Balanced Mix Design (BMD)

Asphalt Pavement Association of Michigan (APAM)
2017 Asphalt Paving Conference
Shane Buchanan
Oldcastle Materials
Discussion Items

• Need for Balanced Mix Design
• Performance Testing Discussion
• Balanced Mix Design Task Force Activities
• Agency Practices Related to Balanced Mix Design
• Future Work
Balanced Mix Design Definition

• “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 (e.g., use the right tool for the job!)
Need for Balanced Mix Design
Why the Need for a New Mix Design Approach?

• Problems:
  o Relying on volumetrics alone to provide performance
  o Dry mixes exist in some (not all) areas

• Solutions:
  o **Recognize performance issues** related to dry mixes in some areas. (Note: Many performance issues are caused by factors outside the mix design)
  o **Increase understanding** of the factors which drive mix performance
  o **Design for performance** and not just to “the spec”.
  o **Start thinking** outside of long held “rules and constraints”
  o **Innovate!**
What Type Distress Is Occurring?

Oldcastle Survey Question: Within the past 5 years, what type of mix performance related distress has been most evident in your mixes?

~40 companies responding from ~30 states
Steps Must be Taken *Now* Towards Solutions

- **Each day**, approximately 1.4 Million tons of HMA are produced in the U.S. (M-F production basis)
  - Equivalent to ~2500 lane miles @ 12’ wide and 1.5” thick
  - *Distance from New York to Las Vegas*

Long term research is certainly needed, but we must take steps *NOW* towards a solution
Mix Design Specifications

- Largely recipe driven
  - Aggregates and grading
  - Volumetrics (Va, VMA, VFA, D/A, etc.)
  - Binder grade and/or minimum %
  - RAP and/or RAS
  - WMA
- While this may work, there are problems
  - What happens when the recipe fails?
  - Specifications have become *convoluted and confounded*
    - Existing specified items compete against each other
    - New requirements get added and nothing gets removed
      - “Spec Book Creep”
  - Innovation has become stifled with our knowledge outpacing specifications
### Agencies are Searching for Solutions: Ndesign

- Ndesign varies widely w/ levels being reduced with the **intent** of gaining more binder

- **Problem:** Lower gyrations do not necessarily equate to more binder

<table>
<thead>
<tr>
<th>State</th>
<th>Gyration Level(^1)</th>
<th>State</th>
<th>Gyration Level(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama</td>
<td>60</td>
<td>New Mexico</td>
<td>75, 100, 125</td>
</tr>
<tr>
<td>Arkansas</td>
<td>50, 75, 100, 125</td>
<td>New York</td>
<td>50, 75, 100</td>
</tr>
<tr>
<td>Colorado</td>
<td>75, 100</td>
<td>North Carolina</td>
<td>50, 65, 75, 100</td>
</tr>
<tr>
<td>Connecticut</td>
<td>75, 100</td>
<td>Ohio</td>
<td>65</td>
</tr>
<tr>
<td>Florida</td>
<td>50, 65, <strong>75, 100</strong></td>
<td>Oklahoma</td>
<td>64-22 (50), 70-28 (60) , and 76-28 (80)</td>
</tr>
<tr>
<td>Idaho</td>
<td>50, 75, 100, 125</td>
<td>Oregon</td>
<td>65, 80, 100</td>
</tr>
<tr>
<td>Iowa</td>
<td>50, 60, 65, 68, 76, 86, 96, 109, 126</td>
<td>Pennsylvania</td>
<td>50, 75, 100</td>
</tr>
<tr>
<td>Kansas</td>
<td><strong>75</strong>, 100</td>
<td>Rhode Island</td>
<td>50</td>
</tr>
<tr>
<td>Kentucky</td>
<td>50, 75, 100</td>
<td>Tennessee</td>
<td>65 or 75 Marshall</td>
</tr>
<tr>
<td>Maine</td>
<td><strong>50</strong>, 75</td>
<td>Texas</td>
<td>50</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>50, <strong>75, 100</strong></td>
<td>Utah</td>
<td>50, 75, 100, 125</td>
</tr>
<tr>
<td>Michigan</td>
<td>45, 50, 76, 86, 96, 109, 126</td>
<td>Vermont</td>
<td>50, 65, 80</td>
</tr>
<tr>
<td>Minnesota</td>
<td>40, 60, 90, 100</td>
<td>Virginia</td>
<td><strong>65</strong></td>
</tr>
<tr>
<td>Mississippi</td>
<td>50, <strong>65</strong>, 85</td>
<td>Washington</td>
<td>50, 75, 100, 125</td>
</tr>
<tr>
<td>Missouri</td>
<td>50, 75, <strong>80</strong>, 100, 125</td>
<td>West Virginia</td>
<td>50, 65, 80, 100</td>
</tr>
<tr>
<td>Montana</td>
<td><strong>75</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nebraska</td>
<td>40, 65, 95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nevada</td>
<td>Use Hveem</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Hampshire</td>
<td>50, 75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Jersey</td>
<td>50, <strong>75</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As of March 2015

South Carolina: 50, 75, 100
Enhancing the Durability of Asphalt Pavements

- “Volume of Effective Binder (Vbe) is the primary mixture design factor affecting both durability and fatigue cracking resistance.”
  - $Vbe = VMA - Air Voids$

- “A number of state highway agencies have decreased the design gyration levels in an attempt to increase effective binder contents. However, decreasing the design gyrations may not always produce mixtures with higher Vbe.”

