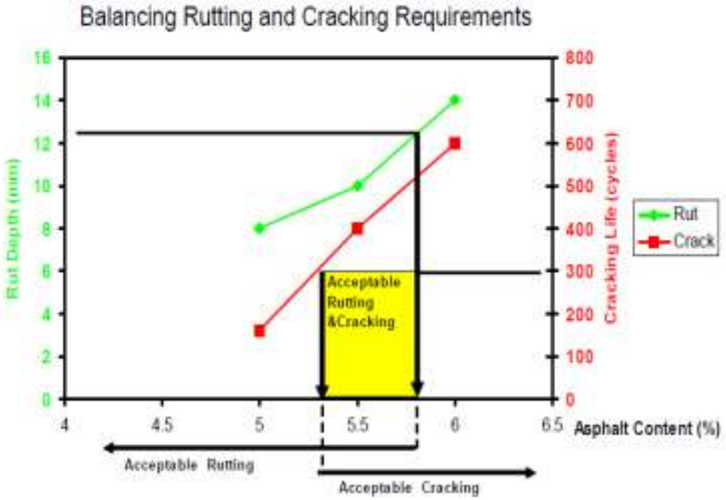
Balanced RAP/RAS Mix Design

- Hamburg test for rutting/moisture damage
- Overlay test for cracking

  OT requirement determined by Overlay program

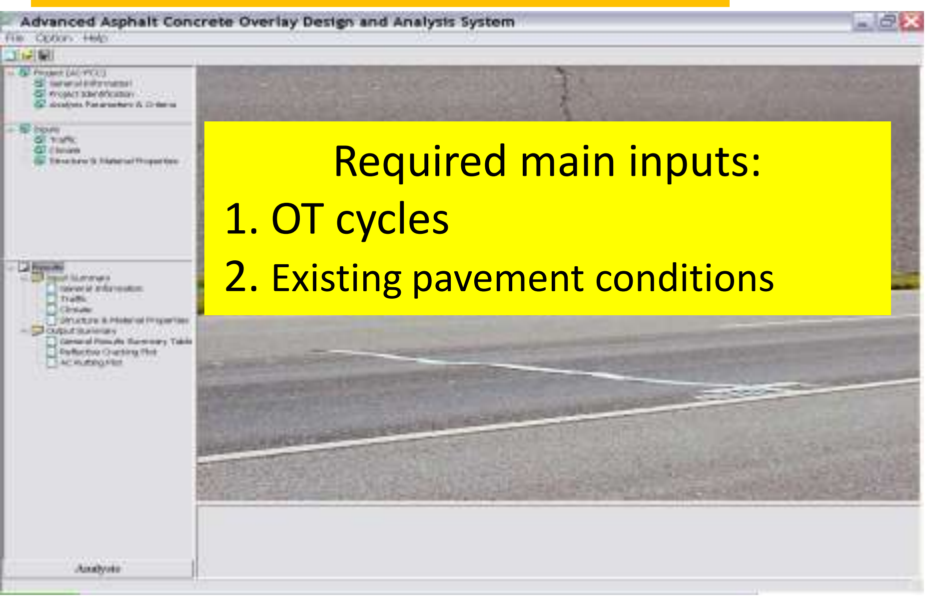
- Max. density-98% for controlling potential bleeding



