"Up the Game" in Pavement Durability

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It's a Team Effort
Balanced RAP/RAS Mix Design for Project- Specific Service Conditions

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Producer’s Session

Original Presentation by:

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Outline

• Introduction
• Existing design methods and limitations
• Balanced RAP/RAS mix design for project-specific conditions
  ▫ Need a mechanical test to assure rutting resistance
  ▫ Need a mechanical test to assure cracking resistance
  ▫ Need volumetric-air voids for quality control
  ▫ Need project-specific rutting and cracking requirements
• Demonstration of project-specific OT requirement
• Summary and conclusions
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!
Introduction

• No.1 concern- variability
  ▫ Binder grade variation
  ▫ Binder content variation
  ▫ Aggregate gradation

• Solution:
  ▫ Best practices for RAP/RAS processing and stockpile management

![Multiple sources RAP](image1.jpg)
![Well Separated RAP](image2.jpg)
Introduction

• No. 2 concern - cracking
  ▫ RAP/RAS binder too stiff

• Solution:
  ▫ Balanced mix design for project-specific conditions
Current mix design methods and limitations

- **Current mix design methods**
  - Volumetrics + Stability
    - Hveem
    - Marshall
  - **Superpave method**
    - Pure volumetrics; no mechanical testing
  - **Superpave plus**
    - Volumetrics+Hamburg/APA/...

- **Control cracking in current methods**
  - $V_{BE} (=VMA-AV)$ to control cracking; OK for virgin mixes
  - No simple cracking test
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.
One Benefit of Layered Pavement

- In a layered flexible pavement design, the material characteristics of each specific layer can be customized for optimum performance.
Plant Mix = AC + FA + CA

- PLUS:
  - WMA - Polymer - AS
  - RAP - GTR - PPA
  - RAS - Fibers
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
Why project-specific design:
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)
Why project-specific design:
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>
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<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>
<td></td>
<td>20%RAP</td>
<td></td>
<td></td>
<td></td>
<td>103</td>
<td>3 yrs: 57% refl. cracking</td>
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<td>35%RAP</td>
<td></td>
<td></td>
<td></td>
<td>200</td>
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<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>
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<td>20%RAP</td>
<td></td>
<td></td>
<td></td>
<td>6</td>
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<tr>
<td></td>
<td>35%RAP</td>
<td></td>
<td></td>
<td></td>
<td>7</td>
<td></td>
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<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>
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<td>Houston</td>
<td>SH146-Very good support</td>
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<td>hot</td>
<td>3.0</td>
<td>3</td>
<td>2.5 yrs: No cracking</td>
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<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>
Why project-specific design:
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 for project specific condition

Cracking

Mix Design

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

- Hamburg test for rutting/moisture damage
- Overlay test for cracking
  \textit{OT requirement determined by Overlay program}
- Max. density-98% for controlling potential bleeding
Balanced RAP/RAS mix design for project specific condition

- RAS (RAP)
- Virgin binder
- WMA additive
- Raw aggregates

Conditioning temperature and time
Mixing temperature and time

SGC(N_design)
Compactability/ workability
Volumetric properties

Select at least 2 asphalt contents

Cracking: Overlay test
Rutting/moisture damage: Hamburg wheel tracking test

Predicted cracking development
Meet requirements

No
Yes

Balanced mix for project-specific conditions

Existing pavement conditions (crack severity level, LTE) if asphalt overlays

Traffic
Pavement structure
Climate

S-TxACOL
Cracking in Mixes

• How rapidly cracks occur:
  ▫ \( Rate = A(\Delta SIF)^n \)

• Stress Intensity Factor (SIF) depends upon:
  ▫ How wide the crack opens
  ▫ How stiff the material is
  ▫ How long the crack is
## OT Cycles vs. A and n