Impact of Mix Design on Asphalt Pavement Durability

RAMON BONAQUIST
Advanced Asphalt Technologies, LLC
Agencies Are Searching for Solutions: Spec Changes

1. Superpave system is becoming unrecognizable with specifications changing rapidly as agencies search for ways to improve durability.
2. Establishing true “cause and effect” is impossible.

**Survey Question:** Which of the following specification changes has your DOT implemented in the last 5 years?

<table>
<thead>
<tr>
<th>Specification Change</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade Bumping</td>
<td>44%</td>
</tr>
<tr>
<td>Lowered Ndesign</td>
<td>42%</td>
</tr>
<tr>
<td>Other (please specify)</td>
<td>37%</td>
</tr>
<tr>
<td>Lowered Design Air Voids</td>
<td>30%</td>
</tr>
<tr>
<td>Performance Testing (Rut)</td>
<td>30%</td>
</tr>
<tr>
<td>Lowered RAP %</td>
<td>26%</td>
</tr>
<tr>
<td>Performance Testing (Crack)</td>
<td>26%</td>
</tr>
<tr>
<td>Increased Design VMA</td>
<td>23%</td>
</tr>
<tr>
<td>Increased Prod VMA</td>
<td>23%</td>
</tr>
<tr>
<td>Set Min Pb Total</td>
<td>16%</td>
</tr>
<tr>
<td>Lowered RAS %</td>
<td>14%</td>
</tr>
<tr>
<td>Increased QC/QA Testing</td>
<td>14%</td>
</tr>
<tr>
<td>Eliminated RAS</td>
<td>12%</td>
</tr>
<tr>
<td>Increased Field Dens...</td>
<td>12%</td>
</tr>
<tr>
<td>None of above</td>
<td>12%</td>
</tr>
<tr>
<td>Set Min Pb Effective</td>
<td>7%</td>
</tr>
</tbody>
</table>

2017 APAM Paving Conference
## Table 501-3
Superpave Gyratory Compactor (SGC) Compaction Criteria

<table>
<thead>
<tr>
<th>Estimated Traffic (million ESAL)</th>
<th>Mix Type</th>
<th>(G_{mm} ) at ((N_i))</th>
<th>Number of Gyrations ((a))</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\leq 0.3)</td>
<td>LVSP</td>
<td>91.5%</td>
<td>(N_i): 6, (N_d): 45, (N_m): 70</td>
</tr>
<tr>
<td>(\leq 0.3)</td>
<td>E03</td>
<td>91.5%</td>
<td>(N_i): 7, (N_d): 50, (N_m): 75</td>
</tr>
<tr>
<td>(&gt; 0.3 - \leq 1.0)</td>
<td>E1</td>
<td>90.5%</td>
<td>(N_i): 7, (N_d): 76, (N_m): 117</td>
</tr>
<tr>
<td>(&gt; 1.0 - \leq 3.0)</td>
<td>E3</td>
<td>90.5%</td>
<td>(N_i): 7, (N_d): 86, (N_m): 134</td>
</tr>
<tr>
<td>(&gt; 3.0 - \leq 10)</td>
<td>E10</td>
<td>89.0%</td>
<td>(N_i): 8, (N_d): 96, (N_m): 152</td>
</tr>
<tr>
<td>(&gt; 10 - \leq 30)</td>
<td>E30</td>
<td>89.0%</td>
<td>(N_i): 8, (N_d): 109, (N_m): 174</td>
</tr>
<tr>
<td>(&gt; 30 - \leq 100)</td>
<td>E50</td>
<td>89.0%</td>
<td>(N_i): 9, (N_d): 126, (N_m): 204</td>
</tr>
</tbody>
</table>

\(a\). Compact mix specimens fabricated in the SGC to \(N_d\). Use height data provided by the SGC to calculate volumetric properties at \(N_i\). Compact mix specimens at optimum \(P_b\) to verify \(N_m\) for mix design specimens only.
Michigan Air Void Regression

