Balanced Mix Design
Regional Workshops
King of Prussia, PA
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Director & Research Professor

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Assistant Research Professor
Acknowledgements

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- Travel costs for some neighboring state DOT personnel is being covered by FHWA.
- Thanks to the PAPA for assistance in coordinating the workshop.

Workshop Objectives

The objective of this workshop is to share current information on Balanced Mix Design and encourage state highway agencies and asphalt contractors to move forward with implementation.
The Need for a New Era of Asphalt Mix Design

- Limitations of the Superpave mix design method
- Refinements to the Superpave mix design method
- Balanced mix design (BMD) definition and approaches
- Overview of NCHRP project 20-07/Task 406

Why change?

- The key properties in volumetric mix design (e.g. Superpave) are air voids and volume of effective binder ($V_{be}$).
- Volumetric properties do not tell us anything about the quality of the binder, or about the interactions of different binder components and additives.
- $V_{be}$ is dependent on $G_{sb}$ which is not a reliable property
  - $G_{sb}$ of source materials are subject to change over time, but not often verified.
  - $G_{sb}$ has a low level of precision
  - $G_{sb}$ of RAP aggregate is questionable
With the current volumetric mix design system...

Performance Testing: 20+ years ago

- Performance tests were supposed to be included in Superpave Level II & III
  - Superpave Shear Tester (SST)
  - Superpave IDT
Performance Testing: 20+ years ago

- Performance tests were supposed to be included in Superpave Level II & III
  - Superpave Shear Tester (SST)
  - Superpave IDT
- Equipment purchased for Regional Superpave Centers
- Tests were too complicated and cost too much to implement for routine use.

Rutting

In the early years of Superpave implementation, most attention was focused on rutting.
Asphalt Pavement Analyzer

- Originally developed as the Georgia Loaded Wheel Tester
- APA Users Group
- NCHRP project 9-17
- AASHTO standard, now T 340
- Use declining in recent years

Current Use of Rutting Tests
The need for mixture cracking tests rises

- A decade after Superpave implementation, we realized we needed to evaluate cracking susceptibility.
- RAP ETG – cracking test is the top research need
- Distracted by WMA, recycled materials, tweaking volumetric criteria
- Fragmented research, no national projects

The proliferation of cracking tests
Balanced Mix Design Approaches

1. Volumetric Design with Performance Verification
2. Performance-Modified Volumetric Mix Design
3. Performance Design

The BIG questions

1. What performance tests will be used?
2. What aging/conditioning protocols should be used?
3. How will the performance tests be used? Where will they fit in the mix design process? (The Framework)
4. What criteria should be used in specifications?
5. Can the performance tests be used in Quality Assurance?
**Approach 1**

1. **Volumetric Design with Performance Verification**
   - Select a trial gradation; check aggregate blend properties.
   - Conduct volumetric analysis. Select design binder content and volumetric properties.
   - Conduct performance tests (rutting & cracking) at optimum Pb.

   **Pass performance tests?**
   - Yes
     - Conduct moisture damage test.
     - **Pass moisture damage test?**
       - Yes
         - Validate JMF / production.
       - No
         - Decrease moisture susceptibility.
   - No
     - Redesign mix.

**Approach 2**

1. **Performance-Modified Volumetric Design**
   - Select a trial gradation; ensure aggregate blend properties.
   - Conduct volumetric analysis. Determine initial design binder content.
   - Conduct performance tests (rutting & cracking) at multiple asphalt contents.

   **Pass performance tests?**
   - Yes
     - Conduct moisture damage test.
     - **Pass moisture damage test?**
       - Yes
         - Verify volumetric properties
         - Validate JMF / production.
       - No
         - Decrease moisture susceptibility.
   - No
     - Adjust mix proportions and/or binder content.
Approach 3

Performance Design
- Select a trial gradation; ensure aggregate blend properties.
- Conduct performance tests (rutting, cracking)
- Select design binder content.
- Conduct moisture damage test.

Pass moisture damage test?
- Yes
  - Determine and report volumetric properties at design binder content.
  - Validate JMF / production.
- No
  - Decrease moisture susceptibility.

BMD State-of-Practice

1. Volumetric Design with Performance Verification
2. Performance-Modified Volumetric Mix Design
3. Performance Design
NCHRP 20-07/Task 406
Framework for Balanced Mix Design

Randy West, Fan Yin, Carolina Rodezno, and Fabricio Leiva

NCHRP 20-07/406 Objectives

- Develop a framework that addresses alternate approaches to devise and implement BMD procedures incorporating performance testing and criteria.