### Table of Mixes and Corresponding OT Cycles, A, and n

<table>
<thead>
<tr>
<th>No.</th>
<th>Mixes</th>
<th>OT Cycles</th>
<th>A</th>
<th>n</th>
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<tbody>
<tr>
<td>1</td>
<td>US87 S1-RAS mix (dense-graded mix)</td>
<td>94</td>
<td>1.3677E-06</td>
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<td>US87 S2-RAS mix (dense-graded mix)</td>
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<td>4</td>
<td>SH359-RAP mix (dense-graded mix)</td>
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<td>7.6451E-04</td>
<td>3.0370</td>
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<td>5</td>
<td>Loop820-RAP/RAS/WMA (dense-graded mix)</td>
<td>8</td>
<td>3.9572E-05</td>
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<td>6</td>
<td>Dallas-Ty B mix (dense-graded mix)</td>
<td>22</td>
<td>6.2163E-05</td>
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<td>7</td>
<td>Dallas-Ty C mix (dense-graded mix)</td>
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<td>8</td>
<td>MnRoad Cell12 (Superpave mix)</td>
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<td>9</td>
<td>MnRoad Cell16 (Superpave mix)</td>
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<td>10</td>
<td>PG64-34 TamKo RAS-5.2AC</td>
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<td>11</td>
<td>PG58-34 TamKo RAS-5.2AC</td>
<td>420</td>
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<td>12</td>
<td>Odessa P. Mix S4 (dense-graded mix)</td>
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<td>13</td>
<td>Buda PG64-34-5% RAS mix (dense-graded mix)</td>
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<td>Buda PG58-34-5% RAS mix (dense-graded mix)</td>
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<td>15</td>
<td>NCAT N9-1 (Superpave mix)</td>
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<td>NCAT N9-2 (Superpave mix)</td>
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<td>17</td>
<td>PG64-22 15%RAP (dense-graded mix)</td>
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<td>PG64-28 15%RAP (dense-graded mix)</td>
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<td>19</td>
<td>PG64-34 15%RAP(dense-graded mix)</td>
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<td>Paris-PG58-34 15%RAP (dense-graded mix)</td>
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<td>21</td>
<td>Amarillo-20%RAP-40 (dense-graded mix)</td>
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<td>22</td>
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<td>NCAT S6-1 (Superpave mix)</td>
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<td>25</td>
<td>NCAT N10-1 (Superpave mix)</td>
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<td>2.4574E-07</td>
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</table>
Balanced RAP/RAS Mix Design for Project-Specific Conditions

**Simplified Overlay design system**

**Determination of Min. OT cycles**

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

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

- Aus
Demonstration of project-specific OT requirement

- McAllen

2" Overlay under 3 MESALs/20 Years

- 5"AC/12"Base
- 3"AC/10"CTB
Approaches for Improving RAP/RAS Mix Cracking Performance

- **Available approaches**
  - *Increase virgin AC* (higher density)
  - *Soft, modified binders:* PG64-28, PG64-34, PG58-34
  - 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.
What Performance Tests Have Been Adopted by Other States?

- Overlay Test (OT)
- Disk-Shaped Compact Tension (DCT)
- Semi-Circular Bend (SCB)
<table>
<thead>
<tr>
<th></th>
<th>Mix Design</th>
<th>Acceptance Quality Characteristics</th>
<th>Initial Verification Go / No Go</th>
<th>Ongoing Go / No Go</th>
<th>Information Only</th>
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</thead>
<tbody>
<tr>
<td><strong>Superpave M323</strong></td>
<td>Volumetric</td>
<td>Volumetric Field Compaction</td>
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<td><strong>California</strong></td>
<td>Volumetric Beam Fatigue Repeated Shear Hamburg</td>
<td>Volumetric Field Compaction</td>
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<td>Beam Fatigue Repeated Shear Hamburg</td>
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<td><strong>Texas</strong></td>
<td>Volumetric Overlay Tester Hamburg</td>
<td>Volumetric Field Compaction</td>
<td>Overlay Tester Hamburg</td>
<td>Overlay Tester Hamburg</td>
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<td><strong>Wisconsin</strong></td>
<td>Volumetric SCB, DC(t) Overlay Tester</td>
<td>Volumetric Field Compaction</td>
<td>DC(t) Overlay Tester Hamburg</td>
<td>DC(t) Overlay Tester</td>
<td>SCB</td>
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<td><strong>Illinois</strong></td>
<td>Volumetric IL-SCB* Hamburg</td>
<td>Volumetric Field Compaction</td>
<td>IL-SCB* Hamburg</td>
<td>IL-SCB* Hamburg</td>
<td>DC(t)</td>
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<td><strong>New Jersey</strong></td>
<td>Volumetric APA Beam Fatigue Overlay Tester</td>
<td>Field Compaction</td>
<td>APA Beam Fatigue Overlay Tester</td>
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<td><strong>Louisiana</strong></td>
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<td>Field Compaction</td>
<td>SCB Hamburg</td>
<td>SCB Hamburg</td>
<td></td>
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</tbody>
</table>
Overlay Test

- Developed at Texas Transportation Institute
- Cyclical Direct Tension
- Primarily for Overlay Layers
- Texas and New Jersey
Overlay Test:
https://www.youtube.com/watch?v=tLGVK_mHX_I
Disk-Shaped Compact Tension

- DCt  (ASTM D 7313-13)
- Direct tension at low temps. (PG + 2C)
- Minnesota & Wisconsin
DCT Test:
https://www.youtube.com/watch?v=r7y-oAziaP8
Semi-Circular Bend

-SCB (AASHTO TP 105)
-Bending Fatigue Test
-Illinois & Louisianna
SCB at Low Temperature:
https://www.youtube.com/watch?v=mWKXZhEHoto