### Table 501-1: Superpave Mix Design Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Mix Number</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>LVSP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of Maximum Specific Gravity (%G&lt;sub&gt;mm&lt;/sub&gt;) at the design number of gyrations, (N&lt;sub&gt;d&lt;/sub&gt;) (c)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>96.0% (a)</td>
</tr>
<tr>
<td>%G&lt;sub&gt;mm&lt;/sub&gt; at the initial number of gyrations, (N&lt;sub&gt;i&lt;/sub&gt;)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>See Table 501-3</td>
</tr>
<tr>
<td>%G&lt;sub&gt;mm&lt;/sub&gt; at the maximum number of gyrations, (N&lt;sub&gt;max&lt;/sub&gt;)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>98.0%</td>
</tr>
<tr>
<td>VMA min % at N&lt;sub&gt;u&lt;/sub&gt; (based on aggregate bulk specific gravity, (G&lt;sub&gt;ba&lt;/sub&gt;) (c)</td>
<td>15.00</td>
<td>14.00</td>
<td>13.00</td>
<td>12.00</td>
<td>14.00</td>
<td></td>
</tr>
<tr>
<td>VFA at N&lt;sub&gt;u&lt;/sub&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>See Table 501-2 (b)</td>
</tr>
<tr>
<td>Fines to effective asphalt binder ratio (P&lt;sub&gt;98/800&lt;/sub&gt;/P&lt;sub&gt;98&lt;/sub&gt;)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.6–1.2</td>
</tr>
<tr>
<td>Tensile strength ratio (TSR)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>80% min</td>
</tr>
</tbody>
</table>

### Table 501-2: VFA Minimum and Maximum Criteria

<table>
<thead>
<tr>
<th>Estimated Traffic (million ESAL)</th>
<th>Mix Type</th>
<th>Top &amp; Leveling Courses</th>
<th>Base Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤0.3</td>
<td>LVSP</td>
<td>70–80</td>
<td>70–80</td>
</tr>
<tr>
<td>≥0.3</td>
<td>E03</td>
<td>70–80</td>
<td>70–80</td>
</tr>
<tr>
<td>&gt;0.3 – ≤1.0</td>
<td>E1</td>
<td>65–78</td>
<td>65–78</td>
</tr>
<tr>
<td>&gt;1.0 – ≤3.0</td>
<td>E3</td>
<td>65–78</td>
<td>65–78</td>
</tr>
<tr>
<td>&gt;3.0 – ≤10</td>
<td>E10</td>
<td>65–78 (a)</td>
<td>65–75</td>
</tr>
<tr>
<td>&gt;10 – ≤30</td>
<td>E30</td>
<td>65–78 (a)</td>
<td>65–75</td>
</tr>
<tr>
<td>&gt;30 – ≤100</td>
<td>E50</td>
<td>65–78 (a)</td>
<td>65–75</td>
</tr>
</tbody>
</table>

a. The specified VFA range for mix Number 5 is 73%–76%.

For mixtures meeting the definition for base course, design mixtures to 96.0% of Maximum Specific Gravity %G<sub>mm</sub> at the design number of gyrations, (N<sub>d</sub>). During field production, increase %G<sub>mm</sub> at the design number of gyrations, (N<sub>d</sub>) to 97.0%.

For base course or regressed shoulder mixtures, the maximum criteria limits do not apply.

Lower Target Air Voids by 1.0% if used in a separate shoulder paving operation, unless otherwise shown on the plans.
Ensure Specification Items Agree

- **Mix 3:**
  - **VMA Min.** = 13%
  - **VFA (E10)** = 65 to 78%

<table>
<thead>
<tr>
<th>VMA Minimum, %</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper VFA, %</td>
<td>78</td>
</tr>
<tr>
<td>Lower VFA, %</td>
<td>65</td>
</tr>
<tr>
<td>Effective Upper Va, %</td>
<td>4.55</td>
</tr>
<tr>
<td>Effective Lower Va, %</td>
<td>2.86</td>
</tr>
<tr>
<td>Effective Upper Vbe, %</td>
<td>10.14</td>
</tr>
<tr>
<td>Effective Lower Vbe, %</td>
<td>8.45</td>
</tr>
</tbody>
</table>
Ensure Specification Items Agree

- **Mix 5:**
  - VMA Min. = 15%
  - VFA (E10) = 73 to 76%

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>VMA Minimum, %</td>
<td>15</td>
</tr>
<tr>
<td>Upper VFA, %</td>
<td>76</td>
</tr>
<tr>
<td>Lower VFA, %</td>
<td>73</td>
</tr>
<tr>
<td>Effective Upper Va, %</td>
<td>4.05</td>
</tr>
<tr>
<td>Effective Lower Va, %</td>
<td>3.6</td>
</tr>
<tr>
<td>Effective Upper Vbe, %</td>
<td>11.4</td>
</tr>
<tr>
<td>Effective Lower Vbe, %</td>
<td>10.95</td>
</tr>
</tbody>
</table>
History of Mix Design

1890
- Barber Asphalt Paving Company
  - Asphalt cement 12 to 15% / Sand 70 to 83% / Pulverized carbonite of lime 5 to 15%

1905
- Clifford Richardson, New York Testing Company
  - Surface sand mix: 100% passing No. 10, 15% passing No. 200, 9 to 14% asphalt
  - Asphaltic concrete for lower layers, VMA terminology used, 2.2% more VMA than current day mixes or ~0.9% higher binder content

1920s
- Hubbard Field Method (Charles Hubbard and Frederick Field)
  - Sand asphalt design
  - 30 blow, 6” diameter with compression test (performance) asphaltic concrete design (Modified HF Method)