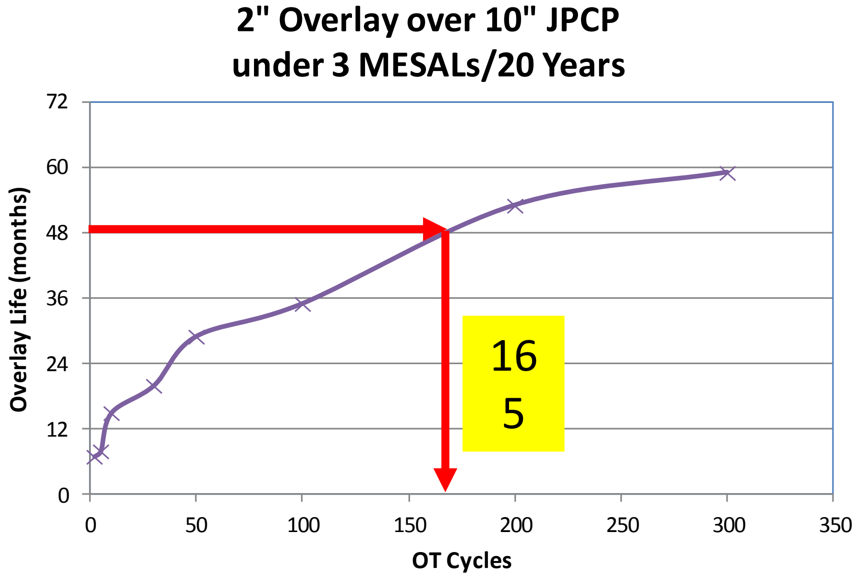


Balanced RAP/RAS Mix Design for Project-Specific Conditions

Simplified Overlay design system

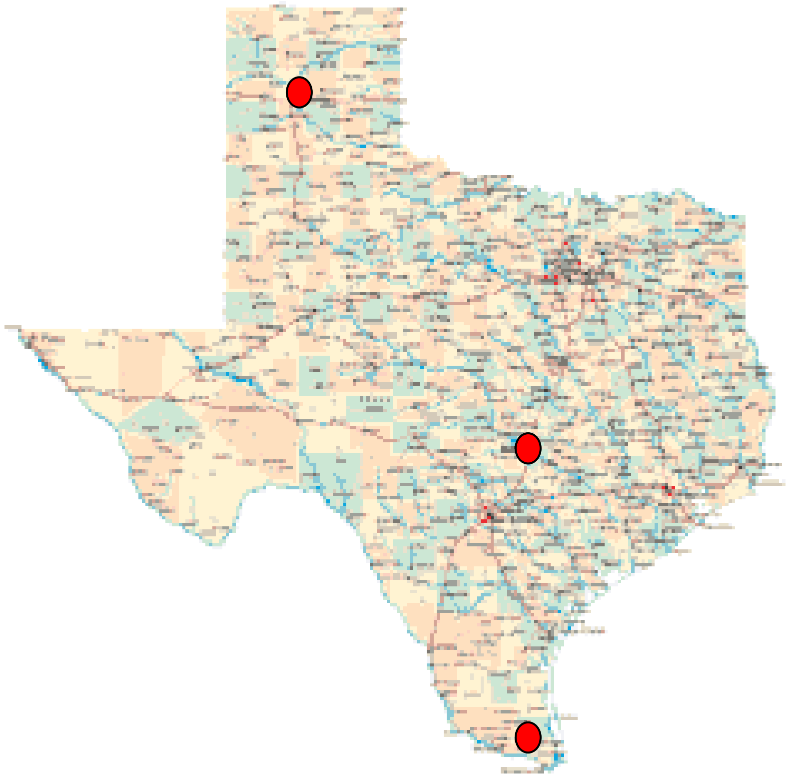


Determination of Min. OT cycles



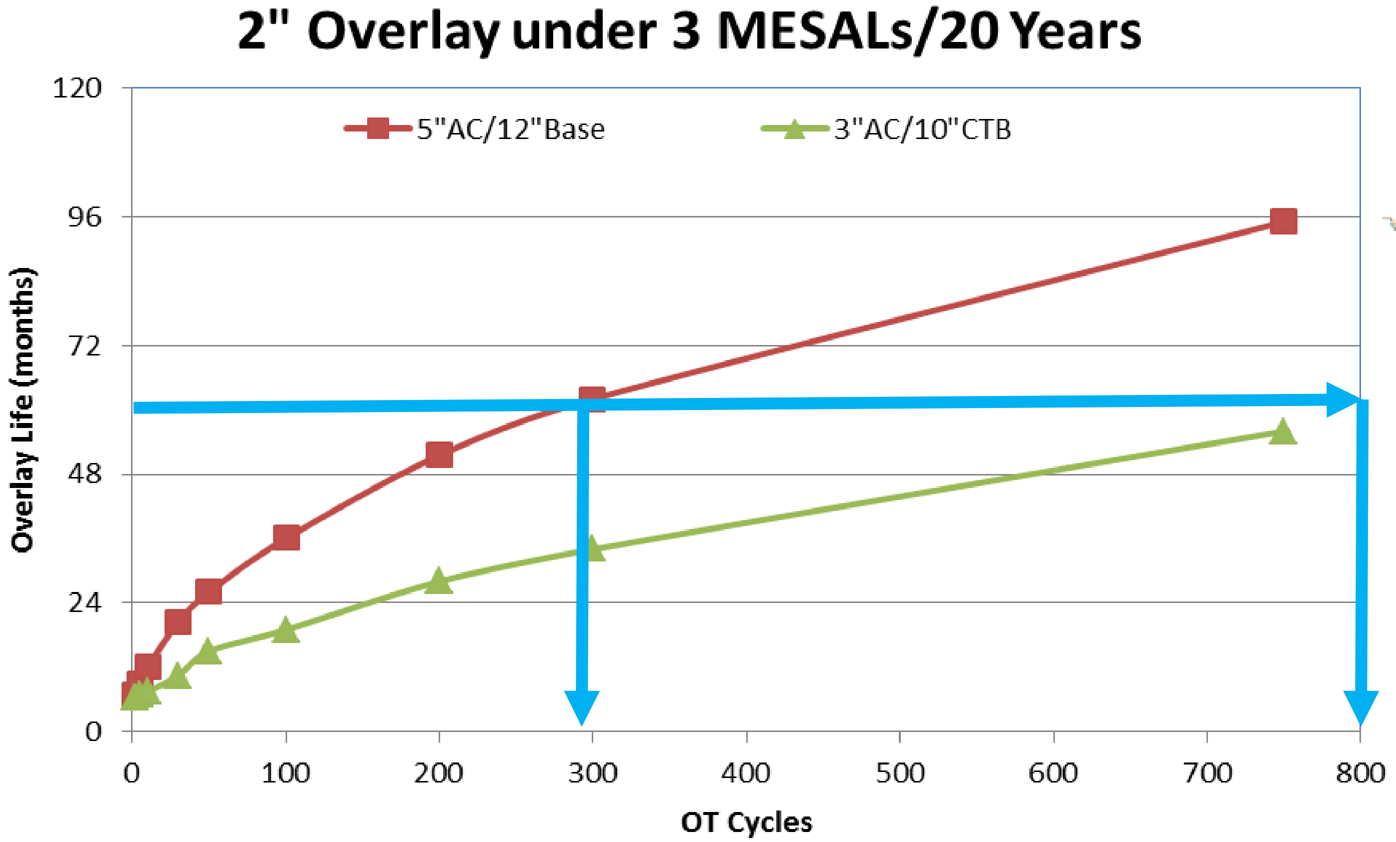
Demonstration of project-specific OT requirement

- AC overlay scenarios
  - AC/PCC
  - AC/AC/CTB
  - AC/AC/granular base
- Traffic level: 3 MESAL
  - **SH/US: 3-5 MESAL**
- Weather:
  - Amarillo
  - Austin
  - McAllen



