Overview

- Status of NCHRP 9-46
  - Preliminary Recommendations
- High RAP Mixes on the NCAT Test Track

Mix Design with High RAP Contents

- NCHRP 9-46: NCAT, UMN, & UNH
- High RAP content is considered >25%
- Current M323 approach is reasonably sound
- General consensus is that the biggest risk for High RAP mixes is long-term durability (resistance to cracking)

Mix Design with High RAP Contents

- Additional guidance needed on:
  - Characterizing RAP
    - RAP aggregate bulk specific gravity
  - Preparing samples in the lab
  - Determining the appropriate PG for the virgin binder
  - Recommendations for performance testing

Characterizing RAP

- Asphalt Content:
  - ignition method is preferred.
  - An aggregate correction factor must be assumed.
  - For regions that utilize dolomite aggregates that have erratic correction factors, a solvent extraction method is recommended.

Characterizing RAP

RAP aggregate bulk specific gravity: estimated from a four step process:
1. Determine \( G_{\text{mm}} \) of RAP sample
   - Add 1% binder to recoat aggregate and avoid dryback
2. Calculate \( G_{\text{se}} \) using the \( G_{\text{mm}} \) from step 1 and the asphalt content from the ignition method (or extraction test if ignition method is not reliable)
3. Determine a historical asphalt absorption for the materials in the area
4. Calculate \( G_{\text{sb}} \) from the following formula:
   \[
   G_{\text{sb}} = \frac{G_{\text{se}} - P_{\text{se}}}{100 \times G_{\text{se}}} + 1
   \]
Why Use This Process?

When the RAP asphalt content and binder absorption can be estimated with confidence, this process is more accurate and faster than recovering the aggregate from solvent extraction or ignition test and performing T84 and T85.

Effect of RAP Agg. Gsb on VMA

Gsb Virgin = 2.6700

Characterizing RAP

- Other key RAP aggregate properties can be performed on aggregate recovered from the ignition oven or solvent extractions.
  - Gradations
  - Fine aggregate angularity
  - F&E
  - Fractured faces

RAP Management

- Uniformity is the Goal
- Fractionation should be the contractor’s choice
- Frequent sampling and testing of RAP stockpiles must be done

RAP Sampling & Testing Flowchart

- At least 10 samples when building stockpile
- Split each sample
- Ignition method tests
- Max. specific gravities
- Gradations
- Asphalt contents
- Gsb

Summary & Analysis of RAP Data

- Calculate average and standard deviation of asphalt contents, gradations, and estimated Gsb
- Compare to the recommended tolerances

<table>
<thead>
<tr>
<th>RAP property</th>
<th>Max. Standard Deviation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Content</td>
<td>0.5</td>
</tr>
<tr>
<td>% Passing Median Sieve</td>
<td>5.0</td>
</tr>
<tr>
<td>% Passing 75 micron Sieve</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Handling the RAP for Mix Design

- **Drying RAP**
  - RAP needs to be dried before testing and batching
  - Dry RAP spread in thin layer with fans overnight, followed by placement in an oven at 230°F for one hour max.

- **Batching**
  - Develop the mix trial blends using gradation of aggregate recovered from RAP
  - Screen the RAP on the 4.75 mm sieve as with coarse aggregates
  - Batch using dried RAP samples

Handling the RAP for Mix Design

- **Heating the RAP**
  - Heat batched RAP in covered cans separate from virgin aggregate for the minimum amount of time to reach the mixing temperature
  - This time will typically range from 2 to 4 hours depending on the mass of the batches and the oven efficiency

