Balanced Mix Design:
The Need and the Process

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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
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
Balanced Mix Design

- Maximum Allowable Density = 98%
- Opt. Asphalt Content < 5.4%

- Example: HWTT Req. < 0.5 in.

- Volumetric Analysis to Set Max. Asphalt Content

- Example: OT Req. > 300 cycles

- HWTT Results
  - Maximum Asphalt Content = 5.4%
  - Opt. Asphalt Content (OAC) = Lowest Asphalt Content for Cracking Resistance or Highest Asphalt Content for Rutting Resistance
  - OAC = 5.1%

- Overlay Tester Results

- Summary of Results
Rutting Tests

- Asphalt Pavement Analyzer
- Hamburg Wheel Track Test
Types of Cracking

- Thermal
- Reflection
- Top-Down Fatigue
- Bottom-Up Fatigue
Thermal Cracking

- Two types
  - Cold Temperature Contraction
  - Temperature Cycling Fatigue

Elko, NV
October 2015
Reflection Cracking

- Due to movement of underlying material

Shrinkage from Temperature Change or Hydration

Lack of Load Transfer
Bottom-Up Fatigue Cracking

Repeated loads cause bending with cracks starting at the bottom and propagating up. Usually occurs in thin pavements.
Top-Down Fatigue Cracking

- Aged pavements are stiffer at the top, and that starts the crack that propagates down very slowly.
- Usually occurs in thick pavements
Approaches for Improving Cracking Resistance of RAS Mixes

• Decrease design air void

- 5.2% AC with 3.0% air voids
- 5.7% AC with 2.3% air voids
### Cracking Tests

<table>
<thead>
<tr>
<th>Low-temp.</th>
<th>Reflection</th>
<th>Bottom-up</th>
<th>Top-down</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCT (D7313-13)</td>
<td>Texas OT (Tex 248-F)</td>
<td>Beam fatigue (T321)</td>
<td>IDT (UF)</td>
</tr>
<tr>
<td>SCB (TP105)</td>
<td>DCT (D7313-13)</td>
<td>S-VECD (TP107)</td>
<td>S-VECD (TP107)</td>
</tr>
<tr>
<td>IDT (T322)</td>
<td>SCB (LTRC)</td>
<td>RDT (TAMU)</td>
<td>RDT (TAMU)</td>
</tr>
<tr>
<td>TSRST/UTSST (UNR)</td>
<td></td>
<td>SCB (LTRC)</td>
<td>SCB (LTRC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Texas OT (Tex 248-F)</td>
<td></td>
</tr>
</tbody>
</table>
Cracking types vs. tests

- Monotonic: Very high strain
- Overlay: High strain
- Fatigue: Lower strain

Variability:
- Low: High strain
- High: Lower strain

Strain level vs. No. of cycles
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.
What’s Measured?

- **Load**: Crack Opening
- **Fracture Energy**: DCT, SCB
- **Stress**: BBF, OT, IDT
- **Tensile Strength**: IDT
- **Creep Compliance**: IDT
- **Number of Cycles**: IDT
- **Time**
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!
• No.1 concern - variability
  – Binder grade variation
  – Binder content variation
  – Aggregate gradation

• Solution:
  – Best practices for RAP/RAS processing and stockpile management
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 field test sections and performance

<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>Amarillo</td>
<td>IH40 (severely cracked thick asphalt pavement)</td>
<td>4 inch/overlay</td>
<td>Cold</td>
<td>30</td>
<td>95</td>
<td>3 yrs: 100% refl. cracking</td>
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<tr>
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<td>103</td>
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<td></td>
<td></td>
<td>200</td>
<td>3 yrs: 57% refl. cracking</td>
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<tr>
<td>Pharr</td>
<td>FM1017-Very good support</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>
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<td>6</td>
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<td>7</td>
<td></td>
</tr>
<tr>
<td>Laredo</td>
<td>SH359-regular support</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>Houston</td>
<td>SH146-Very good support</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>Dalhart</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>
</tbody>
</table>
RAP/RAS field test sections and performance

1. RAP/RAS mixes perform well at certain locations.
2. One OT requirement cannot fit for all.
3. Successful use of RAP/RAS mixes depends on
   - Weather/Traffic
   - AC overlay
     - Overlay thickness, Existing pavement structure (AC/AC; AC/PCC)
     - Existing pavement conditions
   - New construction
     - Pavement structure and which layer (surface, base, etc.)
4. Design the mix for project-specific conditions
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
Existing pavement conditions (crack severity level, LTE) if asphalt overlays

Traffic

Pavement structure

Climate

S-TxACOL

Predicted cracking development

Meet requirements

Yes

No

Balanced mix for project-specific conditions

Mixture engineering properties at selected asphalt contents

Cracking: Overlay test

Rutting/moisture damage:
Hamburg wheel tracking test

Select at least 2 asphalt contents

SGC(\(N_{\text{design}}\))

Compactability/ workability

Volumetric properties

Mixing temperature and time

Conditioning temperature and time

Virgin binder

Raw aggregates

WMA additive

RAS (/RAP)

Virgin binder

Virgin binder

WMA additive

RAS (/RAP)

Virgin binder

WMA additive

RAS (/RAP)
Balanced RAP/RAS Mix Design for Project-Specific Conditions

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

Simplified Overlay design system

Determination of Min. OT cycles

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

Overlay Life (months)

OT Cycles

0 50 100 150 200 250 300 350

Overlay Life (months)

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

OT Cycles

16

5
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

![Graph showing overlay life and cycles](image-url)
Demonstration of project-specific OT requirement

- Austin

2" Overlay under 3 MESALs/20 Years

Overlay Life (months)

OT Cycles
Demonstration of project-specific OT requirement

- McAllen

2" Overlay under 3 MESALs/20 Years

Overlay Life (months)

OT Cycles
Approaches for Improving RAP/RAS Mix Cracking Performance

• Available approaches
  – Increase virgin AC (higher density)
  – Soft, modified binders: PG64-28, PG64-34, PG58-34
  – Decrease air voids
  – Rejuvenators
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 for use.
  – Hamburg test for rutting/moisture damage
  – OT for cracking; Project-specific OT requirement
  – Max. density to control potential bleeding

• Different approaches are available for improving RAP/RAS mix performance if needed.
2" Overlay over 10" JPCP
under 3 MESALS/20 Years
What do We do with This?

Balanced Mix Design

Opt. AC

Set Volumetrics

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</td>
<td>±5.0'</td>
<td>±5.0'</td>
</tr>
<tr>
<td>Individual % retained for sieves smaller than #8 and larger than #200</td>
<td>Tex-236-F</td>
<td>±5.0'</td>
<td>±5.0'</td>
</tr>
<tr>
<td>% passing the #200 sieve</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asphalt binder content, %</td>
<td>Tex-236-F</td>
<td>±0.5</td>
<td>±0.5</td>
</tr>
<tr>
<td>Laboratory-molded density, %</td>
<td>Tex-207-F</td>
<td>±1.0</td>
<td>±1.5</td>
</tr>
<tr>
<td>VMA, % min</td>
<td>Tex-204-F</td>
<td>Note</td>
<td></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 Volumetrics

Some Day

QA Performance Testing
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At the 2015 AAPT Meeting:

- 12 Presentations on High RAP/RAS
- Implementation of Specifications
- Cracking Behavior
- Aging Behavior
- Symposium Topic: Use of Rejuvenators