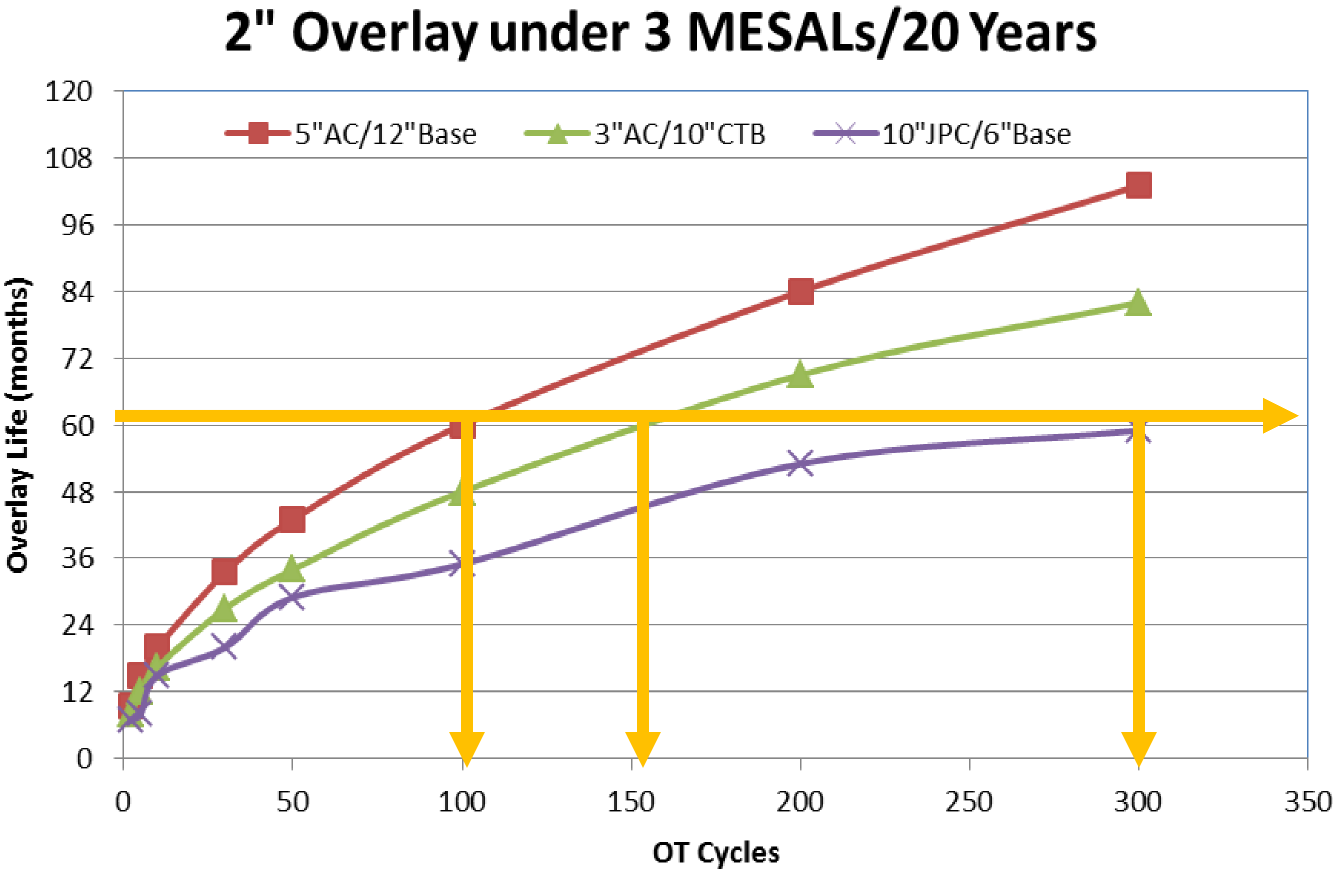
Demonstration of project-specific OT requirement