1927
- Francis Hveem (Caltrans)
  - Surface area factors used to determine binder content; Hveem stabilometer and cohesionmeter used
  - Air voids not used initially, mixes generally drier relative to others, fatigue cracking an issue

1943
- Bruce Marshall, Mississippi Highway Department
  - Refined Hubbard Field method, standard compaction energy with drop hammer
  - Initially, only used air voids and VFA, VMA added in 1962; stability and flow utilized

1993
- Superpave
  - Level 1 (volumetric)
  - Level 2 and 3 (performance based, but never implemented)

2017 APAM Paving Conference

Design and optimum binder content are often used interchangeably. However, they mean two different things. There can be many design binder contents for a mix, but only one truly optimum. Optimum indicates the best binder content based on intended application, performance requirements/needs, and ultimately economics. Goal is to get as close as possible to the true optimum for the mix.
Performance Testing of Asphalt Mixes
Stability Testing

Logging Trucks, Olympic Peninsula, 1947

Source: University of Washington Libraries
Stability Evaluation

- Evaluate mix stability with one of several available “rutting” tools.
  - Hamburg, APA, AMPT Flow Number, etc.
  - Failure criteria
    - Based on best available research (local, regional, or national)
    - Function of traffic (e.g., low, medium, high) and/or mix end-use applications
Durability / Cracking Testing
Durability/Cracking Evaluation

- Durability/cracking evaluation is **substantially more complicated** than stability
  - What is the mode of distress?
  - What is the aging condition?
- Cracking prediction is a known “weak” link in performance testing
  - No general consensus on the best test(s) or the appropriate failure threshold

**GOALS**
- **MATCH THE TEST TO THE DISTRESS**
- **SET APPROPRIATE FAILURE THRESHOLDS**
### Laboratory Cracking Tests

(From: Research Report No. FHWA-ICT-15-017)

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Purpose</th>
<th>Specimen Dimensions</th>
<th>Specimen Preparation</th>
<th>Test Output</th>
<th>Pros/Cons</th>
</tr>
</thead>
</table>
| Semi-circular bending (SCB)     | Cracking resistance          | 6 in (Ø) 3 in (H)   | Notching required = 0.6 in; external LVDTs optional | Fracture energy from load-displacement curve, peak load, critical displacement | - Inexpensive device  
- Relatively easy specimen fabrication  
- Easily obtained field specimens  
- Two specimens per core or slice  
- Simple three-point bending load representing field bending  
- Smaller ligament area |
| Disc compact tension (DCT)      | Cracking resistance          | 6 in (Ø) 5.7 in (H) | Notching required = 2.46 in; extensometer required | Fracture energy from load-displacement curve, peak load, critical displacement | - Direct tensile mode  
- Easily obtained field specimens  
- Possible breakage close to loading holes at intermediate-temperature application  
- Moderately expensive device |
| Texas overlay (TOL)             | Cracking (reflective) potential | 6 in (L) 3 in (W)   | Gluing required; curing time needed; external LVDTs optional | Number of cycles used as measure of crack resistance | - Cyclic loading application  
- High variability  
- No fundamental property related  
- Moderately expensive device |
| Direct tension (DT)             | Tensile strength, cracking resistance, and ductility potential | 4 in (Ø) 4 in (H)  | Gluing required; overnight curing time; external LVDTs required | Tensile strain at max load used as indicator of ductility and cracking resistance potential | - Simple stress state  
- Possibility of load eccentricity because of end fixtures  
- Difficult to obtain field specimens  
- Closed-loop displacement control is difficult  
- High variability  
- Moderately expensive device |
| Indirect tension test (IDT)     | Tensile strength (indirect)  | 6 in (Ø) 2 in (T)   | External LVDTs required | Max horizontal strain at max load and strength used as indicator of ductility and cracking resistance potential | - Relatively easy specimen fabrication  
- Easily obtained field specimens  
- Tensile strength potentially related to cracking resistance  
- No fundamental property related |
Match the Test to the Distress

- Disc Shaped Compact Tension
- Four-point Bending
- Texas Overlay Test
- Indirect Tension
- Semi-Circular Bending
- Fatigue
- Thermal
- Reflective

From: Louay Mohammad, LTRC
Cracking Tests: Strain and Cycles Illustration

- **Monotonic**
  - Very high strain

- **Overlay**
  - High strain

- **Fatigue**
  - Lower strain

- **Test Time**
  - Low
  - High

- **No. of cycles**
  - 1
What is the Best Cracking Test? It Depends!

- NCHRP 9-57: Experimental Design for Field Validation of Laboratory Tests to Assess Cracking Resistance of Asphalt Mixtures

Table 3 Cracking tests selected at the workshop.

