2016 PAPA REGIONAL MEETINGS
Allentown - State College – Cranberry Township

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

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Original Presentation by:

Texas A&M Transportation Institute
Dave Newcomb
TXAPA, September 2014
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
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   - etc.
Balanced 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

<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</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>0%RAP</td>
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<td></td>
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<td>200</td>
<td>3 yrs: 57% refl. cracking</td>
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<td>20%RAP</td>
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<tr>
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<td>35%RAP</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>
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<tr>
<td></td>
<td>0%RAP</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>20%RAP</td>
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</tr>
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<td>35%RAP</td>
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<td>6</td>
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<td>Houston</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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<tr>
<td></td>
<td>15%RAP/5%RAS</td>
<td>2 inch/new const.</td>
<td>hot</td>
<td>3.0</td>
<td>3</td>
<td>2.5 yrs: No cracking</td>
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<tr>
<td></td>
<td>SH146-Very good support</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                          Rutting

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

- 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 condition

1. RAS (RAP) - WMA additive
2. Virgin binder - Raw aggregates
3. Mixing temperature and time
4. Conditioning temperature and time
5. SGC(Ndesign)
6. Compactability/ workability
7. Volumetric properties
8. Select at least 2 asphalt contents

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

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
Cracking in Mixes

- How rapidly cracks occur:
  - \( \text{Rate} = A(\Delta SIF)^n \)
- Stress Intensity Factor (SIF) depends upon:
  - How wide the crack opens
  - How stiff the material is
  - How long the crack is
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

165
Approaches for Improving RAP/RAS Mix Cracking Performance

• Available approaches
  ▫ **Increase virgin AC** *(higher density)* **minimum Vbe**
  ▫ **Soft, modified binders:** PG64-28, PG64-34, PG58-34
  ▫ Rejuvenators
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>State</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>Superpave M323</td>
<td>Volumetric</td>
<td>Volumetric Field Compaction</td>
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<tr>
<td>California</td>
<td>Volumetric Beam Fatigue Repeated Shear Hamburg</td>
<td>Volumetric Field Compaction</td>
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<td></td>
<td>Beam Fatigue Repeated Shear Hamburg</td>
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<tr>
<td>Texas</td>
<td>Volumetric Overlay Tester Hamburg</td>
<td>Volumetric Field Compaction</td>
<td>Overlay Tester Hamburg</td>
<td>Overlay Tester Hamburg</td>
<td></td>
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<tr>
<td>Wisconsin</td>
<td>Volumetric SCB, DC(t) Overlay Tester</td>
<td>Volumetric Field Compaction</td>
<td>DC(t) Overlay Tester</td>
<td>DC(t) Overlay Tester</td>
<td>SCB</td>
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<td>Illinois</td>
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<td>Volumetric Field Compaction</td>
<td>IL-SCB* Hamburg</td>
<td>IL-SCB* Hamburg</td>
<td>DC(t)</td>
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<tr>
<td>New Jersey</td>
<td>Volumetric APA Beam Fatigue Overlay Tester</td>
<td>Field Compaction</td>
<td>APA Beam Fatigue Overlay Tester</td>
<td>APA Beam Fatigue Overlay Tester</td>
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<td>Louisiana</td>
<td>Volumetric SCB Hamburg</td>
<td>Field Compaction</td>
<td>SCB Hamburg</td>
<td>SCB Hamburg</td>
<td></td>
</tr>
</tbody>
</table>
Overlay Test

- Developed at Texas Transportation Institute
- Cyclical Direct Tension
- Primarily for Overlay Layers
- Texas and New Jersey
Overlay Test:
VIDEOS FOR POWERPOINT\Overlay Test.mp4

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:
VIDEOS FOR POWERPOINTS\DCT Test.mp4

https://www.youtube.com/watch?v=r7y-0Azip8
Semi-Circular Bend

- SCB  (AASHTO TP 105)
- Bending Fatigue Test
- Illinois & Louisiana
SCB at Low Temperature:
VIDEOS FOR POWERPOINTS\SCB at Low Temperature.mp4

https://www.youtube.com/watch?v=mWXXZnEHot0
Summary and Conclusions

- RAP/RAS and other modified binder mixes can have same or better performance with proper design.

- Balanced or optimized mix design using laboratory performance tests for project-specific conditions is recommended for use.
  - Hamburg test for rutting/moisture damage
  - OT, DCt, SCB for cracking; Project-specific requirements or thresholds
  - Max. density to control potential bleeding
QUESTIONS?
Thanks for your attention!

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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)**
## OT Cycles vs. 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>1.367E-06</td>
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<td>2</td>
<td>US87 S2-RAS mix (dense-graded mix)</td>
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<td>SH143-RAP 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>7.645E-04</td>
<td>3.0370</td>
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<tr>
<td>5</td>
<td>Loop820-RAP/RAS/WMA (dense-graded mix)</td>
<td>8</td>
<td>3.957E-05</td>
<td>3.2465</td>
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<td>6</td>
<td>Dallas-Ty B mix (dense-graded mix)</td>
<td>22</td>
<td>6.216E-05</td>
<td>3.3900</td>
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<td>7</td>
<td>Dallas-Ty C mix (dense-graded mix)</td>
<td>128</td>
<td>7.905E-06</td>
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<tr>
<td>8</td>
<td>MnRoad Cell12 (Superpave mix)</td>
<td>356</td>
<td>1.114E-08</td>
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<td>9</td>
<td>MnRoad Cell16 (Superpave mix)</td>
<td>100</td>
<td>2.460E-06</td>
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<td>10</td>
<td>PG64-34 TamKo RAS-5.2AC</td>
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<td>2.900E-08</td>
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<td>11</td>
<td>PG58-34 TamKo RAS-5.2AC</td>
<td>420</td>
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<td>5.1560</td>
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<td>12</td>
<td>Odessa P. Mix S4 (dense-graded mix)</td>
<td>161</td>
<td>7.359E-08</td>
<td>4.8755</td>
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<td>13</td>
<td>Buda PG64-34-5% RAS mix (dense-graded mix)</td>
<td>72</td>
<td>6.698E-07</td>
<td>4.4910</td>
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<td>Buda PG58-34-5% RAS mix (dense-graded mix)</td>
<td>274</td>
<td>6.164E-08</td>
<td>5.0803</td>
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<td>NCAT N9-1 (Superpave mix)</td>
<td>55</td>
<td>8.155E-07</td>
<td>4.1200</td>
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<td>16</td>
<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>SMA PG70-28 0RAP AC 6.6</td>
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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
Demonstration of project-specific OT requirement

- Austin

![Diagram showing 2" Overlay under 3 MESALs/20 Years]
Demonstration of project-specific OT requirement

- McAllen