### Preliminary RAP Heating Results

<table>
<thead>
<tr>
<th>Virgin Heating Time</th>
<th>Virgin Temp.</th>
<th>RAP Heating Time</th>
<th>RAP Temp.</th>
<th>Average Asphalt Content</th>
<th>Recov. PG</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 hours</td>
<td>355 °F</td>
<td>30 min</td>
<td>355 °F</td>
<td>1.98</td>
<td>85.0-17.8</td>
</tr>
<tr>
<td>3 hours</td>
<td>355 °F</td>
<td>3 hours</td>
<td>355 °F</td>
<td>2.11</td>
<td>89.3-13.9</td>
</tr>
<tr>
<td>16 hours</td>
<td>355 °F</td>
<td>16 hours</td>
<td>355 °F</td>
<td>0.79</td>
<td>n.a.</td>
</tr>
<tr>
<td>3 min</td>
<td>500 °F</td>
<td>0</td>
<td>Room Temp.</td>
<td>2.35</td>
<td>95.0-10.0</td>
</tr>
</tbody>
</table>

**Theoretical Asphalt Content = 2.44%**

**RAP binder True Grade: 85.1-15.7**

Current Superpave Guidelines for Selecting the Virgin Binder

- **Tier 1:** Up to 15% RAP **Binder**
  - use specified binder grade
- **Tier 2:** 15%-25% RAP **Binder**
  - use one full binder grade lower, e.g., PG 58-28 instead of PG 64-22
- **Tier 3:** Over 25% RAP **Binder**
  - use blending charts to determine required binder grade

### RAP Nomograph - High PG Temp.

- Graph showing the relationship between % RAP Binder and RAP Temperature.
- The graph uses different colored lines to represent different ranges: red for 52 to 64 °C, green for 64 to 76 °C, and yellow for 76 to 80 °C.
**RAP Nomograph - Low PG Temp.**

- PG -16 (98% Reliability)

**Binder Characterization Issues**
- Can we determine RAP binder properties without solvents?
- Is traditional blending approach correct?
  - Is there 100% blending?
  - Should we adjust the virgin binder grade at all?

**Mix Design for High RAP Contents**
- Start mix design with standard virgin binder grade
- Determine optimum binder content in accordance with M 323
- Estimate the “effective binder grade” in the mixture using back-calculated binder properties from E*
- If the effective binder grade is suitable, then perform appropriate performance tests
- If the effective binder grade is too stiff, select a new virgin PG and repeat step 3

**Proposed Performance Test Options**
- Moisture Susceptibility (always)
  - TSR or Hamburg
- Permanent Deformation (mixes within top 100 mm)
  - AMPT Flow Number or APA
- Fatigue (surface or base mixes)
  - AMPT fatigue or Overlay Tester
- Low Temperature (for cold climates)
  - SCB and BBR with mix beams

**Lab Experiment**
- Validate the mix design approach and performance tests
- Mix designs with 4 sets of materials: UT, MN, NH, FL
- RAP contents: 0 & 40% or 0, 25, & 55%
- Two binder grades and two binder sources
- Volumetrics, E*, FN, TSR, SCB and BBR, and Push-Pull fatigue
- Current effort on:
  - Fatigue testing using AMPT push-pull fatigue
  - Back-calculation of binder properties from E*
Backcalculation of Effective Binder Grade

- Prepare and test specimens for dynamic modulus, AASHTO TP 63
- Test at 3 temperatures, 7 frequencies
- Calculate $G^*$ from Hirsh model, 6 using G. Rowe’s technique

Summary

- Sample and test RAP, check variability
- Conduct mix design (determine Opt. Pb) as usual
- Use dynamic modulus test (with AMPT) to check the effective binder grade, adjust virgin PG as needed
- Conduct performance tests as appropriate and check against criteria for standard mixes
- Majority of the process is conducted by routine mix design labs
- Additional testing will add roughly one week and may initially require farming out to specialist labs

NCAT Pavement Test Track

- 1.7 mile oval asphalt track
- 45 experimental test sections, each 200 ft. long
- A pooled-fund project with test sections sponsored by highway agencies and businesses to evaluate specific materials and/or pavement design strategies
- Realistic traffic applies 10 million ESALs in each two year cycle
- Currently 60% complete with the 4th cycle
High RAP Mixes on the NCAT Test Track

- 2006:
  - 45% RAP surface mix with four different virgin binder grades
- 2009:
  - 2006 high RAP sections continued
  - 45% RAP surface mix from Mississippi
  - 50% RAP HMA & 50% RAP WMA in structural sections