- The framework shall be in the format of an AASHTO recommended practice and will provide DOTs with options on which performance tests to use and how the tests can be used in the overall mix design framework.
Final Report

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The Need for a New Generation of Asphalt Mix Design</td>
</tr>
<tr>
<td>2</td>
<td>Survey of State DOTs and Asphalt Contractors</td>
</tr>
<tr>
<td>3</td>
<td>Literature Review on Asphalt Mixture Performance Testing</td>
</tr>
<tr>
<td>4</td>
<td>Preliminary Draft AASHTO Standard Practice and Specification for Balanced Mix Design</td>
</tr>
<tr>
<td>5</td>
<td>Identifying Knowledge Gaps and Research Needs</td>
</tr>
<tr>
<td>6</td>
<td>Development of Research Problem Statements</td>
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</table>
## Test Selection and Criteria
(see NCHRP 20-07, Task 406)

### Test Selection and Criteria

<table>
<thead>
<tr>
<th>Rutting Test</th>
<th>Cracking Test</th>
<th>Moisture Damage Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Pavement Analyzer</td>
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<tr>
<td>Flow Number</td>
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<tr>
<td>Hamburg Wheel Tracking Test</td>
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<td>Simple Shear Test</td>
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### Rutting Test

<table>
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<tr>
<th>Traffic (MESALs)</th>
<th>Min. FN</th>
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<tbody>
<tr>
<td>&lt; 3</td>
<td>N/A</td>
</tr>
<tr>
<td>3 to &lt; 10</td>
<td>53</td>
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<tr>
<td>10 to &lt; 30</td>
<td>180</td>
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<tr>
<td>&gt; 30</td>
<td>740</td>
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</tbody>
</table>

### Cracking Test

- Bending Beam Fatigue
- Direct Tension Cyclic Fatigue
- Disc-shaped Compact Tension
- IDT Energy Ratio
- Illinois Flexibility Index Test
- Overlay Test
- Semicircular Bend (Jc)

### Moisture Damage Test

| Agency FN Criteria | |
|--------------------||
| Traffic (MESALs)   | |
| < 3                | |
| 3 to < 10          | |
| 10 to < 30         | |
| > 30               | |

Agency FN Criteria:
- Traffic (MESALs) Min. FN
  - < 3: N/A
  - 3 to < 10: 53
  - 10 to < 30: 180
  - > 30: 740
Test Selection and Criteria
(see NCHRP 20-07, Task 406)

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Flow Number

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Min. Fracture Energy (J/m²)

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Min. TSR 0.80

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Recommended 10-Steps to Implementation

1. Develop draft test method and prototype equipment
2. Laboratory sensitivity to materials and relationship to other lab properties
3. Establish preliminary field performance relationship
4. Conduct ruggedness experiment to refine its critical aspects
5. Develop commercial equipment specification and pooled fund purchasing
6. Conduct round-robin testing to establish precision and bias information
7. Conduct robust validation of the test to set criteria for specifications
8. Conduct training
9. Conduct pilot projects
10. Implement into engineering practice

Identifying Gaps – Example: Thermal Cracking Tests

<table>
<thead>
<tr>
<th>Steps</th>
<th>Low-temperature SCB</th>
<th>DCT</th>
<th>I-FIT</th>
<th>DT Creep and Strength</th>
<th>TRSR and UTSST</th>
<th>BBR Mixture</th>
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</thead>
<tbody>
<tr>
<td>1. Develop draft test method and prototype equipment</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
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<td>2. Laboratory sensitivity to materials and relationship to other lab properties</td>
<td>(1, 2, 3, 4)</td>
<td>(9, 10, 11, 12, 13)</td>
<td>(13, 16, 19)</td>
<td>27, 28, 29, 30</td>
<td>(32, 34, 39)</td>
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<td>3. Establish preliminary field performance relationship</td>
<td>(3)</td>
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<td>(15)</td>
<td>(3, 25, 26)</td>
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<td>4. Conduct ruggedness experiment to refine its critical aspects</td>
<td>(5)</td>
<td>(5)</td>
<td>(5, 20)</td>
<td>(31)</td>
<td>(40)</td>
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<td>5. Develop commercial equipment specification and pooled fund purchasing</td>
<td>(6, 7)</td>
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<td>(7, 21, 22)</td>
<td>(36, 37)</td>
<td>41, 42, 43, 44</td>
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<td>6. Conduct round-robin testing to establish precision and bias information</td>
<td>(14)</td>
<td>(23)</td>
<td>(31)</td>
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<td>8. Conduct training</td>
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<td>IA, MN, MO</td>
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Questions?