<table>
<thead>
<tr>
<th>Thermal Cracking Tests</th>
<th>Reflection Cracking Tests</th>
<th>Bottom-Up Fatigue Cracking Tests</th>
<th>Top-Down Cracking Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. DCT</td>
<td>1. OT</td>
<td>1. Beam fatigue</td>
<td>1. IDT-Florida</td>
</tr>
<tr>
<td>2. SCB-IL</td>
<td>2. SCB-LTRC</td>
<td>2. SCB-LTRC</td>
<td>2. SCB-LTRC</td>
</tr>
<tr>
<td>3. SCB (AASHTO TP 105)</td>
<td>3. BBF</td>
<td>3. OT*</td>
<td></td>
</tr>
</tbody>
</table>

*OT for fatigue cracking was added later by request of the panel.

Note: SCB-IL is now I-FIT
Use of Performance Testing in Design - Illinois

From: Imad Al-Qadi, University of Illinois
Use of Performance Testing in Design - Wisconsin

Thermal Cracking
DC(t)

Fatigue
Semi-Circular Bend

Rutting
Hamburg

LT (-18 or -24°C)  IT (25°C)  HT (50°C)

Long Term Aging – AASHTO R30 (5 days at 85°C)
- SCB and DCT
- Recovered binder grade and ΔTc

From: Erv. Dukatz, Mathy Construction, TRB 2015
Performance space diagrams show the performance of a mix related to multiple tests.

Allows the mix designer to visualize the mix performance and how to engineer the mix to provide the desired performance.
Balanced Mix Design Task Force - Development and Work
Pavement Implementation Executive Task Group (PIETG)

- At the request of the National Pavement Implementation Executive Task Group (PIETG) a Balanced Mix Design Task Force formed at the September 2015 FHWA Mixture and Construction ETG meeting
- The PIETG is focused on the strategic program level challenges and opportunities in the deployment of pavement technologies.
- Focus areas include:
  - Pavement Design and Analysis;
  - Pavement Materials and Quality Assurance;
  - Pavement Surface Characteristics;
  - Construction Technology;
  - Pavement Sustainability;
  - Technical Capacity; and
  - Field Support/Technical Assistance.
<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>John Bukowski</td>
<td>Materials Team Leader</td>
</tr>
<tr>
<td>Christopher Wagner</td>
<td>Pavment and Materials Tech. Srvs. Team Leader</td>
</tr>
<tr>
<td>Gina Ahlstrom</td>
<td>Pavment Design and Analysis Team Leader</td>
</tr>
<tr>
<td>Jeff Withee</td>
<td>Pavment Materials Engineer</td>
</tr>
<tr>
<td>Mark Swanlund</td>
<td>Infrastructure R&amp;D Program Coordinator</td>
</tr>
<tr>
<td>Bryan Cawley</td>
<td>Construction Mgmt. Team Leader</td>
</tr>
<tr>
<td>Stephen Gaj</td>
<td>Asset Mgmt. Team Leader</td>
</tr>
<tr>
<td>Hari Kalla</td>
<td>Director, Office of Asset Mgmt., Pavement &amp; Construction</td>
</tr>
<tr>
<td>Mike Acott</td>
<td>President</td>
</tr>
<tr>
<td>Audrey Copeland</td>
<td>VP, Engineering, Tech. and Research</td>
</tr>
<tr>
<td>Gerald Voigt</td>
<td>President/CEO</td>
</tr>
<tr>
<td>Leif Wathne</td>
<td>VP, Highways and Federal Affairs</td>
</tr>
<tr>
<td>Jim Duit</td>
<td>President</td>
</tr>
<tr>
<td>Dave Howard</td>
<td>President/CEO</td>
</tr>
<tr>
<td>Ron Sines</td>
<td>VP - Asphalt Performance</td>
</tr>
<tr>
<td>Jay Winford</td>
<td>President</td>
</tr>
<tr>
<td>Carlos Braceras</td>
<td>Executive Director</td>
</tr>
<tr>
<td>Dave Huft</td>
<td>Research Program Mgr.</td>
</tr>
<tr>
<td>Richard Tetreault</td>
<td>Deputy Secretary</td>
</tr>
<tr>
<td>Russell McMurry</td>
<td>Commissioner</td>
</tr>
<tr>
<td>Garrett Moore</td>
<td>Chief Engineer</td>
</tr>
<tr>
<td>Peter Taylor</td>
<td>Associate Director</td>
</tr>
<tr>
<td>Kevin Hall</td>
<td>Professor and Head</td>
</tr>
<tr>
<td>David Newcomb</td>
<td>Senior Research Scientist</td>
</tr>
<tr>
<td>Paul Tikalsky</td>
<td>Dean of Engineering</td>
</tr>
</tbody>
</table>

**FHWA**

- John Bukowski
- Christopher Wagner
- Gina Ahlstrom
- Jeff Withee
- Mark Swanlund
- Bryan Cawley
- Stephen Gaj
- Hari Kalla

**INDUSTRY**

- Mike Acott
- Audrey Copeland
- Gerald Voigt
- Leif Wathne
- Jim Duit
- Dave Howard
- Ron Sines
- Jay Winford

**DOTs**

- Carlos Braceras
- Dave Huft
- Richard Tetreault
- Russell McMurry
- Garrett Moore

**ACADEMIA**

- Peter Taylor
- Kevin Hall
- David Newcomb
- Paul Tikalsky

**NAPA**

- Audrey Copeland (attendee)