- Amarillo



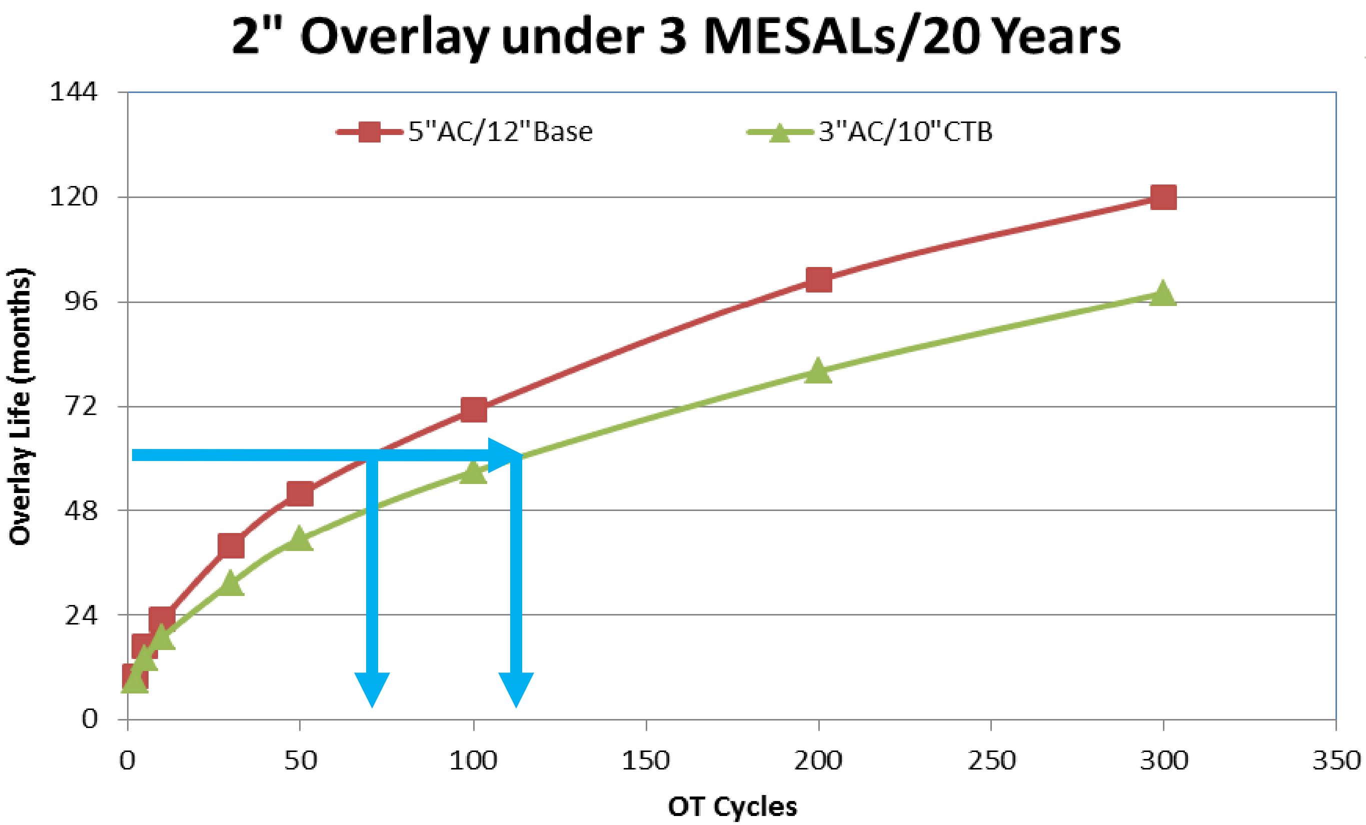
Demonstration of project-specific OT requirement

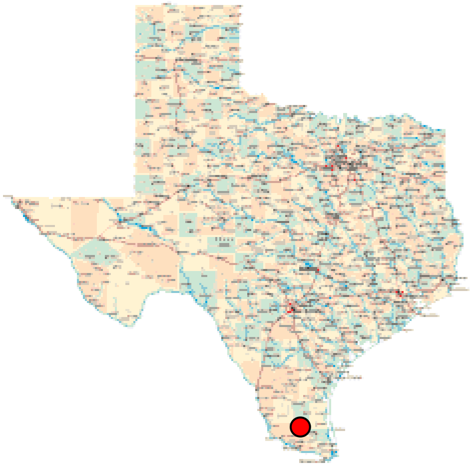
- Austin



Demonstration of project-specific OT requirement

- McAllen





Summary and Conclusions

- RAP/RAS mixes can have same or better performance with proper design.
- Balanced RAP/RAS mix design for project-specific conditions is recommended.
- Different approaches are available for improving RAP/RAS mix performance if needed.

What do We do with This?

Balanced Mix Design

Opt. AC

Set Volumetrics

Set Tolerances

Table 11
Operational Tolerances

Description	Test Method	Allowable Difference Between Trial Batch and JMF1 Target	Allowable Difference from Current JMF Target
Individual % retained for #8 sieve and larger	Tex-200-F or Tex-236-F	Must be within master grading limits in Table 8	±6.0[1]
Individual % retained for sieves smaller than #8 and larger than #200			±4.0[1]
% passing the #200 sieve			±2.0[1]
Asphalt binder content, %	Tex-236-F	±0.5	±0.5
Laboratory-molded density, %	Tex-207-F	±1.0	±1.5
VMA, %, min	Tex-204-F	Note[2]	Note[2]

1. When within these tolerances, mixture production gradations may fall outside the master grading limits; however, the % passing the #200 will be considered out of tolerance when outside the master grading limits.
2. Mixture is required to meet Table 8 requirements.

QC Volumetrics

QA Volumetrics

Some Day

QA Performance Testing