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 displaced
  – 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?

![Graph showing the binder temperatures for different materials. The graph compares Virgin, RAP, MWAS, and TOAS with their average PG values: Virgin PG = 70, RAP PG = 91, MWAS PG = 131, TOAS Average PG = 178.](image)
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
- Bottom-Up Fatigue
- Top-Down 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=xyvcvHX0XoyA
- 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

<table>
<thead>
<tr>
<th>Items</th>
<th>Thermal Cracking</th>
<th>Reflection Cracking</th>
<th>Bottom-up Fatigue Cracking</th>
<th>Top-down Fatigue Cracking</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Selected cracking tests</strong></td>
<td></td>
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<td></td>
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<tr>
<td>1. DCT</td>
<td></td>
<td>1. OT</td>
<td>1. BBF</td>
<td>1. SCB at intermediate temp.</td>
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<tr>
<td>2. SCB-IL</td>
<td></td>
<td>2. SCB at intermediate temp.</td>
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<tr>
<td>3. SCB at low temp.</td>
<td></td>
<td>3. BBF</td>
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<tr>
<td><strong>Key factors for designing field experimental test sections</strong></td>
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<tr>
<td><strong>Potential field test sections</strong></td>
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<tr>
<td>1. LTPP; 2. SPS10; 3. MnRoad; 4. NCAT Test Track; 5. Test sections under NCHRP 9-55, 9-58, and 9-59.</td>
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</table>
Disk Compact Tension (DCT)

- Low Temp. Cracking
- ASTM D7313
- Fracture Energy
- Relatively Simple
- Low Variability
- Correlated to Thermal Cracking at Mn/ROAD
- 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

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

Required main inputs:
1. OT cycles
2. Existing pavement conditions

**Determination of Min. OT cycles**

2" Overlay over 10" JPCP under 3 MESALs/20 Years

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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

2" Overlay under 3 MESALs/20 Years
Demonstration of project-specific OT requirement

- Austin

2" Overlay under 3 MESALs/20 Years

![Graph showing overlay life vs. OT cycles for different materials: 5"AC/12"Base, 3"AC/10"CTB, 10"JPC/6"Base.](Image)
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.
Balanced Mix Design

Opt. AC

Set Tolerances

Table 11 Operational Tolerances

<table>
<thead>
<tr>
<th>Description</th>
<th>Test Method</th>
<th>Allowable Difference Between Trial Batch and JMF1 Target</th>
<th>Allowable Difference from Current JMF Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual % retained for #8 sieve and larger</td>
<td>Tex-200-F or Tex-236-F</td>
<td>Must be within master grading limits in Table 8</td>
<td>±6.0’</td>
</tr>
<tr>
<td>Individual % retained for sieves smaller than #8 and larger than #200</td>
<td>Tex-236-F</td>
<td>±0.5</td>
<td>±0.5</td>
</tr>
<tr>
<td>% passing the #200 sieve</td>
<td>Tex-236-F</td>
<td>±1.0</td>
<td>±1.5</td>
</tr>
<tr>
<td>Asphalt binder content, %</td>
<td>Tex-207-F</td>
<td>Note*</td>
<td>Note*</td>
</tr>
<tr>
<td>Laboratory-molded density, %</td>
<td>Tex-204-F</td>
<td>Note*</td>
<td>Note*</td>
</tr>
</tbody>
</table>

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 Performance Testing

Some Day