**ACPA**

- Gerald Voigt (alternate)

**Duit Construction Co.**

- Jim Duit

**Koss Construction**

- Dave Howard

**Oldcastle Materials**

- Ron Sines

**Prairie Contractors, Inc.**

- Jay Winford

**Utah DOT**

- Carlos Braceras

**South Dakota DOT**

- Dave Huft

**Vermont Agency of Transportation**

- Richard Tetreault

**Georgia DOT**

- Russell McMurry

**Virginia DOT**

- Garrett Moore

**Iowa State University**

- Peter Taylor

**University of Arkansas (CE)**

- Kevin Hall

**Texas A&M Transportation Institute**

- David Newcomb

**Oklahoma State University**

- Paul Tikalsky
Balanced Mix Design Task Force

- **BMD TF Focus Areas**
  - Define Balanced Mix Design
  - Determine the current “state of practice” of BMD
  - Present approaches/concepts for immediate use
  - Recommend future needs (potential research) to advance BMD approaches
  - Disseminate information

- **Cross sectional membership**
  - FHWA
  - State Agency
  - Industry
  - Academia/Research
  - Consultant
<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Category</th>
<th>e-mail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dave Newcomb</td>
<td>Texas Transportation Institute</td>
<td>Academia/Research</td>
<td><a href="mailto:d-newcomb@ttimail.tamu.edu">d-newcomb@ttimail.tamu.edu</a></td>
</tr>
<tr>
<td>John Haddock</td>
<td>Purdue University</td>
<td>Academia/Research</td>
<td><a href="mailto:jhaddock@purdue.edu">jhaddock@purdue.edu</a></td>
</tr>
<tr>
<td>Kevin Hall</td>
<td>University of Arkansas</td>
<td>Academia/Research</td>
<td><a href="mailto:kdhall@uark.edu">kdhall@uark.edu</a></td>
</tr>
<tr>
<td>Louay Mohammad</td>
<td>Louisiana State University</td>
<td>Academia/Research</td>
<td><a href="mailto:Louaym@LSu.edu">Louaym@LSu.edu</a></td>
</tr>
<tr>
<td>Brian Pfeifer</td>
<td>Illinois DOT</td>
<td>Agency</td>
<td><a href="mailto:Brian.Pfeifer@illinois.gov">Brian.Pfeifer@illinois.gov</a></td>
</tr>
<tr>
<td>Bryan Engstrom</td>
<td>Massachusetts DOT</td>
<td>Agency</td>
<td><a href="mailto:Brian.Pfeifer@illinois.gov">Brian.Pfeifer@illinois.gov</a></td>
</tr>
<tr>
<td>Charlie Pan</td>
<td>Nevada DOT</td>
<td>Agency</td>
<td><a href="mailto:cpan@dot.state.nv.us">cpan@dot.state.nv.us</a></td>
</tr>
<tr>
<td>Curt Turgeon</td>
<td>Minnesota DOT</td>
<td>Agency</td>
<td><a href="mailto:curt.turgeon@state.mn.us">curt.turgeon@state.mn.us</a></td>
</tr>
<tr>
<td>Derek Nener-Plante</td>
<td>Maine DOT</td>
<td>Agency</td>
<td><a href="mailto:derek.nener-plante@maine.gov">derek.nener-plante@maine.gov</a></td>
</tr>
<tr>
<td>Eliana Carlson</td>
<td>Connecticut DOT</td>
<td>Agency</td>
<td><a href="mailto:Eliana.Carlson@CT.gov">Eliana.Carlson@CT.gov</a></td>
</tr>
<tr>
<td>Howard Anderson</td>
<td>Utah DOT</td>
<td>Agency</td>
<td><a href="mailto:handerson@utah.gov">handerson@utah.gov</a></td>
</tr>
<tr>
<td>Oak Metcalfe</td>
<td>Montana DOT</td>
<td>Agency</td>
<td><a href="mailto:rmetcalfe@mt.gov">rmetcalfe@mt.gov</a></td>
</tr>
<tr>
<td>Robert Lee</td>
<td>Texas DOT</td>
<td>Agency</td>
<td><a href="mailto:Robert.Lee@txdot.gov">Robert.Lee@txdot.gov</a></td>
</tr>
<tr>
<td>Steven Hefel</td>
<td>Wisconsin DOT</td>
<td>Agency</td>
<td><a href="mailto:Steven.Hefel@dot.wi.gov">Steven.Hefel@dot.wi.gov</a></td>
</tr>
<tr>
<td>Frank Fee</td>
<td>Consultant</td>
<td>Consultant</td>
<td><a href="mailto:frank.fee@verizon.net">frank.fee@verizon.net</a></td>
</tr>
<tr>
<td>John D'Angelo</td>
<td>Consultant</td>
<td>Consultant</td>
<td><a href="mailto:johndangelo@dangeloconsultingllc.com">johndangelo@dangeloconsultingllc.com</a></td>
</tr>
<tr>
<td>Lee Gallivan</td>
<td>Consultant</td>
<td>Consultant</td>
<td><a href="mailto:lee@gallivanconsultinginc.com">lee@gallivanconsultinginc.com</a></td>
</tr>
<tr>
<td>Richard Duval</td>
<td>FHWA - Turner Fairbank</td>
<td>FHWA Agency</td>
<td><a href="mailto:Richard.Duval@dot.gov">Richard.Duval@dot.gov</a></td>
</tr>
<tr>
<td>Tim Aschenbrener</td>
<td>FHWA - Denver</td>
<td>FHWA Agency</td>
<td><a href="mailto:timothy.aschenbrener@dot.gov">timothy.aschenbrener@dot.gov</a></td>
</tr>
<tr>
<td>Andrew Hanz</td>
<td>Mathy Construction</td>
<td>Industry</td>
<td><a href="mailto:Andrew.Hanz@mteservices.com">Andrew.Hanz@mteservices.com</a></td>
</tr>
<tr>
<td>Chris Abadie</td>
<td>Pine Bluff S&amp;G</td>
<td>Industry</td>
<td><a href="mailto:abadie3522@icloud.com">abadie3522@icloud.com</a></td>
</tr>
<tr>
<td>Erv Dukatz</td>
<td>Mathy Construction</td>
<td>Industry</td>
<td><a href="mailto:Ervin.Dukatz@mathy.com">Ervin.Dukatz@mathy.com</a></td>
</tr>
<tr>
<td>Gerry Huber</td>
<td>Heritage Research</td>
<td>Industry</td>
<td><a href="mailto:Gerald.huber@hrglab.com">Gerald.huber@hrglab.com</a></td>
</tr>
<tr>
<td>Shane Buchanan</td>
<td>Oldcastle Materials</td>
<td>Industry</td>
<td><a href="mailto:sbuchanan@oldcastlematerials.com">sbuchanan@oldcastlematerials.com</a></td>
</tr>
<tr>
<td>Anne Holt</td>
<td>Ontario Ministry of Transportation</td>
<td>Provincial Agency</td>
<td><a href="mailto:Anne.Holt@ontario.ca">Anne.Holt@ontario.ca</a></td>
</tr>
<tr>
<td>Randy West</td>
<td>NCAT</td>
<td>Research</td>
<td><a href="mailto:westran@auburn.edu">westran@auburn.edu</a></td>
</tr>
</tbody>
</table>
Agency Practices Related to BMD
A number of SHAs have begun to either explore or adopt BMD approaches and others are in the process of investigating performance testing (specifically cracking tests) for integration into their mixture designs.

- Other states are considering/evaluating approaches (Minnesota, Ohio, Utah, Maryland, Florida, Georgia, etc.)

<table>
<thead>
<tr>
<th>State</th>
<th>Approach</th>
<th>Stability Test</th>
<th>Conditioning (S)</th>
<th>Durability/Cracking Test</th>
<th>Conditioning (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>Performance Mod Vol Design</td>
<td>SST Repeated Shear, Hamburg</td>
<td>Short Term</td>
<td>Bending Beam Fatigue (BBF)</td>
<td>Long Term</td>
</tr>
<tr>
<td>Illinois</td>
<td>Vol Design w/ Performance</td>
<td>Hamburg</td>
<td>Short Term</td>
<td>Semi Circular Bend (IFIT)</td>
<td>Long Term</td>
</tr>
<tr>
<td></td>
<td>Verification</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Louisiana</td>
<td>Vol Design w/ Performance</td>
<td>Hamburg</td>
<td>Short Term</td>
<td>Semi Circular Bend (LTRC)</td>
<td>Long Term</td>
</tr>
<tr>
<td></td>
<td>Verification</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Jersey</td>
<td>Vol Design w/ Performance</td>
<td>Asphalt Pavement Analyzer</td>
<td>Short Term</td>
<td>Texas Overlay Test (OT)</td>
<td>Long Term</td>
</tr>
<tr>
<td></td>
<td>Verification</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Texas</td>
<td>Vol Design w/ Performance</td>
<td>Hamburg</td>
<td>Short Term</td>
<td>Texas Overlay Test (OT)</td>
<td>Long Term</td>
</tr>
<tr>
<td></td>
<td>Verification</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Vol Design w/ Performance</td>
<td>Hamburg</td>
<td>Short Term</td>
<td>Disc Shaped Compact Tension + Bending Beam Fatigue (IFIT)</td>
<td>Long Term</td>
</tr>
</tbody>
</table>
The state of practice examples indicate that SHAs are selecting different performance tests.

Variance is driven by different pavement distress considerations (e.g., thermal cracking in Minnesota versus top-down cracking in Florida).

Additionally, SHAs are sometimes selecting performance tests based on the intended mix application or mix component of interest.

- For example,
  - Caltrans is addressing high traffic mixtures,
  - WisDOT and IDOT are addressing recycled materials,
  - LADOTD is focusing on wearing and binder course mixtures, and
  - TxDOT and NJDOT are both focused on high-performance and specialty mixtures.
Agency Approaches – 3 Main Approaches Identified

Balanced Mix Design Flowchart: v. 03-03-16

Select Trial Gradation: Ensure Aggregate Blend Properties

Conduct Volumetric Analysis
Select Design Binder Content & Volumetric Properties

Conduct Performance Tests
- Rutting
- Cracking

Performance Passed?
Yes
Conduct Moisture Damage Test
Moisture Damage Passed?
Yes
Verify Volumetric Properties
Validate JMF / Production

No
Adapt Mix Proportions And/or Binder Content

Conduct Volumetric Analysis
Determine Initial Design Binder Content

Conduct Performance Tests
- Rutting
- Cracking

Performance Passed?
Yes
Conduct Moisture Damage Test
Moisture Damage Passed?
Yes
Decrease Moisture Susceptibility

No
Decrease Moisture Susceptibility

Conduct Moisture Damage Test

Conduct Performance Tests

Performance Design

Conduct Moisture Damage Test

Conduct Volumetric Analysis
Determine & Report Volumetric Properties at Design Binder Content

Yes
Decrease Moisture Susceptibility

No
Decrease Moisture Susceptibility

Conduct Performance Tests

Performance Passed?
Yes
Verify Volumetric Properties
Validate JMF / Production

No
Adapt Mix Proportions And/or Binder Content
Volumetric Design w/ Performance Verification – basically, it is straight Superpave with verifying performance properties; if the performance is not there, start over and re-design the mix.

Volumetric properties would have to fall within existing AASHTO M323 limits.

Example States: Illinois, Louisiana, New Jersey, Texas, Wisconsin
Performance Modified Volumetric Design

- **Performance-Modified Volumetric Design** – the initial design binder content is selected using AASHTO M323/R35 prior to performance testing; the results of performance testing could ‘modify’ the mixture proportions (and/or) adjust the binder content – and the final volumetric properties may be allowed to drift outside existing AASHTO M323 limits. Example State: California
Performance Design – this involves conducting a suite of performance tests at varying binder contents and selecting the design binder content from the results. Volumetrics would be determined as the ‘last step’ and reported – with no requirements to adhere to the existing AASHTO M323 limits. Example States: New Jersey w/ draft approach.
BMD Basic Example – Volumetric Design w/ Performance Verification

- **Texas DOT**
  - Volumetric design conducted
  - Hamburg Wheel Tracking Test (HWTT) AASHTO T 324
  - Overlay Tester (OT) Tex-248-F
  - Three asphalt binder contents are used: optimum, optimum +0.5%, and optimum -0.5%.
  - The HWTT specimens are short-term conditioned.
  - The OT specimens are long-term conditioned.

Within this acceptable range (5.3 to 5.8 percent), the mixture at the selected asphalt content must meet the Superpave volumetric criteria.
**BMD Basic Example – Volumetric Design w/ Performance Verification**

- **New Jersey**
  - APA (Rutting)
  - Texas OT (Cracking)
  - Mixes are designed to optimize performance not around a target air void content

---

**Graph Details**

- **APA Rutting (mm)**
- **Overlay Tester Fatigue (cycles)**
- **Optimum AC% (JMF)**

**Graph Information**

- **Area of Balanced Performance**: 5.2 - 5.9%
- **Courtesy of Tom Bennert**

---

**Oldcastle Materials**

**AMAP | 2017**
Technical Brief being developed to provide a current summary of the BMD TF efforts.

Under review by FHWA Public Affairs

Balanced Mixture Design Approaches for Asphalt Pavement Construction

This *Technical Brief* provides an overview of balanced mixture design (BMD) approaches currently used by states in asphalt pavement construction. These approaches are still under development and this document will attempt to show the current status and some of the issues that will need to be addressed in the future.
Research Upcoming: NCHRP Project 20-07/Task 406

- Development of a Framework for Balanced Asphalt Mixture Design

- Objective is to develop a framework that addresses alternate approaches to devise and implement balanced mix design procedures incorporating performance testing and criteria.

**NCHRP Project 20-07/Task 406, FY 2017**

**Development of a Framework for Balanced Asphalt Mixture Design**

**Funds Available:** $100,000

**Contract Time:** 12 months (includes 3 months for NCHRP review and for contractor revision of the final report)

**Staff Responsibility:** Edward Harrigan, 540-454-2149 (email: eharriga@nas.edu)

**Authorization to Begin Work:** 04/01/2017 (estimated)

**Proposal Due Date:** 01/26/2017
The Path Forward for Balanced Mix Design

- Recognize the need and move incrementally in the appropriate direction to limit risk of mix performance issues.

- Must continue with theoretical research/modeling efforts, but not be afraid to utilize practical approaches to find solutions.

- Recognize that this is a long term effort with ups/downs, but we must start now.
Final Thoughts on Mix Design

- Key Points to Keep in Mind
  1. “Use What Works”
  2. “Eliminate What Doesn’t”
  3. “Be as Simple as Possible, Be Practical, and Be Correct”

“Good doesn’t have to be complicated and complicated isn’t always good!”
Thoughts and Questions?